

Ectomycorrhizal epigeous basidiomycete diversity in Oregon Coast Range *Pseudotsuga menziesii* forests—Preliminary observations

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Norvell, L. L. (Pacific Northwest Mycology Service, Portland, OR, 97229-1309, U.S.A.) & R.L. Exeter, R. L. (USDI Bureau of Land Management, District Office, Salem, OR 97306, U.S.A.). Ectomycorrhizal epigeous basidiomycete diversity in Oregon Coast Range *Pseudotsuga menziesii* forests—preliminary observations. *Memoirs of The New York Botanical Garden* 89: 159–189. 2004. —The authors present four years of data obtained from concurrent studies researching species richness of western North American Douglas-fir ectomycorrhizal epigeous basidiomycete (EEB) communities in two different Oregon Coast Range forests. Also targeted are 40 non-ectomycorrhizal basidiomycetes (NEB) flagged in the US government's Northwest Forest Plan. A BLM Reserve Forest near Pedee (Polk County) is the site for a 5-year chronosequence study sampling EEB fruitbodies from 25-, 55-, and 150-year old stands. The 56-year old Green Peak (Benton County) BLM Research Forest hosts a 6-year BLM Density Management companion study that explores the impact of timber removal on the same target fungal community by monitoring adjacent plots that in 1999 were regeneration cut (leaving no residual trees/ha), thinned (leaving approximately 300, 200, or 100 residual trees/ha), or left untreated as a control (with ~420 trees/ha). In 1998, permanent strip transects (2 per stand or plot = 400 m²) were established at both sites. During fall and spring from 1998 to 2002, chronosequence and density transects were inventoried a total of 20 and 18 times respectively; 253 (chronosequence) and 203 (density) EEB species were identified from a combined total of 4,123 collections and 531 (309 EEB) species. Agaricales comprised ~69%, Russulales ~19%, Phallales ~7%, Boletales ~3%, and Cantharellales ~2% of the overall EEB species. Cortinariaceae comprised ~85% of the Agaricales; *Cortinarius* (95 spp), *Inocybe* (62 spp), and *Russula* (50 spp) were the most species-rich genera. Preliminary analyses show that while all Douglas-fir age classes exhibit high species richness (130-164 EEB species per stand), there are differences between stand age and generic representation, in part correlated to the presence of western hemlock. After timber removal, density study stand species richness post/pre-treatment ratios were significantly depressed in the two most heavily thinned stands, but light to moderate forest thinning did not appear to have much effect on EEB species diversity. The unusually high number of species identified supports earlier hypotheses regarding a highly diverse mycorrhizal potential for Douglas-fir and suggests that close scrutiny of EEB fruitbodies in relatively small permanent transects over time can be used to predict species diversity over a wider area. The need for developing regional monographs and keys to the larger ectomycorrhizal genera is also addressed.

KEY WORDS: Douglas-fir, ecology, ectomycorrhizae, forest management, fungi, mushrooms, Oregon, *Pseudotsuga menziesii*, survey

Introduction

Western North America's Pacific coast is home to one of the world's last great extant temperate coniferous

rainforests. Initially mycoecologists investigated fungal communities within old-growth or ancient forests, building in part upon a taxonomic base developed by early mycologists with a penchant for collecting in

beautiful, pristine habitats. During the past two decades, regional mycologists launched long-term fungal species richness monitoring studies in western forests dominated by Douglas-fir (*Pseudotsuga menziesii* var. *menziesii* (Mirb.) Franco), the tree species that forms the base of the region's economy. Many studies have concentrated on mycorrhizal fungi associated with Douglas-fir and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.). The fact that ectomycorrhizal fungi produce easily surveyed macroscopic basidiomes makes them particularly appropriate for large-scale monitoring studies.

Research on Douglas-fir associated fungi has focused primarily on hypogeous ectomycorrhizal fungi (Colgan et al. 1999, Fogel, 1976; Fogel & Hunt, 1979; Hunt & Trappe, 1987; Luoma, 1989, 1991; O'Dell et al., 1992). Because epigeous fungi tend to fruit more unpredictably and often produce more ephemeral basidiomes than do hypogeous fungi, monitoring studies of organisms producing epigeous fruit-bodies have developed more slowly and tend to focus on specific aspects of the fungal community: e.g. fungal succession and spatial relationships in a plantation (Ammirati et al., 1987), impact of basidiome (Norvell, 1995a) or timber (Pilz & Molina, 2002) removal upon fungal fruiting, and comparisons of species richness across varying weather zones (O'Dell et al., 1999) or forest age (Smith et al., 2000).

Within the Pacific Northwest, the United States Department of the Interior's Bureau of Land Management (BLM) manages or holds in trust an unusually large number of tracts of young, mature, and ancient western hemlock-Douglas-fir stands. The presence of so many variously aged and differently managed stands within one jurisdiction provided a unique opportunity to compare and contrast fungal communities through time as well as to investigate the impact of timber removal on fungal diversity. In October 1998, the authors joined in a cooperative effort to conduct two five-year species richness studies designed to evaluate these different aspects of Douglas-fir ectomycorrhizal basidiomycete communities in the Oregon coast range: (i) a 5-year "chronosequence" study to compare epigeous-fruited ectomycorrhizal basidiomycete (EEB) species richness across three different Douglas-fir age-classes and (ii) a 6-year "density management" companion study to assess the short-term fruiting response of the same targeted fungal community to five different degrees of forest thinning (Norvell, 2000a, 2000b, 2002a, 2002b, 2002c, 2002d; Norvell & Exeter, 1999a, 1999b, 2002a, 2002b).

Materials and Methods

PEDEE CHRONOSEQUENCE STUDY SITE

Prior to funding approval, Exeter surveyed possible forests before selecting a study site in a montane BLM reserve forest located near Pedee in Polk County, ~20 miles SW of Monmouth, Oregon. The site has a relatively long growing season and the forest is composed of 80–100% closed canopy stands of coast Douglas-fir intermixed with occasional western hemlock and big-leaf maple (*Acer macrophyllum* Pursh). Understories contain vine-leaf maple (*Acer circinatum* Pursh), salal (*Gaultheria shallon* Pursh), Oregon grape (*Berberis nervosa* Pursh) and sword fern (*Polystichum munitum* (Kaulf.) C. Presl) with Oregon crane moss *Eurhynchium oregonum* (Sull.) Jaeg. characteristically lush and abundant on the forest floor. Three closely situated stands within the same township, range, and section were selected, each belonging to a different age class: (i) early successional (26-year old, or "early"), (ii) mid-successional (53-year old, or "mid"), and (iii) late-successional (~150-year old, or "late"). Plot elevations range from 455 m (early) to 518 m (mid). Oregon Surveyor General Tolman described the area in 1880 as almost wholly covered with "a vast growth of fine fir and hemlock timber ... standing as thick as it can possibly grow" with standing tree diameters of 20–32" DBH. The basic soil type is a well-drained *Blachly silty clay loam*, a residuum and colluvium weathered from igneous and sedimentary rock common to the montane uplands. Annual averages include 36–39 cm precipitation and 7–12°C air temperature.

According to Mary's Peak Resource Area BLM records, the **early** stand (9S 7W 13NESW; 44.79°N 123.49°W) was clear-cut in 1970, planted with Douglas-fir in 1972, re- or inter-planted in 1976, and thinned of competing vegetation and hardwoods in 1987. This young Douglas-fir forest, with trees averaging 8–10" DBH, has begun to differentiate into a single 80%+ canopy layer with a ground cover mix of salal, sword fern, Oregon grape, and Oregon crane-moss. Internal BLM documents show that the timber-cutting contract covering the **mid** stand terminated in 1945, and Douglas-fir trees in the ~55-year old stand now average ~12–14" DBH. The possibly virgin **late** stand was initially proposed for harvest circa 1989, when a few trees were felled to estimate probable timber volume. The proposed sale was halted after court injunctions and implementation of the President's Northwest Forest Plan for preservation of Northern Spotted Owl Habitat (USDA-USDI, 1993, 1994a, 1994b; see below).

GREEN PEAK DENSITY MANAGEMENT STUDY SITE

Since 1994, federally managed western coniferous forests within the Northern Spotted Owl habitat zone must be managed according to guidelines followed by the Northwest Forest (NWF) Plan (USDA-USDI, 1993, 1994a-b). The NWF Plan fosters forest-oriented biological research and monitoring studies in a region with a historically timber-based economy. Instituting a policy of “adaptive management” in federal and state forestlands, the BLM developed a density management study to research whether thinning prescriptions could be used in late-seral (40–70 years old) Douglas-fir forests to accelerate development of late-successional stand characteristics while concurrently providing some level of marketable wood volume. The stated goal was to enhance habitat development in relatively young forests during traditional timber extraction while advancing ecological knowledge and generating “a meaningful volume of wood for the regional economy”. Density management protocols include treating upland forests by alternating thinned (“from below”) areas with one-acre patch openings and untreated islands so as to foster stand structural features that encourage species biodiversity (Tappeiner et al., 1997).

In 1998, the junior author surveyed a ~56-year old Douglas-fir montane forest (T.14S, R.6W, Section 7, SE1/4, Willamette meridian; 44.37°N 123.46°W) scheduled for experimental thinning the next year. Like the Pedee Reserve forest, the BLM Research forest, located near the summit of Green Peak in the Oregon Coast Range (Benton County), belongs to the western hemlock (*Tsuga heterophylla*) plant association (Hemstrom & Logan, 1986). The BLM Green Peak Environmental Assessment (December 8, 1977; Or-080-97-25) stated that the site was logged in 1933 and aerially seeded with Douglas-fir during 1934–1936. Stand age as determined from 19 cores show a range of 49–61 years, averaging 56 years old (Snook, pers. comm., 2002). The mid-successional forest has a canopy closure of 70–100%, average DBH of 14” and an approximate stand density of 420 trees/ha, and basal area of 41 m²/ha. Occasional western hemlock trees are also present along with an understory of vine maple or mosaic of vine-maple and openings and a ground-cover mix of salal, Oregon grape, sword fern, and Oregon crane-moss. The soil is primarily Martyr gravelly loam, a deep, well-drained type common to colluvial uplands with 25–60% slopes. Such soils are moderately erosive when disturbed and/or compacted, so that activity displacing topsoil >7 cm would probably impact timber productivity to a high degree.

The authors were granted permission to conduct a companion fungal community study at the site designed to research the impact of different logging practices on fungal species richness. The five plots selected for the density management companion study share the same vegetation, soil composition, slope, and aspect (primarily north to north-east). Two adjacent “upper unit” plots (elev. 589–602 m) are higher in elevation than the three contiguous “lower unit” plots (elev. 499–520 m). The authors selected **control** (“uncut”) and **clear** (“regeneration cut” where no residual trees would remain following treatment) stands from the upper unit and stands designated as **low**, **moderate**, and **high** retention (*i.e.*, thinned to 100, 200, 300 residual trees/ hectare respectively) from the lower unit.

INVENTORY DESIGN

In each chronosequence stand or density management plot, permanent strip transects measuring 50 m X 4 m were stratified by upper and lower slopes. All transects were flagged and staked with flexible fiberglass rods at 10 m intervals and photographed from both ends to record original habitat. In 1999, the research team installed soil temperature gauges (one each in the **control**, **high**, **low**, and **clear** plots in the density study and one per transect in the chronosequence study stands) to record temperatures hourly from late March to January. Among the fungi, only epigeous basidiomycetes were targeted. Target species included all ectomycorrhizal epigeous basidiomycetes [EEB] plus 40 non-ectomycorrhizal epigeous basidiomycete [NEB] species flagged for surveys in the Record of Decision (USDA-I, 1994b). Opportunistic collections of other fungi were encouraged, but only EEB species were analyzed.

The research team conducted daylong field visits weekly during the October–December and March–May fungal fruiting seasons, alternating study sites so that all transects were sampled every other week. An effort was made to collect basidiomes representing all target species, with several specimens per putative target species collected when possible. Smaller basidiomes were placed in coded compartmentalized plastic transect boxes, and larger specimens were coded and wrapped in aluminum foil. An initial tendency to “collect for the box” (*i.e.*, to select smaller rather than larger specimens) was noted after the first two years, after which the authors took care to collect a full range of sizes for keying and descriptive purposes. After each field visit, the senior author transported all collections to the PNW-MS laboratory for immediate processing. The authors were occasionally assisted in the field by BLM botanists

Claire Hibler (1998), Terry Fennell (1998), Hugh Snook (2000, 2001) and Canadian agaric expert Scott Redhead (1999).

COLLECTION PROCESSING

Initially, collections were photographed and/or described briefly and immediately dried after small fresh samples were removed for spore printing, diagnostic chemical spot tests, and preliminary microscopic examination. Specimens were inspected using hand lenses, a Leica SGE dissecting microscope, and a Leitz DMRB compound microscope equipped with bright-field and Nomarski optics. This protocol was modified as the senior author developed more efficient triage techniques, became more familiar with target genera, and upgraded equipment. After noting that microscopical examinations of the 1085 first-year collections were only partly completed during the 1999 winter season, Norvell found it more efficient and reliable to key all targeted specimens microscopically before drying. After 1998, collections were first photographed (see below) and then segregated according to genera to expedite the keying process. Within genera, collections field-keyed to the same species were examined in sequence to compare character variability and to highlight diagnostic features separating similar yet distinct species. Because species concepts were continually undergoing revision, reevaluation of species determinations remained (and remains) ongoing, and many problematic collections will be reconsidered at the conclusion of the final 2003 and 2004 field seasons. Specimens not immediately processed were stored in the lab refrigerator at 5°C for up to 6 days (comparisons between promptly and “delayed” dried exsiccati revealed few to no misleading artifacts). Spore prints were taken from all *Russula pilei* (either whole or quartered) in compartmentalized containers at 15–18°C. To forestall larval infestation and/or expansion, fresh *Russula* specimens were usually keyed before *Galerina*, *Cortinarius*, *Ramaria*, *Hebeloma*, and *Inocybe* collections. Mycenoid and other fragile basidiomes with potentially amyloid features were photographed, described, and usually dried promptly before microscopic examination. Remaining genera contained fewer species that were well known to, or quickly keyed by, the senior author. In 1999, Brandon Matheny (University of Washington) verified or redetermined several *Inocybe* collections in the *I. lanuginosa* complex, and Scott Redhead (Curator, Canadian National Mycological Herbarium) identified many non-ectomycorrhizal opportunistic collections. Fresh basidiomes were dried at 65–75°C on forced-air American Harvester or Sigg dehydrators for

>24 hours until crispy dry. Thoroughly dried exsiccati were placed into zip-lock plastic bags, frozen for >1 week at –20°C, and then labeled, and databased before temporary curation in the PNW-MS fungal herbarium. Collections are refrozen periodically to forestall insect infestation and will be sent to the Oregon State University Fungal Herbarium (OSC) at the conclusion of the studies.

PHOTOGRAPHY

HABITAT: All stands and transects were photographed annually to record changes in ground cover, understory, and overstory during the study period. **MACROPHOTOGRAPHY:** From 1998–2000, Norvell photographed collections both in the field and in the lab using a tripod with natural lighting (1998–2000) or a copy-stand with full-spectrum lamps (2000–2002). Relatively few photographs of specimens were taken the first year, but by 2001 virtually all target collections were photographed. Cameras included a film-based Canon Eos Elan with 10–80 zoom and 100mm macro-lenses (1998–2001) and a Canon Eos D-30 with the same lenses plus a 50 mm lens (2001–2002). Addition of the copy-stand and digital camera reduced processing time by half and permitted color correction from fresh material using Adobe Photoshop® when needed. All film transparencies and negatives were scanned on a Canon Canoscan® FS2710 scanner and converted to .jpg or .tif files for inclusion in final project CD-ROMs and publications. **MICROPHOTOGRAPHY:** From 1998–2000, measurements were determined using the eyepiece micrometer on the compound microscope; thereafter, a computer mouse was used to measure features in images generated by the InSpot® computerized imaging system attached to the compound microscope and visualized on a PC monitor. Stored computer-generated images formed a comprehensive reference base for on-going microscope-based identifications and for inclusion in final project CD-ROMs.

LITERATURE

The literature consulted during the project included specialized taxonomic literature found in monographs, journal papers, and keys supplemented by field guides when necessary. Norvell, a trained agaric taxonomist and *Phaeocollybia* expert, developed extensive nomenclatural species indices for the most common conifer-associated large genera (*Inocybe*, *Cortinarius*, *Russula*, *Galerina*) to forestall “double-listing” identical fungi when using different extra-limital keys; reliance on Eu-

ropean monographs and individual North American research papers was necessitated by the lack of comprehensive, recent regional monographs. These indices, modified from the list of identified species generated during the studies, aided in the development of field and microscopical synoptic keys to the species, a research goal. Exeter developed extensive dichotomous and synoptic literature-based keys to western North American *Ramaria* species.

COLLECTION DATABASES AND INTERIM REPORTS

Norvell annotated all collections by hand before developing several MS Excel® spreadsheet “databases”. Master cumulative COLLECTIONS databases included separate fields for collection number (project designation + date + transect + #), genus, species, microscopic work, photo confirmations, diagnostic features, transect number, and ectomycorrhizal groups roughly based on clades proposed by Hibbett and Thorn (2000) and modified by Moncalvo et al. (2002). SPECIES summaries included annual and cumulative comprehensive summaries for all species recorded within each study as well as independent worksheets devoted to each age or treatment class. A separate herbarium collections database housed full locality, geographic coordinates, collector, and habitat information on labeled collections. Reference collection photographs were maintained in an iView Multimedia® database. The senior author filed interim reports with the Salem District BLM office that provided background information, protocols, progress, collections, species, tables, graphs, and photographs covering annual progress made in the density management (Norvell, 2000a, 2002a, 2002c) and chronosequence (Norvell, 2000b, 2002b,d) studies and delivered project overviews at scientific meetings (Norvell & Exeter, 1999a, 1999b, 2002a, 2002b).

STATISTICAL ANALYSIS

During the first four years, rough individual stand ratios were calculated by comparing the number of species recorded each year to the number of target species recorded during the first, or baseline, year. Species-richness data obtained from the 56-year old density control plot was (and will be) compared with those from the 55-year old chronosequence stand, and rough EEB species similarity indices were calculated for the four different aged stands. Full data analysis and computation of diversity indices derived from species richness ratios will be completed at the end of both studies, with

ANOVA, multivariate, and/or other appropriate analyses conducted so as to assess correlation between stand age or treatment and target fungal community composition. At the conclusion of the study, selected trees within each transect will be cored to compute stand productivity for correlation with EEB fruiting response. All species richness ratios will be recalculated as necessary to reflect changes of earlier identifications after taxonomic reevaluation.

Results

COLLECTIONS (FIGS. 1A-B)

VISITS: The authors visited the density and chronosequence study sites 18 and 20 times respectively, accompanied by Hibler (28 October) and Fennell (11 & 24 November) in 1998, Redhead (24 November, 2 & 8 December) in 1999, and Snook in 2000 (8 & 15 November) and 2001 (28 November). Because active logging at the density study conflicted with field visits in 1999, the field team was prohibited from sampling the **control** plots once (December 8) and the **clear-cut** plots twice (November 24, December 8). Furthermore, although during the same field season the lower unit containing the **high**, **moderate**, and **low** retention stands was logged before the first field visit (10 November), debris and slash completely (**low**) or greatly (**moderate**) obscured four transects. Additionally two deep skids running through both **high** transects severely complicated fieldwork during subsequent visits.

NUMBERS: In the density study, 2055 fungal (1611 target) collections were made during 1998–2002, including 547 EEB and NEB target collections during the 1998–1999 baseline year and 183, 448, and 423 each year thereafter. The chronosequence overall total of 2065 fungal collections included 1648 target collections with 344, 132, 742, and 420 from 1998, 1999, 2000, and 2001, respectively. The most numerous collections per year per study were made during 1998–1999, the baseline pre-treatment year (density) and 2000–2001 (chronosequence). Considering, however, that the density **control** plot produced its highest number of collections during 2000–2001, it appears that the depressed 2000–2001 overall density total resulted from stand thinning. AUTUMN VS. SPRING: Relatively few collections were made during the spring months, with spring target collections comprising only 2.3% of all collections (1.6% and 3% of the totals for density and chronosequence studies, respectively). A higher spring average percentage of 6.7% for both studies is computed when opportunistic

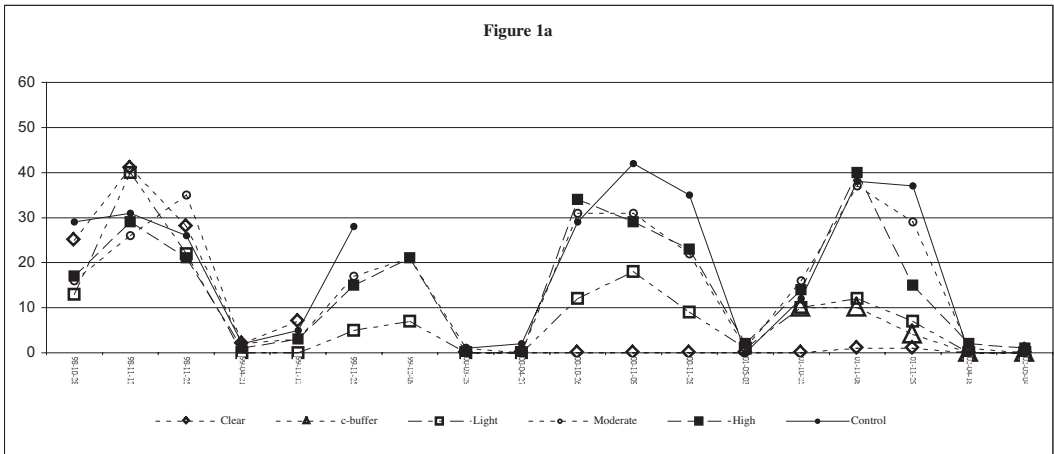
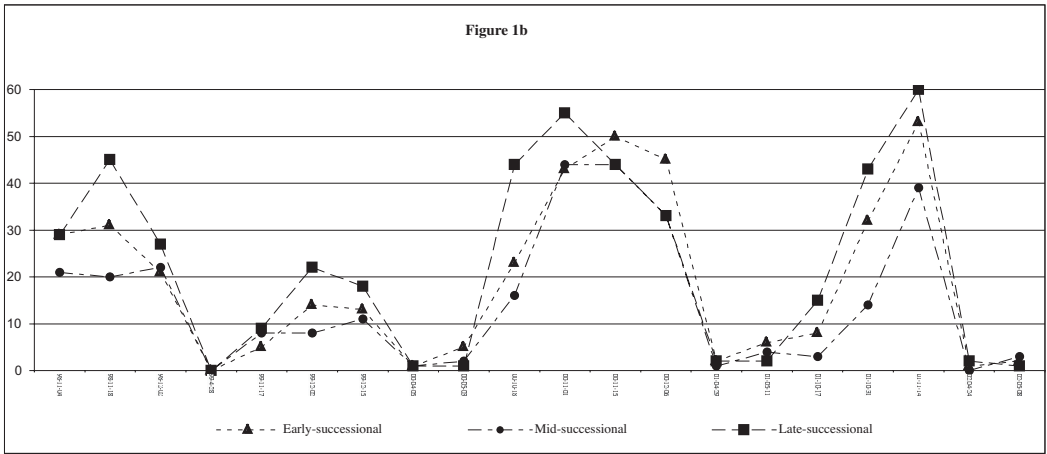


FIG. 1. Number of epigeous ectomycorrhizal basidiomycete species (EEB) collected per 400m² plot transects per sampling visit. **1a.** Species collected during 18 visits to Green Peak, Benton County, 56yo BLM Douglas-fir Research Forest. **Clear** = clear-cut (no residual trees); **C-buffer** = post-treatment collections from clear-cut within 10m of residual standing buffer trees; **Light** = 100 residual trees/ha; **Moderate** = 200 residual trees/ha; **High** = 300 residual trees/ha; **Control** = ~450 trees/ha (no trees removed). Pre-treatment baseline data obtained during 4 sampling visits in 1998-1999. Clear, Low, Moderate, and High stands were clear-cut or thinned during October-November, 1999; no trees removed from the Control stand. **1b.** Species collected during 20 visits to Pedee, Polk County, BLM Reserve Forest. Stand ages in 1998: **Early** (early-successional) = 26yo; **Mid** (mid-successional) = 55yo; **Late** (late-successional) = ~150yo.

collections of non-targeted fungi (including ascomycetes) are included.

SPECIES (TABLES 1 & 2; FIG. 2)

The total of 531 species, including 309 ectomycorrhizal epigeous basidiomycete (EEB) and 11 non-

ectomycorrhizal epigeous basidiomycete (NEB) targets, were identified from the two studies during the first four years.

ECTOMYCORRHIZAL TARGETS (Tables 1a, 2): The 44 EEB species identified from all stands at both sites included 17 *Inocybe*, 11 *Russula*, 6 *Cortinarius*, 2 *Gomphi-*

TABLE 1A
 PRELIMINARY ‡ LIST OF EEB SPECIES IDENTIFIED FROM PEDEE AND GREEN PEAK DOUGLAS-FIR FORESTS, OREGON COAST
 RANGE (YO = YEARS OLD)

EEB species	Succession age-class			
	Early 26 yo	Mid 55 yo	Mid ^{density} 56 yo	Late 150 yo
AGARICALES: Cortinariaceae				
<i>Cortinarius</i> subg. <i>Cortinarius</i>				
<i>C. limonius</i> (Fr. : Fr.) Fr.		+	+	
<i>C. violaceus</i> (L. : Fr.) S.F.Gray				+
<i>Cortinarius</i> subg. <i>Dermocybe</i>				
<i>C. californicus</i> A.H.Sm.	+			
<i>C. cascadenis</i> Ammirati & A.H.Sm.	+	+	+	
<i>C. cinnamomeus</i> (L. : Fr.) S.F.Gray	+*			
<i>C. croceus</i> (Schaeff. : Fr.) S.F.Gray			+*	
<i>C. malicorius</i> Fr.	+		+	
<i>C. phoeniceus</i> var. <i>occidentalis</i> A.H.Sm.	+	+	+	
<i>C. sanguineus</i> (Wulf in Jacq. : Fr.) S.F.Gray	+*			
<i>C. semisanguineus</i> (Fr.) Gillet		+		
<i>C. thiersii</i> Ammirati & A.H.Sm.	+		+	
† <i>C. zakii</i> Ammirati & A.H.Sm.	+	+	+	+
<i>Cortinarius</i> subg. <i>Leproclybe</i>				
<i>C. clandestinus</i> Kauffman	+	+	+	
<i>C. cotoneus</i> Fr.				+*
† <i>C. gentilis</i> (Fr.) Fr.	+	+	+	+
<i>C. cf. rubicundulus</i> (Rea in Masee) Pearson				+*
<i>Cortinarius</i> subg. <i>Myxacium</i>				
<i>C. delibutus</i> Fr.				+
<i>C. emunctus</i> Fr.				+*
<i>C. mucifluus</i> Fr.				+
<i>C. mucosus</i> (Bull. : Fr.) Kickx.			+	
<i>C. pluvius</i> (Fr. : Fr.) Fr.			+	+
<i>C. vanduzerensis</i> A.H.Smith & Trappe				+
<i>C. vibratilis</i> (Fr. : Fr.) Fr.			+	+
<i>C. sp.</i>		+	+	+
<i>Cortinarius</i> subg. <i>Phlegmacium</i>				
<i>C. allutus</i> Fr. sensu Moser			+	+
<i>C. caesiostramineus</i> Henry			+	+
† <i>C. calochrous</i> var. <i>coniferarum</i> (M.M.Moser) Brandrud	+	+	+	+
<i>C. cf. colymbadinus</i> Fr.		+*		
<i>C. elegantior</i> var. <i>americanus</i> M.M.Moser & McKnight			+*	
<i>C. glaucopus</i> (Schaeff. : Fr.) S.F.Gray	+		+	+
<i>C. infractus</i> (Pers. : Fr.) Fr.	+		+	
<i>C. cf. miser</i> M.M.Moser sensu Moser			+*	
<i>C. multififormis</i> Fr.			+	+
<i>C. pallidifolius</i> A.H.Sm.			+	
<i>C. papulosus</i> Fr.			+*	
<i>C. ponderosus</i> A.H.Sm.				+*
<i>C. cf. purpurascens</i> Fr.	+*			
<i>C. cf. subtortus</i> (Pers. : Fr.) Fr.			+	
<i>C. superbus</i> A.H.Sm.			+	+
<i>C. turmalis</i> Fr.				+
<i>C. cf. variipes</i> Henry				+*
<i>C. sp.</i>	+		+	+
<i>Cortinarius</i> subg. <i>Sericeocybe</i>				
<i>C. cf. alboviolaceus</i> (Pers. : Fr.) Fr.			+*	
<i>C. camphoratus</i> Fr. : Fr.) Fr.				+*

TABLE 1A (continued)

EEB species	Succession age-class			
	Early 26 yo	Mid 55 yo	Mid ^{density} 56 yo	Late 150 yo
<i>C. cyanites</i> Fr.	+		+	
<i>C. traganus</i> var <i>ochraceus</i> Moser, Ammirati & M.T.Seidl	+		+	+
<i>C. sp.</i>		+		
<i>Cortinarius</i> subg. <i>Telamonia</i>				
<i>C. acutus</i> (Pers. : Fr.) Fr.	+		+	+
<i>C. albovariegatus</i> (Velen.) Melot			+	
<i>C. angelesianus</i> A.H.Smith	+		+	+
<i>C. aurantiomarginatus</i> J. Schaeff. ex Moser	+			
<i>C. aff. barlowensis</i> nom. prov.				+
<i>C. aff. bibulus</i> Quél.	+			
<i>C. biformis</i> Fr. / <i>subpurpureus</i>	+		+	
<i>C. brunneus</i> (Pers. : Fr.) Fr.	+	+	+	+
<i>C. aff. brunneus</i> (spring, yellow veil)			+	
<i>C. brunneus</i> var <i>glandicolor</i> (Fr.) H.Lindstr. & Melot	+	+	+	
<i>C. cagei</i> Melot			+	
<i>C. casimiri</i> (Velen.) Huijsman	+		+	+
<i>C. cedriolens</i> (M.M. Moser) M.M. Moser	+	+	+	
<i>C. cypriacus</i> Fr.				+
<i>C. damascenus</i> Fr.			+	
<i>C. decipiens</i> (Pers.) Fr.	+			+
<i>C. depauperatus</i> (J.E.Lange) K.Soop				+
<i>C. detonsus</i> (Fr. : Fr.) Fr.		+		
<i>C. cf. dilutus</i> (Fr.) Fr.				+
<i>C. distans</i> var <i>olympianus</i> A.H.Sm.	+		+	
† <i>C. dolabratus</i> Fr.	+	+	+	+
<i>C. duracinus</i> Fr.	+			
<i>C. erubescens</i> M.M.Moser		+	+	+
<i>C. evernius</i> (Fr. : Fr.) Fr.	+	+		+
<i>C. fasciatus</i> Fr.		+	+	
<i>C. flexipes</i> (Pers. : Fr.) ss Moser			+	
<i>C. illuminus</i> Fr.			+	+
<i>C. imbutus</i> Fr.			+	+
<i>C. ionophyllus</i> M.M.Moser				+
<i>C. jubarinus</i> Fr.			+	+
<i>C. laniger</i> Fr.	+	+	+	
<i>C. leucopus</i> (Bull. : Fr.) Fr.		+		
<i>C. miniatopus</i> J.E.Lange	+		+	
† <i>C. obtusus</i> complex (several species)	+	+	+	+
<i>C. ochrophyllus</i> Fr. / <i>cacao-color</i> A.H.Sm.				+
<i>C. psammocephalus</i> (Bull. : Fr.)	+			
<i>C. aff. quarciticus</i> H. Lindstr.				+
<i>C. renidens</i> Fr.		+	+	+
<i>C. rigidus</i> Fr.			+	
<i>C. cf. saturninus</i> (Fr. : Fr.) Fr.				+
<i>C. cf. scandens</i> Fr.	+		+	
<i>C. cf. scaurus</i> (Fr. : Fr.) Fr.				+
<i>C. cf. stemmatus</i> Fr.			+	
<i>C. umbilicatus</i> P. Karst.			+	+
<i>C. uraceus</i> Fr.		+		
<i>C. aff. vernus</i> H.Lindstr. & Melot				+
<i>C. sp.</i>	+	+	+	+
<i>Cortinarius</i> (unknown subg.) sp.	+	+	+	+

TABLE 1A (continued)

EEB species	Succession age-class			
	Early 26 yo	Mid 55 yo	Mid ^{density} 56 yo	Late 150 yo
<i>Hebeloma</i>				
† <i>H. aff. crustuliniforme</i> (coniferous species)	+	+	+	+
<i>H. longicaudum</i> (Pers.) Fr.	+		+	
<i>H. mesophaeum</i> (Pers. : Fr.) Quél.	+*			
<i>H. perplexum</i> A.H.Sm., Evenson, Mitchel	+		+	
<i>H. praeolidum</i> A.H.Sm., Evenson, Mitchel	+		+	
<i>H. pumilum</i> J.E.Lange	+*			
<i>H. sacchariolens</i> Quél. complex	+*			
<i>H. cf. stenocystis</i> Favre			+*	
<i>H. sp.</i>	+*			
<i>Inocybe</i>				
<i>I. agglutinata</i> Peck (-> <i>whitei</i> , confused concept)		+	+	
<i>I. cf. amethystina</i> Kuyper	+	+	+	
<i>I. assimilata</i> (Britz.) Sacc.	+		+	+
<i>I. boltonii</i> Heim ss Matheny		+	+	+
<i>I. aff. bresadolae</i> Massee			+	
† <i>I. calamistrata</i> (Fr. : Fr.) Gillet	+	+	+	+
<i>I. castanea</i> Peck		+	+	
† <i>I. catalaunica</i> Singer (<- <i>leiocephala</i> D.E.Stuntz)	+	+	+	+
† <i>I. cf. chondroderma</i> Stuntz nom prov	+	+	+	+
† <i>I. cincinnata</i> (Fr.) Quél.	+	+	+	+
<i>I. cincinnata</i> var <i>major</i> (S.Peterson) Kuyper	+		+	
<i>I. cinnamomea</i> A.H. Sm.		+	+	
<i>I. cf. curvipes</i> P.Karst.	+		+	
<i>I. cf. earleana</i> Kauffman	+		+	
<i>I. cf. eutheloides</i> Peck		+	+	
<i>I. flavidolilacina</i> (Britz.) Sacc. (<- <i>pubica</i> Kühner)	+	+	+	+
<i>I. aff. flocculosa</i> (Berk.) Sacc.	+	+	+	
<i>I. aff. flocculosa</i> var <i>crocifolia</i> (Herink) Kuyper	+		+	
<i>I. cf. furfurea</i> Kühner (dubious)	+	+		
<i>I. cf. fuscidula</i> Velen.		+	+	
† <i>I. fuscodisca</i> (Peck) Massee	+	+	+	+
† <i>I. geophylla</i> (Fr. : Fr.) P.Kumm.	+	+	+	+
<i>I. glabrodisca</i> P.D.Orton		+	+	
<i>I. grammata</i> Quél.	+		+	
<i>I. griseolilacina</i> J.E.Lange	+		+	
<i>I. griseoscabrosa</i> (Peck) Earle	+*			
† <i>I. hirsuta</i> var <i>maxima</i> A.H.Sm.	+	+	+	+
<i>I. hotsoniana</i> D.E.Stuntz (dubious taxon)			+*	
<i>I. aff. inodora</i> Velen.			+*	
† <i>I. kauffmanii</i> A.H.Sm.	+	+	+	+
† <i>I. lacera</i> (Fr. : Fr.) P.Kumm.	+	+	+	+
<i>I. laetior</i> D.E.Stuntz			+*	
<i>I. lanatodisca</i> Kauffman			+*	
<i>I. langei</i> Heim and/or <i>hirtella</i> Bres.			+	+
† <i>I. lanuginosa</i> (Bull. : Fr.) P. Kumm.	+	+	+	+
<i>I. cf. leptocystis</i> G.F.Atk.			+*	
<i>I. leptophylla</i> G.F.Atk.			+	
<i>I. lilacina</i> (Peck) Kauffman	+	+	+	
<i>I. cf. margaritispota</i> (Berk.) Sacc.			+*	
† <i>I. mixtilis</i> (Britz.) Sacc.	+	+	+	+
<i>I. napipes</i> J.E.Lange	+	+	+	

TABLE 1A (continued)

EEB species	Succession age-class			
	Early 26 yo	Mid 55 yo	Mid ^{density} 56 yo	Late 150 yo
<i>I. nitidiuscula</i> (Britz.) Sacc.	+	+	+	
<i>I. obscurobadia</i> (J. Favre) Grund & D. E. Stuntz sensu Kuyper	+	+	+	
<i>I. olympiana</i> A. H. Sm.		+	+	
† <i>I. praetervisa</i> Quél.	+	+	+	+
<i>I. pruinosa</i> Heim			+*	
<i>I. pusio</i> P. Karst.	+			
<i>I. cf. queletii</i> Maire & Konrad	+	+		
<i>I. cf. retipes</i> G.F.Atk. / <i>griseovelata</i> Kühner			+	
<i>I. rimosa</i> (Bull. : Fr.) P. Kumm.		+	+	+
† <i>I. sindonia</i> (Fr.) P. Karst.	+	+	+	+
† <i>I. sororia</i> Kauffman	+	+	+	+
<i>I. cf. splendens</i> Heim / <i>abietis</i> Kühner	+		+	
<i>I. cf. squarrosa</i> Rea	+*			
<i>I. suaveolens</i> D. E. Stuntz				+*
† <i>I. subcarpta</i> Kühner & Boursier ss Matheny	+	+	+	+
† <i>I. substricta</i> Kauffman (same as <i>nitidiuscula</i> ?)	+	+	+	+
<i>I. cf. subochracea</i> Peck			+	
<i>I. umboninota</i> Peck sensu Peck, non sensu Heim, Lange			+	
<i>I. xanthomelas</i> Boursier & Kühner	+		+	
<i>I. sp.</i> (several)	+	+	+	+
<i>Phaeocollybia</i>				
<i>P. ammiratii</i> Norvell			+	+
<i>P. attenuata</i> (A. H. Sm.) Singer			+	+
<i>P. benzokauffmanii</i> Norvell				+
<i>P. dissiliens</i> A. H. Sm. & Trappe			+	
<i>P. fallax</i> A. H. Sm.			+	+
<i>P. gregaria</i> A. H. Sm. & Trappe				+
<i>P. kauffmanii</i> (A. H. Sm.) Singer				+
<i>P. aff. luteosquamulosa</i> [Norvell sp. nov.]				+
<i>P. olivacea</i> A. H. Sm.				+*
<i>P. pleurocystidiata</i> Norvell & Redhead			+	
<i>P. piceae</i> A. H. Sm. & Trappe				+*
<i>P. ruffipes</i> Norvell				+*
<i>P. sipei</i> A. H. Sm.			+	
<i>P. spadicea</i> A. H. Sm.			+	+
<i>P. tibiikauffmanii</i> Norvell sp. nov. in ed.			+	+
AGARICALES: non-Cortinariaceae				
<i>Amanita</i>				
<i>A. aprica</i> Tulloss & Lindgren nom prov.		+		
<i>A. franchetii</i> (Boud.) Fayod				+
† <i>A. gemmata</i> (Fr.) Gillet	+	+	+	+
<i>A. pachycolea</i> D. E. Stuntz in Thiers & Ammirati			+	+
<i>A. pantherina</i> DC.	+			
<i>A. silvicola</i> Kauffman		+		+
<i>A. smithiana</i> Bas		+*		
<i>A. vaginata</i> (Fr.) Vittadini			+*	
<i>A. sp.</i> parasitized by <i>Sepedonium</i>				+*
<i>Laccaria</i>				
<i>L. amethysteooccidentalis</i> G.M.Muell.	+		+	+
† <i>L. bicolor</i> (Maire) P. D. Orton	+	+	+	+
† <i>L. laccata</i> var <i>pallidifolia</i> (Peck) Peck	+	+	+	+

TABLE 1A (continued)

EEB species	Succession age-class			
	Early 26 yo	Mid 55 yo	Mid ^{density} 56 yo	Late 150 yo
<i>Limacella</i>				
<i>L. glioderma</i> (Fr.) Earle			+	*
<i>Hygrophorus</i>				
<i>H. agathosmus</i> (Fr.) Fr.		+		
<i>H. atramentosus</i> (Alb. & Schwein.) H. Haas & Haller			+	
<i>H. bakerensis</i> A.H.Sm. & Hesler		+	+	+
<i>H. eburneus</i> (Fr.) Fr.			+	+
<i>H. odoratus</i> A.H.Sm. & Hesler		+	+	
<i>Tricholoma</i>				
<i>T. atroviolaceum</i> A.H.Sm.				+
<i>T. cf. aurantium</i> (Schaeff.) Ricken [sterile]				+
<i>T. inamoenum</i> (Fr.) Gillet		+		+
<i>T. cf myomyces</i> (Pers.) J.E.Lange /moseri Singer	+			
<i>T. orirubens</i> Quél.				
<i>T. cf pardinum</i> Quél.				+
<i>T. portentosum</i> (Fr.) Quél.		+	+	+
<i>T. saponaceum</i> (Fr.) P.Kumm.		+	+	+
<i>T. sejunctum</i> Fr.			+	+
<i>T. sulphureum</i> (Bull.) F.	+	+	+	
† <i>T. terreum</i> (Schaeff.) Quél.	+	+	+	+
<i>T. cf. virgatum</i> (Fr.) P. Kumm.				+
<i>T. sp.</i>		+	+	
BOLETALES				
<i>Boletus luridiformis</i> Rostk.			+	*
<i>Chalciporus piperatoides</i> (A.H.Sm. & Thiers)T. J. Baroni&Both	+	+	+	
<i>Suillus</i>				
<i>S. caeruleascens</i> A.H.Sm. & Thiers			+	
<i>S. lakei</i> (Murrill) A.H.Sm. & Thiers	+	+	+	+
<i>Xerocomus zelleri</i> Murrill				
		+		+
<i>Gomphidius</i>				
† <i>G. glutinosus</i> (Schaeff.) Fr.	+	+	+	+
† <i>G. subroseus</i> Kauffman	+	+	+	+
<i>Phylloporus rhodoxanthus</i> (Schwein.) Bres.			+	*
CANTHARELLALES				
<i>Cantharellus</i>				
<i>C. formosus</i> Corner	+		+	+
<i>C. subalbidus</i> A. H. Sm. & Morse	+			+
<i>C. cf. sp. nov.</i>	+		+	+
<i>Craterellus neotubaeformis</i> nom. prov.				
			+	+
<i>Hydnum</i>				
<i>H. repandum</i> L. : Fr. (also var <i>albidum</i>)		+	+	+
<i>H. umbilicatum</i> Peck			+	
GOMPHALES				
<i>Gomphus clavatus</i> (Pers. : Fr.) S.F.Gray			+	
<i>Ramaria</i>				
<i>R. abietina</i> (Pers. : Fr.) Quél.		+		
<i>R. acriscescens</i> Marr & D. E. Stuntz		+	+	+
<i>R. apiculata</i> (Fr.) Donk	+			
<i>R. araiospora</i> Marr & D. E. Stuntz				+
<i>R. aurantiscescens</i> Marr & D. E. Stuntz			+	
<i>R. celerivirescens</i> Marr & D. E. Stuntz				+
<i>R. flavigelatinosa</i> var <i>carnisalmonea</i> Marr & D. E. Stuntz	+		+	

TABLE 1A (continued)

EEB species	Succession age-class			
	Early 26 yo	Mid 55 yo	Mid ^{density} 56 yo	Late 150 yo
<i>R. flavobrunnescens</i> var <i>aromatica</i> Marr & D.E.Stuntz				+
<i>R. formosa</i> (Pers.) Fr.		+		+
<i>R. cf fumosiavellanea</i> Marr & D.E.Stuntz				+*
<i>R. gelatinosa</i> var <i>oregonensis</i> Marr & D.E.Stuntz		+		+
<i>R. gelatiniaurantia</i> Marr & D.E.Stuntz			+*	
<i>R. leptiformosa</i> Marr & D.E.Stuntz		+	+	+
<i>R. longispora</i> Marr & D.E.Stuntz			+	
<i>R. rubricarnata</i> Marr & D.E.Stuntz				+
<i>R. sandaracina</i> var <i>euosma</i> Marr & D.E.Stuntz				+
<i>R. cf stricta</i> (Pers.) Quél.	+*			
<i>R. stuntzii</i> Marr				+*
<i>R. sp</i>				+
RUSSULALES				
<i>Lactarius</i>				
<i>L. cf alpinus</i> Peck			+*	
<i>L. deliciosus</i> (L.) Fr.	+			
<i>L. fallax</i> var <i>concolor</i> A.H.Sm. & Hesler		+	+	
<i>L. kauffmanii</i> Hesler & A.H.Sm	+		+	+
<i>L. pseudomucidus</i> Hesler & A.H.Sm			+	+
† <i>L. rubidus</i> (Hesler & A.H.Sm) Methven	+	+	+	+
† <i>L. rubrilacteus</i> Hesler & A.H.Sm	+	+	+	+
<i>L. subflammeus</i> Hesler & A.H.Sm		+		+
<i>Russula</i>				
† <i>R. abietina</i> Peck (confused concept)	+	+	+	+
<i>R. aff adulterina</i> Fr.			+*	
† <i>R. cf aeruginea</i> Lindbl. ex Fr.	+	+	+	+
<i>R. albidula</i> Peck				+*
<i>R. alcalinicola</i> Burl.	+*			
<i>R. alutacea</i> (Fr.) Fr.	+	+	+	
<i>R. atroviolacea</i> Burl.	+	+	+	
<i>R. aurantiolutea</i> Kauffman			+	+
<i>R. cf azurea</i> Bres.		+		+
† <i>R. bicolor</i> Burl.	+	+	+	+
<i>R. brevipes</i> Peck		+		+
<i>R. brunneoviolacea</i> (Crawshay) Bon		+	+	
<i>R. cf caerulea</i> Pers. and/or <i>lilacea</i> Quél.	+	+		
† <i>R. cessans</i> A.Pearson ss Thiers	+	+	+	+
<i>R. claroflava</i> Grove	+*			
<i>R. consobrina</i> (Fr. : Fr.) Fr.	+	+		
<i>R. cremoricolor</i> Earle	+	+		+
<i>R. cristata</i> Romagn. ss Romagnesi, Moser		+*		
<i>R. decipiens</i> (Singer) Svrček ss Sarnari	+			+
<i>R. decolorans</i> (Fr. : Fr.) Fr.		+		
<i>R. dissimulans</i> Shaffer		+	+	+
<i>R. flaviceps</i> Peck				+*
<i>R. fragilis</i> (Pers. : Fr.) Fr.			+	
<i>R. graveolens</i> Romagn.	+		+	
<i>R. grisea</i> Fr.	+	+		
<i>R. cf laurocerasi</i> Melzer		+	+	
<i>R. maculata</i> Quél. & Roze	+			+
† <i>R. murrillii</i> Burl.	+	+	+	+
<i>R. olivacea</i> (Schaeff.) Fr.	+		+	+

TABLE 1A (continued)

EEB species	Succession age-class			
	Early 26 yo	Mid 55 yo	Mid ^{density} 56 yo	Late 150 yo
† <i>R. cf. parazurea</i> J.Schaeff.	+	+	+	+
<i>R. pectinata</i> Fr.			+*	
<i>R. cf. pelargonia</i> Niolle	+			
<i>R. placita</i> Burl.		+	+	+
<i>R. puellaris</i> Fr.	+	+	+	
† <i>R. raoultii</i> Quél.	+	+	+	+
† <i>R. aff. rhodopoda</i> Zvara ss Thiers (<i>sp. nov.</i>)	+	+	+	+
<i>R. risigallina</i> f. <i>chamaeleontina</i> (Lasch) Bon	+		+	
<i>R. rosea</i> Quél. ss Thiers	+	+		+
<i>R. sanguinea</i> Peck (<- <i>rosea</i> (Pers.)S.F.Gray?)		+	+	
<i>R. semirubra</i> Singer		+	+	
<i>R. sphagnophila</i> Kauffman ss Grund	+			+
<i>R. cf. stuntzii</i> Grund			+*	
† <i>R. turci</i> Bres. ss Thiers	+	+	+	+
<i>R. cf. versicolor</i> J.Schaeff.		+	+	
<i>R. vesca</i> Fr.	+		+	+
† <i>R. veteriosa</i> Fr.	+	+	+	+
<i>R. vinosobrunnea</i> (Bres.) Romagn. ss Thiers	+*			
† <i>R. viscida</i> Kudrna ss Thiers	+	+	+	+
<i>R. xerampelina</i> (Schaeff.) Fr.	+	+	+	
<i>R. sp.</i>	+	+	+	+
THELEPHORALES				
<i>Phellodon tomentosus</i> (L.) Banker		+*		
<i>Thelephora</i>				
<i>T. cf. palmata</i> (Scop.) Fr.		+	+	
<i>T. terrestris</i> *	+*			

‡ Species concepts are undergoing revision and not all collections have been microscopically examined; therefore, the list above will be supplanted by a final EEB species list to be published after both studies have ended.

* Species (81 total) represented by single collection.

† Species (44 total) collected from all four stands. The 24 NWFP targeted EEB species are in **bold italics**.

dius, 2 *Laccaria*, and 2 *Lactarius* species, as well as 1 species each of *Amanita*, *Hebeloma*, *Tricholoma*, and *Suillus*. A total of 24 out of 146 EEB species flagged by the Northwest Forest Plan (USDA-I 1993, 1994a, 1994b) were collected. It should be emphasized that 1998–1999 totals are artificially depressed and do not reflect the true number of species as most collections await full microscopic examination.

DENSITY STUDY: 203 EEBs, eight NEBs, and 143 non-target species were identified from the Green Peak site during 1998–2002. Of these, 115 EEBs (or 55.4% of the 4-year EEB species total) and 3 NEBs were sampled during the pre-treatment baseline year (1998–1999); 116 EEBs (or 57.3% of EEB density species) and 6 NEBs were collected during the post-treatment years (1999–2002). Preliminary post-thin data show early reestablishment of pre-treatment fruiting patterns in the lightly (**high**) to moderately (**moderate**) thinned stands

(see below). However, EEB species richness was depressed in the heavily (**low**) thinned stand, and of the 10 EEB species (24 collections) recorded from the **clear** stand in the second post-treatment year, all but one were collected from within 10 m of standing residual buffer trees between the **clear** and **control** plots.

CHRONOSEQUENCE STUDY: A total of 253 EEBs, 8 NEBs, and 146 non-target species were identified from the Pedee site during the same four years, including 136, 124, and 158 EEB species from the **early**, **mid**, and **late** successional stands respectively.

NON-ECTOMYCORRHIZAL TARGETS (Table 1b) – The Northwest Forest (NWF) Plan (USDA-I 1993, 1994a, 1994b) targeted 29 NEBs as rare, uncommon, or endemic to late-successional and ancient forests west of the Cascade/Sierra crest in Washington, Oregon, and California. Many of the small and fragile targeted organisms cannot be identified in the field. NEB targets

TABLE 1B

PRELIMINARY ‡ LIST OF NEB SPECIES TARGETED IN THE NORTHWEST FOREST PLAN IDENTIFIED FROM PEDEE & GREEN PEAK DOUGLAS-FIR FORESTS, OREGON COAST RANGE

NWFP targeted NEB species	Succession age-class			
	Early 26 yo	Mid 55 yo	Mid ^{density} 56 yo	Late 150 yo
<i>Asterophora parasitica</i> (Bull. Fr.)				+*
<i>Clavariadelphus subfastigiatus</i> Wells & Kempton				+
† <i>Clavulina cristata</i> (Holmskj. : Fr.) Schroeter	+	+	+	+
† <i>Clitocybe senilis</i> (Fr.) Gillet	+	+	+	+
<i>Galerina</i>				
† <i>G. atkinsoniana</i> A.H.Sm.	+	+	+	+
<i>G. heterocystis</i> (G. F. Atk.) A. H. Sm. & Singer		+*		
<i>G. vittiformis</i> f. <i>tetraspora</i> Singer		+	+	+
<i>Gymnopilus punctifolius</i> (Peck) Singer			+*	
<i>Lichenomphalia umbellifera</i> ¹ (L.) Redhead et al.			+	+
<i>Sparassis crispa</i> Wulfen : Fr.		+*		
<i>Stropharia albovelata</i> ² (Murrill) Norvell & Redhead			+	

‡ A final EEB species list will be published after both studies have ended and all collections have been taxonomically reevaluated.

* = species (4 total) represented by single collection.

† = species (3 total) collected from all four stands.

¹Cited as *Phytoconis ericetorum* (Pers.) Redhead & Kuyper in the Record of Decision (USDA-I, 1994) and as *Omphalina ericetorum* (Pers.) Bigelow in Castellano et al., 2003.

²Cited as *Pholiota albivelata* (Murrill) A.H.Sm. & Hesler in the Record of Decision (USDA-I, 1994b) and Castellano et al. (1999). The original spelling "albivelata" (retained in the transfer of the species to *Stropharia* by Norvell & Redhead, 2000) is an orthographic variant, corrected here in accordance with the ICBN (St. Louis Code; Greuter et al., 2000).

are not included in species richness computations below for a number of reasons. One rationale given for flagging inconspicuous fungal species was that systematic rigorous surveys might provide more complete distributional data for fungi suspected to be rare or poorly understood. Because such a large proportion of the NEBs found in the studies produce ephemeral basidiomes easily missed in biweekly visits, the authors feel their data are too incomplete to be informative. More than onethird (11 species) of NWF Plan NEB targets were collected from the two studies: *Asterophora parasitica*, *Clavariadelphus subfastigiatus*, *Clavulina cristata*, *Clitocybe senilis*, *Galerina atkinsoniana*, *G. heterocystis*, *G. vittiformis* f. *tetraspora*, *Gymnopilus punctifolius*, *Lichenomphalia umbellifera* (<- *Omphalina ericetorum* (Pers.) Bigelow; see Redhead et al., 2002), *Sparassis crispa*, and *Stropharia albovelata*. Of the four most frequently collected species (recorded from 5–8 plots), *Clavulina cristata*, *Galerina atkinsoniana*, and *G. vittiformis* var. *vittiformis* f. *tetraspora* were found at both sites and all age-classes, and *Clitocybe senilis* was found in all age-classes except the 25-year old stand. The presence of so many collections over the relatively small survey area in

these studies suggests that the four species are more common than previously believed, at least in the central Oregon Coast Range. (That the senior author, who has inspected all NEB collections surveyed since 1999 for the NWF Plan's Regional Mycologist, has verified no *C. senilis* collections sent in by surveyors of other sites, yet the junior author has personally collected representatives from three non-study sites suggests that even with published photos, surveyors do not recognize smaller NEB targets in the field.) No inference can be made with respect to the other single collections other than to note that the single saprophytic *Gymnopilus punctifolius* collected from the **clear** plot before logging has not been collected since, possibly because the well-decomposed woody substrate was exposed to harsh environmental conditions after logging. Among the remaining collections, *Clavariadelphus subfastigiatus* was found only under one hemlock in one **late** transect; *Lichenomphalia umbellifera* was collected from both **late** and density stands; and *Stropharia albovelata* was collected all five times from the density **control** plot. Significantly, the *S. albovelata* collections prompted re-evaluation of the species, orig-

TABLE II
SPECIES PER AGE CLASS: PRELIMINARY NUMBER OF EEB SPECIES IDENTIFIED FROM OREGON COAST RANGE DOUGLAS-FIR FORESTS DURING 1998-2002[†].

Genera/Orders	Overall 3 classes	Chrono 3 classes	Density 56-yo	Early ¹ (25-yo)	Mid ¹ (55-yo)	Control ² (56-yo)	Late ¹ (150-yo)
Agaricales (Cortinariaceae)							
<i>Cortinarius</i>	95	78	58	37	25	40	51
<i>Hebeloma</i>	9	8	5	8	0	5	1
<i>Inocybe</i>	62	49	56	37	36	39	23
<i>Phaeocollybia</i>	15	12	8	0	0	0	12
Agaricales (Other)							
<i>Amanita</i> + <i>Limacella</i>	10	7	4	2	3	4	5
<i>Hygrophorus</i>	5	4	5	0	3	2	2
<i>Laccaria</i>	3	3	3	3	2	2	3
<i>Tricholoma</i>	13	12	6	3	5	3	10
Boletales	9	5	8	4	5	6	4
Cantharellales	6	5	5	3	1	2	5
Phallales	21	15	6	2	6	3	11
Russulales							
<i>Lactarius</i>	8	6	6	4	4	2	5
<i>Russula</i>	50	46	32	31	32	18	26
Thelephorales	3	3	1	2	2	1	0
Total	309	253	203	136	124	127	158

[†]List subject to change after closure of studies and taxonomic reevaluation of all collections).

¹Data from Pedee Chronosequence study site.

²Data from Green Peak density management study control plot.

inally flagged in the NWFP (USDA-I, 1994b) as *Pholiota albivelata* [sic] (Murrill) A.H.Sm. & Hesler, and led to its transfer to the genus *Stropharia* (Norvell & Redhead, 2000).

Determination of what is, and what is not, an ectomycorrhizal fungus is not yet complete. Recent evidence establishing the ectomycorrhizal status of *Phaeocollybia* (Norvell, 1998a, 1998b) and *Craterellus* (Trappe, 2001) led to their incorporation in the current study. On the other hand, although *Tapinella atrotomentosa* (Batsch) Sutara (as *Paxillus atrotomentosus* (Batsch) Fr.) has often been treated as ectomycorrhizal in other studies, its recognition as a saprophyte (Redhead & Ginns, 1985) excluded it from the final species list. Similar suspicions about the ectomycorrhizal status of *Clavariadelphus* dictated its exclusion from the following EEB analyses.

SPECIES RICHNESS COMPARISONS (TABLE 3; FIGS. 2 & 3)

The Agaricales comprised 69% of the two–study four–year EEB species total. The Cortinariaceae, by far the most species-rich family overall, represented 85%

(88% in the *density* study) of the Agaricales, with *Cortinarius* and *Inocybe* comprising 30.7% and 20.1% respectively of the species reported for both studies. Of the 95 species of *Cortinarius* identified, 48.4% represented one subgenus: subg. *Telamonia*. *Phaeocollybia*, which was absent from five plots, comprised 4.9% of the combined overall EEB species richness, contributing 4.3%–10.0% to EEB stand/plot totals where present. *Hebeloma*, found in all but the chronosequence **mid** stand, comprised 0.6–5.9% of the other EEB stand totals. Other Agaricales EEB species richness ranges were *Tricholoma* (2.2–6.3%), *Hygrophorus* (0–2.5%), *Laccaria* (1.5–2.2%), and *Amanita* (1.5–3.2%). Russulales comprised 18.8% (16.2% *Russula*, 2.6% *Lactarius*) of the combined overall EEB species richness and contributed 15.8%–29% to EEB stand/plot totals. Remaining orders contributed 6.8% (Phallales—*Gomphus* and *Ramaria*), 2.9% (Boletales—*Boletus*, *Chalciporus*, *Gomphidius*, *Phylloporus*, *Suillus*, and *Xerocomus*), 1.9% (Cantharellales—*Cantharellus*, *Craterellus*, *Hydnum*), and <1% (Thelephorales and others—*Phellodon*, *Thelephora*) to the combined overall EEB species richness. As noted above, most 1998 collections (including a great many difficult *Cortinarius*, *Inocybe*, and *Russula*

Figure 2a

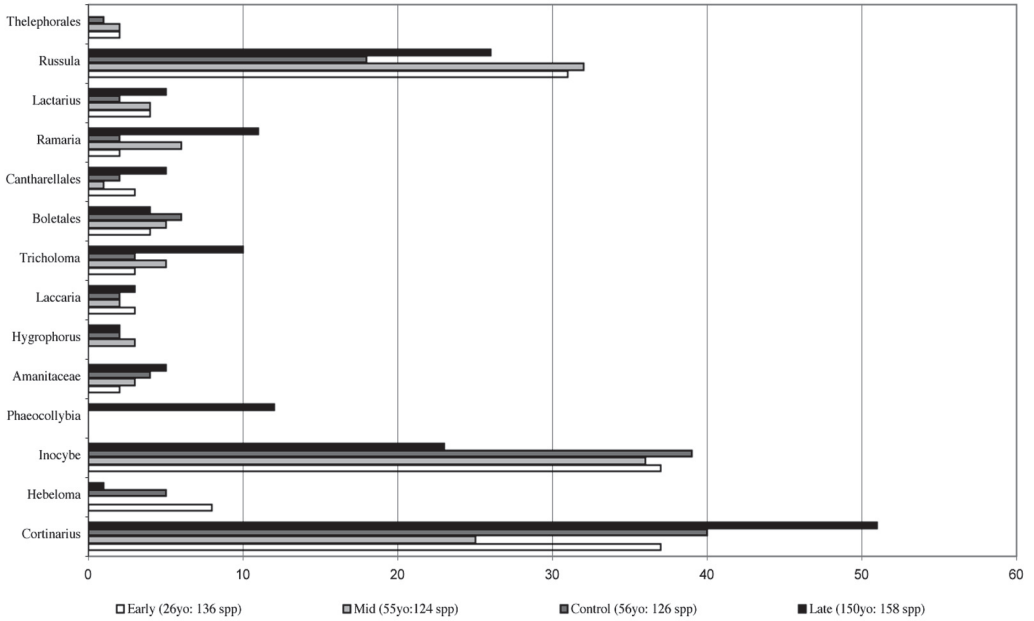


Figure 2b

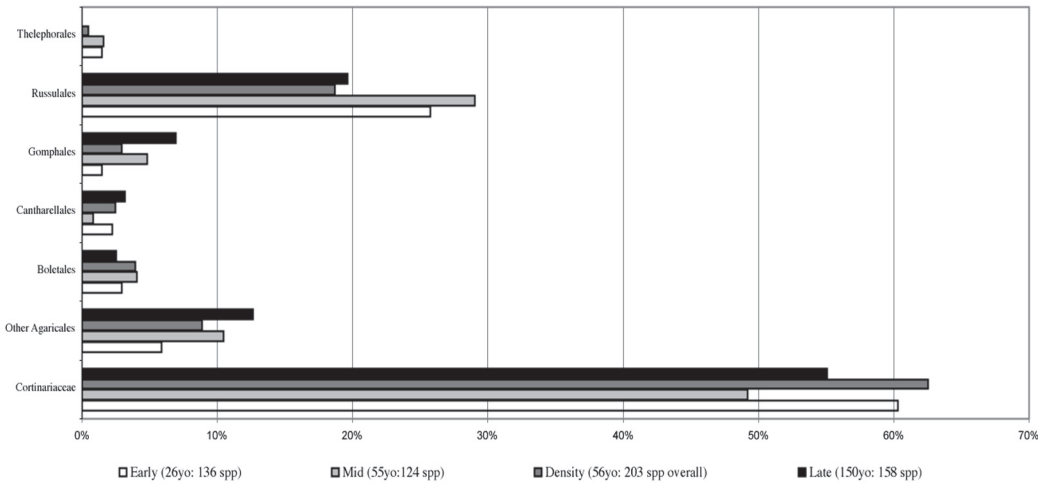


FIG. 2. Comparison of EEB species richness across three different forest age classes in Douglas-fir forests in Benton (Green Peak BLM Research Forest) and Polk (Pedece BLM Reserve Forest) counties during 1998-2002. **2a.** Number of EEB species identified per genus/order per 400m² in early- (**Early**), mid- (**Mid**), **Control**, and late- (**Late**) successional transects. **2b.** Distribution of EEB families/orders represented for each age class. Percentages based on total EEB species identified per stand. **Early**, **Mid**, and **Late** transects (400 m² each) are in the Pedece Chronosequence Study; the **Density** (Green Peak) percentage base includes total species for 2000 m² identified from all five treatment types (**clear**, **low**, **mod**, **high**, **control**) since 1998.

TABLE IIIA

EPIGEOUS ECTOMYCORRHIZAL BASIDIOMYCETE COMMUNITY COMPOSITION IN OREGON COAST RANGE DOUGLAS-FIR FORESTS (1998–2002).[†] UNITS ARE PERCENTAGES

Genera/Orders	Overall 3 classes	Chrono 3 classes	Density 1 class	Early 25 yo	Mid chrono 55 yo	Mid density 56 yo	Late 150 yo
<i>Cortinarius</i>	30.7	30.8	28.6	27.2	20.2	31.5	32.3
<i>Inocybe</i>	20.1	19.3	27.6	27.2	29	30.7	14.6
<i>Russula</i>	16.2	18.2	15.8	22.8	25.8	14.2	16.5
<i>Ramaria</i> + 1 <i>Gomphus</i>	6.8	5.9	3.0	1.5	4.8	2.4	7.0
<i>Phaeocollybia</i>	4.9	4.7	3.9	0.0	0.0	0.0	7.6
<i>Tricholoma</i>	4.2	4.7	3.0	2.2	4.0	2.4	6.3
<i>Amanita</i> + <i>Limacella</i>	3.2	2.8	2.0	1.5	2.4	3.1	3.2
Boletales ¹	2.9	2.0	3.9	2.9	4.0	4.7	2.5
<i>Hebeloma</i>	2.9	3.2	2.5	5.9	0.0	3.9	0.6
<i>Lactarius</i>	2.6	2.4	3.0	2.9	3.2	1.6	3.2
Cantharellales ²	1.9	2.0	2.5	2.2	0.8	1.6	3.2
<i>Hygrophorus</i>	1.6	1.6	2.5	0.0	2.4	1.6	1.3
<i>Laccaria</i>	1.0	1.2	1.5	2.2	1.6	1.6	1.9
Thelephorales ³	0.97	1.2	0.5	1.5	1.6	0.8	0.0

[†]Percentages based on species per age-class/total species per study and listed in descending order according to percent of overall species richness.

¹Includes two gilled (*Gomphidius*, *Phylloporus*) and four tubed (*Boletus*, *Chalciporus*, *Suillus*, *Xerocomus*) genera.

²Includes *Cantharellus*, *Craterellus*, *Hydnum*.

³Includes *Phellodon*, *Thelephora*.

collections) still await final microscopic determination, and so the percentages cited here can be expected to change.

GENERAL FRUITING FACTORS

SOIL TEMPERATURES: *Green Peak* — July (1999) monthly average soil temperatures were 14.6°C (**control**, upper unit), 15.0°C (**low**, lower unit), 16.8°C (**high**,

lower unit), and 18.6°C (**clear**, upper unit). (High-retention stand readings included unexplained frequent (but intermittent) 5–10°C temperature jumps around 1 p.m. Averages eliminating these spikes computed a stand soil temperature of 15.9°C—still high given the canopy closure over the gauge site). January (2000) monthly averages were 3.3°C (**clear**), 3.9°C (**low**), and 4.5°C (**high, control**). The **clear** July average was 2.7–4°C warmer and the January average 0.6–1.2°C colder

TABLE IIIB

ALLOCATION OF *Cortinarius* subgenera in Oregon Coast Range Douglas-fir forests (1998–2002).[†] Units are percentages (%)

Genera/Orders	Overall 3 classes	Chrono 3 classes	Density 1 class	Early 25 yo	Mid chrono 55 yo	Mid density 56 yo	Late 150 yo
<i>C. subg. Telamonia</i>	48.4	51.3	48.3	54.1	56.0	57.5	49.0
<i>C. subg. Phlegmacium</i>	18.9	15.4	20.7	13.5	8.0	17.5	17.6
<i>C. subg. Dermocybe</i>	10.5	11.5	10.3	18.9	12.0	10.0	2.0
<i>C. subg. Myxacium</i>	8.4	7.7	6.9	0.0	4.0	7.5	13.7
<i>C. subg. Sericeocybe</i>	6.3	5.1	5.2	5.4	4.0	2.5	5.9
<i>C. subg. Leprocybe</i>	4.2	5.1	3.4	5.4	8.0	5.0	5.9
<i>C. subg. Cortinarius</i>	2.1	2.6	1.7	0.0	4.0	0.0	3.9

[†]Percentages based on species per age-class/total *Cortinarius* species per study/stand and listed in descending order according to % of overall *Cortinarius* spp.

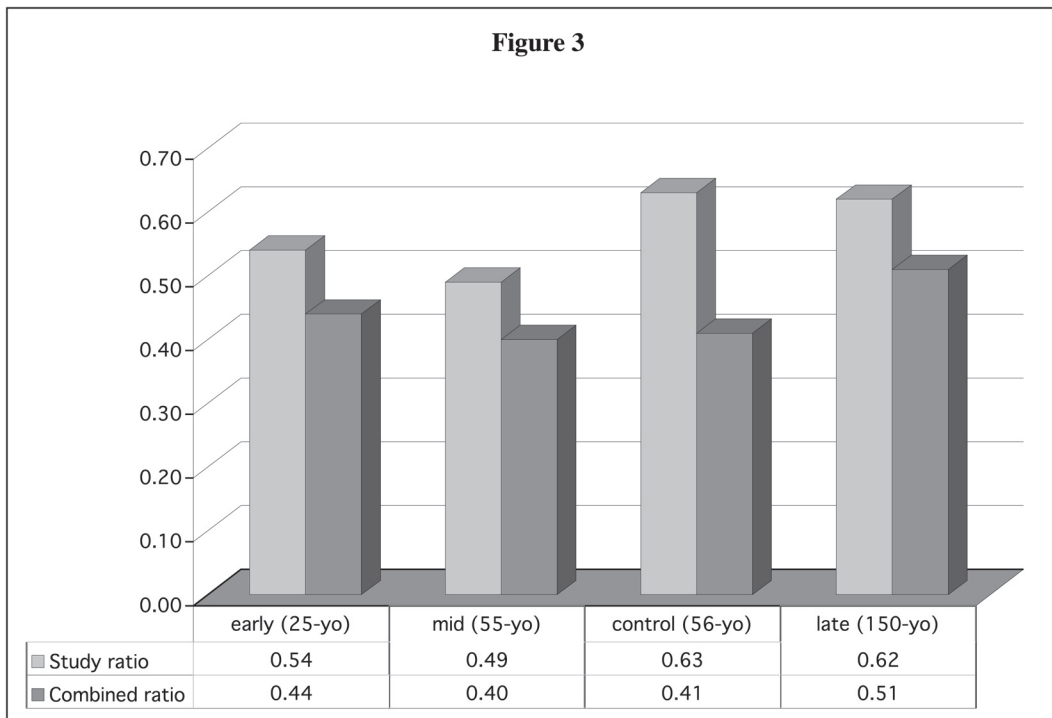


FIG. 3. The number of EEB species per stand at the Pedee (chronosequence) and Green Peak (density study) sites suggest different trends depending on whether data from one or both studies are analyzed. Individual study comparisons computed from number of EEB species per stand / number of total species per individual study (early, mid, or late / chronosequence; control/ density management total) suggest conflicting trends (study ratio). Ratios computed from the total number of EEB species reported from both fungal community studies (combined ratio) show comparable species richness ratios for both mid-successional forests. This underscores the value in analyzing species richness data from more than one site.

than the other three stands measured. *Pedee*—July monthly soil temperatures averaged 13.3–13.6°C (**early**—lowest elevation, closed canopy), 13.4–13.8°C (**mid**—highest elevation, adjacent to clear-cut), and 13.4–13.9°C (**late**—mid-elevation, canopy closure variable). Soil temperature differences were negligible among the three *Pedee* stands. No January temperatures were recorded. Both density and chronosequence studies record only slight soil temperature differences from contiguous transects where standing trees offer protection: generally the more closed the canopy, the lower the soil temperature volatility. The Green Peak **clear** plot was, as anticipated, colder in winter and warmer in summer than all other plots. Except for the **high** stand's unexplained 1 p.m. temperature spikes, hourly soil temperature fluctuation as recorded at both Green Peak and *Pedee* was minimal, suggesting that recording soil temperatures twice daily (during early morning and late afternoon) is sufficient.

PRECIPITATION: No precipitation data were gathered on site. Comparison with precipitation data collected by the Corvallis Water Bureau (44.52°N, 123.45°W; 253 m elev.), the closest weather station to both sites, will be used to evaluate fruiting trends at the conclusion of the studies.

Discussion

SPECIES RICHNESS AND FUNGAL SUCCESSION

SITE SUITABILITY: The primary criterion for selecting the chronosequence site was the close proximity of three stands representing different age classes but sharing as many other ecological factors as possible. While *Pedee* was the best choice among the possible sites, the 55-year old mid-successional (**mid**) stand presented several drawbacks. A logging road through the stand and numerous non-ectomycorrhizal big-leaf maple trees in

the lower half dictated placing both transects near the stand edge close to a recent clear cut, which was sufficiently large that it still generated its own weather and thus could be expected to influence EEB fruiting phenology in the **mid** transects. The mid-successional stand's north-facing slopes also contrasted with the southerly slopes of the early- and late-successional stands. For these and other reasons, data from the 56-year old density **control** plot are used to supply additional mid-successional EEB information. Both study sites are close to the valley fringe east of the Coast Range crest. Differences between the Pedee **mid** and Green Peak **control** stands include a northeast-southwest 12-mile separation, elevation, aspect, and slightly different weather patterns.

CORRELATION BETWEEN GENUS AND FOREST AGE-CLASS IN THE OREGON COAST RANGE (Tables 2-4, Figure 2a): Of the 11 ectomycorrhizal genera present in all chronosequence stands and the density **control** plot, *Cortinarius*, *Inocybe*, *Russula*, *Ramaria*, and *Tricholoma* were the most species-rich. Combined data support the hypothesis (O'Dell et al., 1999; Smith et al., 2002) that *Cortinarius*, *Inocybe*, and *Russula* are the dominant EEB genera of western Douglas-fir forests. The genus *Cortinarius* comprises 30.7% of the total, with a trend toward a greater diversity with increased stand age demonstrated (Tables 2, 3a). However, the fact that the smallest number of *Cortinarius* species was recorded from the chronosequence **mid** stand suggests that stand structure, slope, and exposure are more important factors than age. A possibly significant correlation between stand age and subgeneric species richness is implied for two out of seven *Cortinarius* subgenera. Table 3b shows that the difficult subgenus, *Cortinarius* subg. *Telamonia*, which comprises the greatest proportion of *Cortinarius* species, is the most species rich in mid-successional stands. This is no doubt influenced by trends exhibited by two other *Cortinarius* subgenera: subg. *Dermocybe*

species richness was highest in the **early** and lowest in the **late** stand while subg. *Myxaciium* species richness increased consistently with age. A direct correlation between *Tricholoma* and *Ramaria* EEB species richness and stand age was implied at the Pedee site (Table 3a), but the relatively low 56-year-old density **control** percentages (2.4 and 1.6%) suggest other factors such as microclimate or stand structure warrant consideration. Neither *Inocybe* nor *Russula* show a significant correlation between EEB species richness and stand age; the lower percentages in the late-successional stand may be explained by that stand's generally higher EEB species richness. *Phaeocollybia*, a notoriously "patchy" and "sociable" genus long thought to be an old-growth indicator species (Norvell, 1995b, 1998a, 1998b, 1998c), was never collected in the chronosequence **early** stand, only once off-transect in the **mid** stand, and comprised 7.6% of the EEB species in the **late** stand. While *Phaeocollybia* species were absent from the 56-year-old density **control**, they were well represented in the adjacent **clear** stand during the pre-treatment baseline year, comprising 10% of **clear**'s overall four-year EEB species richness total despite absence from the plot following logging operations.

COMPARISON OF INDIVIDUAL STAND EEB SPECIES RICHNESS ACROSS FOREST AGE IN OREGON (Table 4, Figure 3): EEB species richness was high for both Coast Range studies. Density and chronosequence EEB species each comprised 65.7% and 81.9% of the combined 309 EEB total species identified thus far. Highest "genus" (if not species) richness was found in the more complex late-successional stand, which had the greatest number of western hemlock trees (the presence of two different host-tree species should contribute to a higher EEB generic diversity). Taken independently, study-specific EEB species richness ratios (i.e., stand /*t*-study overall total) do not confirm a species richness trend, but when stand species/stand are compared to the over-

TABLE IV
ECTOMYCORRHIZAL EPIGEOUS BASIDIOMYCETE (EEB) SPECIES RICHNESS ACCORDING TO STAND AGE IN PNW DOUGLAS-FIR FORESTS.

Study	Early-successional 25-45 yo	Mid-successional 45-80 yo	Late-successional 90-200 yo	Old-Growth >200 yo
Olympic Peninsula, WA ¹	—	—	—	160
Coast Range, OR ²	136	124-127	158	—
Cascade Mountains, OR ³	86	83	—	105

¹O'Dell et al. 1999

²Norvell & Exeter (current preliminary)

³Smith et al. 2002

all species total for both studies (Figure 3), the combined EEB ratios imply slightly higher EEB species richness for colonial over mid-successional stands, with EEB species richness for late-successional stands even higher. This trend (Table 4) is also implied by Cascade Range study data (Smith et al., 2002).

DENSITY MANAGEMENT STUDY

During much of the twentieth century, timber managers “clean” cut stands by felling and removing all trees and burning all residual slash and debris on site to prepare sites for Douglas-fir plantation and to prevent pathogenic fungi from infecting transplanted seedlings. The resulting hot burns robbed soils of needed organic matter, essentially setting back the ectomycorrhizal fruiting clock to zero. Timber managers, who “regeneration” cut stands by felling all trees as before, now retain occasional wildlife refuge trees and plant seedlings into ground still covered with slash, stumps, other coarse woody debris, and residual understory and ground cover. The ectomycorrhizal legacy associated with trees and/or refuge seedlings are thought to advance an otherwise stopped fungal clock (Kranabetter, 1999), and density study data (Figure 4) showing that **high** and **moderate** EEB species richness plot ratios were not appreciably depressed suggest an unanticipated resilient EEB fruiting response even after half or more trees were removed from two plots. Kranabetter recommends obtaining some measure of stand productivity to relate to mushroom response in timber thinning studies (pers. comm., 2002). He reports a 5-year delay in fruiting response after thinning of a western hemlock-western redcedar forest, possibly linked to energy directed toward canopy development instead of root storage (Kranabetter & Kroeger, 2001). Pilz et al. (2003), who report a 67% (in lightly thinned stands) to 90% (in heavily thinned stands) decrease in chanterelle fruiting in Douglas-fir stands in one Oregon timber thinning study, report that chanterelle productivity appears to have rebounded after seven years.

MEASURING TREATMENT IMPACT (Fig. 4) — Individual stand ratios can be used to compare EEB species richness based on stand age or stand treatment. The simplest ratio compares the number of EEB species for post-treatment year(s) per stand/plot (yr1, yr2, yr3) to the number of EEB species per baseline year (yr0) per same stand/plot. For example, lower individual *density* plot ratios might imply a negative response to a particular treatment. Present baselines (derived from too many expedient “field” identifications) will change after complete microscopic reevaluation of first-year collections. How-

ever, considering that identification protocols were fairly consistent for all stands/plots within a given field year, even these preliminary ratios can suggest certain trends. Current yr 2/yr 0 EEB ratios show that in the third year the **high** plot (1.41) produced more EEB species in relation to its baseline richness than did the **moderate** (1.18) and **control** (1.19) stands. **Low** (0.62) and **clear** (0.00) ratios reflect a depressed EEB response for the same post-treatment year, as are also indicated by yr 3/yr 0 EEB richness ratios: 1.1 (**control**), 1.1 (**high**), 1.24 (**moderate**), 0.52 (**low**), and 0.33 (**clear**). (Note: when collections found within 10 m of residual **control-clear** buffer trees are excluded, the yr3/yr0 **clear** EEB richness ratio = 0.08.) Comprehensive post/pre-treatment (yr1-3/yr0) ratios are 1.93 (**control**), 2.11 (**high**), 2.0 (**moderate**), 1.0 (**low**), and 0.33 (**clear**), or 0.08 when “buffer” collections are excluded as above). It should be noted that the depressed **control** ratio as compared to the **high** and **moderate** ratios may reflect elevational, and not treatment, differences. Obviously, it is premature to make reliable predictions.

THE SPACE/TIME CONTINUUM (Impact of fruiting “patchiness” on fungal species richness data—Table 5): Oregon Coast Range study data support the oft-cited observation that fruiting of epigeous fleshy macrofungi is “patchy” and unpredictable. The four-year chronosequence study data for a 1200 m² area in three different aged stands show that 54% out of 254 EEB species occurred in only one stand, 27% in two stands, and only 19% were found in all three stands. Comparisons of 211 EEB species sampled from 2000 m² in an even-aged 56-year-old forest (density study) during the four years show that 36.1% were sampled in only one plot and 24.4%, 13.7%, 12.2%, and 13.2% were found in two, three, four, and five plots respectively. Equally problematic is using basidiome data to determine whether or not a species occurs at a given location, as many organisms do not fruit every year. In the chronosequence study, only 13.4% EEB species were collected all four years while 45.7% were collected during only one year (25.6% and 17.7% were collected two and three years respectively). The density study showed a similar pattern despite only one stand age being investigated: 43.4% EEB species were collected once, 25.4% twice, 17.7% three times, and 14.1% all four years. Stand similarity indices were calculated by assigning 1 to stands for each species shared and dividing those numbers by the total number of species shared between stands. The resulting indices (Table 5) imply the greatest similarity between the chronosequence 26-year-old and density 56-year-old (**early + control**) stands and the greatest (albeit inconclusive) differences between the chronosequence 150-

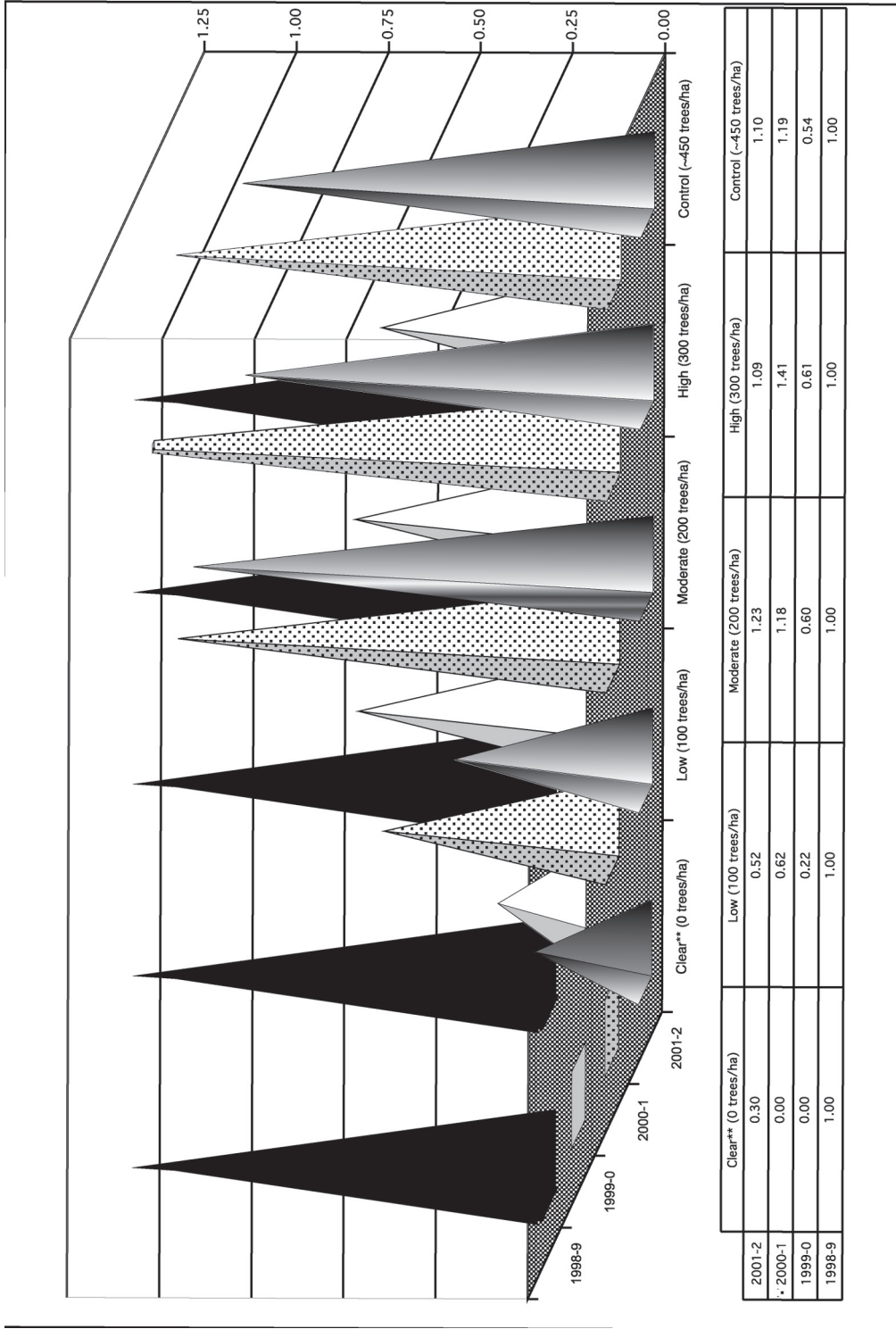


FIG. 4. Comparison of EEB species richness before and after forest treatment at the Green Peak BLM Research Forest in Benton County, Oregon. Species richness ratios are computed by dividing the number of species sampled each year by the number of species sampled during the baseline (pre-treatment) year, 1998-1999. 1999-2000 ratios are differentially depressed for the clear and control plots; access to **control** (once) and **clear** (twice) plots was prohibited during logging operations during the 1999 fall season. The seeming rebound shown for the **clear** plot in 2001-2 is misleading: 9 out of 10 species identified were collected from within 10 m of residual standing trees in the uncut buffer between the **control** and **clear** plots.

TABLE V
SIMILARITY INDICES: AGE TO AGE COMPARISON OF EEB SPECIES RICHNESS IN OREGON COAST RANGE DOUGLAS-FIR STANDS.¹

Stand Ages	Total species	Species in common	Similarity Index
26–30 yo (early) :: 56–60 yo (control) ¹	187	77	0.412
26–30 yo (early) :: 54–58 yo (mid)	192	74	0.385
54–58 yo (mid) :: 56–60 yo (control) ¹	183	69	0.377
54–58 yo (mid) :: 150–154 yo (late)	217	71	0.327
26–30 yo (early) :: 150–154 yo (late)	231	69	0.299
56–60 yo (control) ¹ :: 150–154 yo (late)	221	65	0.294

¹Comparisons of chronosequence (**early**, **mid**, **late**) and density management (**control**) study data are complicated by a 19 km separation between the two study sites, nonsynchronous sampling schedule (averaging a 7-day separation in sampling visits), and three fewer sampling visits at the **control** site.

year-old and density 56-year-old or chronosequence 25-year-old (**late** + **control**, **late** + **early**) stands. Patently, to attempt to generalize fruiting occurrence of individual EEB species over either space or time is frustrating at best.

FACTORS COMPLICATING FINAL ANALYSES

REAPPEARANCE OF ECTOMYCORRHIZAL FUNGI IN THE DENSITY MANAGEMENT CLEAR-CUT STAND: Two years after logging, ectomycorrhizal fungi were collected from the **clear** transect ends lying 10 m from the bases of standing buffer trees separating the **control** and **clear** plots. While basidiome and species numbers remained greatly depressed on the **clear** plot, the 23 collections representing 9 EEB species will complicate final analyses, particularly considering that only one other collection (representing a tenth post-treatment EEB species for the **clear** plot) was made from the remaining ~340 m² transect area. Monitoring fruiting responses of such “buffer” EEB species could provide NWF Plan administrators with additional information about the optimum size of protective buffers around rare or threatened ectomycorrhizal fungi (Sperling pers. comm., 2001, 2002). In their research on spatiotemporal patterns in ectomycorrhizal populations, Dahlberg and Stenlid (1995) noted that mycelial genet sizes (which vary greatly between species) tend to be smaller in younger and larger in older forests, suggesting that the older the stand, the larger the buffer size needed. Despite the 10 m tree-base radius for the “buffer” basidiomes, forest managers are cautioned that it is necessary both to retain sufficient canopy, understory, and ground cover around EEB fruiting sites and to ensure against winter blow-down of the residual trees. Continued monitoring after the density study’s conclusion should provide better in-

sights as to re-establishment of easily identified and unique fungi in the clear-cut proper. The seven *Phaeocollybia* species collected in 1998 ~40 m from the standing buffer have not fruited since the stand was logged in 1999. The fact that the uncommon yet easily recognizable *Phaeocollybia* basidiomes are long-lasting and tend to fruit annually in the same location (Norvell, 1998a, 1998b) makes them suitable indicators for other reemergent fungi in the **clear** stand.

PRESENCE OF INTERMIXED WESTERN HEMLOCK IN DOUGLAS-FIR STUDY: While every effort was made to select pure Douglas-fir stands for study sites, western hemlock still occurred on half the density transects (one **moderate** and all **high** & **low** transects) and two thirds the chronosequence transects (both **late** transects and one each of the **mid** and **early** transects). Western hemlock, which until the 1980’s was generally not replanted (although it did naturally reseed itself after logging), does not form a major component of older Douglas-fir timber plantations. The species is now included in otherwise “pure” Douglas-fir plantations, however, because it is also a valuable timber product and because it helps to prevent widespread infections (e.g., Swiss needle cast) in Douglas-fir. Currently, both western hemlock and the non-ectomycorrhizal western redcedar (*Thuja plicata* Donn ex D. Don) are planted among Douglas-fir at a 20% to 80% Douglas-fir ratio. The fact that western hemlock (the obvious climax species of the western-hemlock zone) forms a major component of the 150-year old stand and is intermittently present elsewhere in the studies may well prevent extrapolating a “pure” Douglas-fir EEB species richness index.

ELEVATIONAL DIFFERENCES IN THE DENSITY TREATMENT STAND: Although the upper and lower units share common vegetation, soils, slope, and aspect, the authors were aware that an 80 m elevational difference might

complicate comparative analyses. For that reason, they decided to place the two most extreme density treatments (**control** vs. **clear**) together in the adjacent upper plots. During the pre-treatment year, the upper and lower units produced 84 % and 73% respectively of the 112 EEB species identified from the Green Peak site. The 1999–2002 post-treatment data, however, show that the upper and lower units produced 63% and 82% respectively of the 175 EEB species identified. Ignoring elevational differences, one might infer from these data that clear-cutting had sufficient deleterious impact by altering the species richness of the entire unit (a possibility that cannot be ruled out). Unfortunately, an additional complication was that sampling of the upper unit was variably prohibited during the treatment year. Calculation of an artificially “average” EEB species richness per stand does imply differences between the two units: pre-treatment and post-treatment average species per stand (both with and without 1999–2000 collections) are 42% (pre–) and 31.7–32.3% (post–) for the upper unit and 24.4% (pre–) and 27.2–27.3% (post–) for the lower. It appears that the impact of varying weather regimes experienced by stands in different elevations on Green Peak is significant.

WEATHER FACTORS: Although precipitation was not recorded on site, the authors hope to use data from the general area to provide additional information regarding species richness during a given year once all identifications have been confirmed. For instance, 2001 autumn collections following an unusually dry summer were greatly depressed compared to the previous autumn, with Pedee **early**, **mid**, and **late** yr4/yr3 EEB richness stand ratios computed at only 48%, 36%, and 46% respectively. The particularly low **mid** stand ratio suggests that proximity to a large clear-cut intensified the impact of drought on the **mid** transects and delayed onset of fruiting. Without on-site microclimate measurements, however, there are few data to demonstrate a correlation between species richness and precipitation, and comparisons to more generalized precipitation data are inconclusive.

UNPREDICTABLE TREATMENT OR STAND VARIABILITY: (1) The depressed post-treatment EEB species richness recorded from the lower unit's **high** plot may be tied to two 5m wide skids running down the steep slope through both transects. (**Moderate** and **low** plots have no such skids.) (2) Despite the fewer overall residual trees in the **moderate** plot, a more extensive refuge understory of vine-maple and shrubs provides a sheltering moisture barrier not found in the more open **high** understory. (3) The **low** plot was differentially thinned: after treatment the upper **low** transect retained consid-

erably more shrubby understory and residual trees so that its structure resembled that of the adjoining **moderate** plot while the lower transect was virtually barren of residual vegetation, more reminiscent of the **clear** plot.

Conclusions

TOTAL SPECIES RICHNESS OF ECTOMYCORRHIZAL FUNGI IN OREGON—WASHINGTON DOUGLAS-FIR FORESTS: (Tables 4, 6): The two concurrent studies provide impressive fungal species richness data for Oregon coastal montane forests and additional support for the wide fungal diversity associated with *Pseudotsuga menziesii*. Four years and 38 field visits to two sites separated by only 19 km yielded 531 macrofungal species including 309 EEB and 11 NEB target species. During the four autumn fruiting seasons, EEB species per 400 m² ranged from a low of 5 to a high of 60 per plot visit for untreated density plots (Figure 1b); at the chronosequence site EEB stand visit highs were 53 (early), 44 (mid), and 60 (late) per 400 m² (FIG. 1a-b). The total area monitored was only 3200 m² (chronosequence 1200 m² + density 2000 m²), with transects covering 400 m² per age stand or treatment plot. Based on density **control** plot data, EEB species richness averaged 136 per stand age. The chronosequence EEB species richness totals were 136 (25-year-old), 124 (55-year-old), and 158 (150-year-old) per stand. Density plot EEB totals ranged from a low of 70 (**clear**) to a high of 127 (**control**) per plot. It is noteworthy that the untreated 56-year-old density **control** plot and the 55-year-old chronosequence **mid** stand yielded comparable species richness totals even though the authors regard the latter as the most depauperate chronosequence stand. The fact that the overall chronosequence EEB species richness (253) exceeded the density (212) study total is not unexpected, since three different age classes were represented and no sites were logged in the age study.

The Oregon Coast Range studies recorded more ectomycorrhizal species than did the two most rigorous previous Douglas-fir EEB community studies (Tables 4, 6). O'Dell et al. (1999) listed 146 (out of a reported 160) EEBs from eight different Douglas-fir/western hemlock dominant “late seral” stands (ranging in age from 246 to 311 years) across a precipitation gradient on Washington's Olympic peninsula. Smith et al. (2002) listed 133 (from a reported 215) EEBs from nine stands representing three Douglas-fir age classes: 30–35-year-old (86 spp.), 45–50-year-old (83 spp.), and >400-year-old (105 spp.) from the Andrews Experimental Forest in the Oregon Cascade Range.

TABLE VI
ECTOMYCORRHIZAL EPIGEOUS BASIDIOMYCETE (EEB) SPECIES RICHNESS IN WASHINGTON AND OREGON DOUGLAS-FIR FORESTS.¹

Genus	Olympic Peninsula, WA ²	Coast Range, OR ³	Cascade Mountains, OR ⁴
<i>Amanita</i>	5	9	5
<i>Boletus</i>		1	
<i>Cantharellus</i>	2	3 (1)	2
<i>Camarophyllus</i>			1
<i>Chalciporus</i>		1	1
<i>Chroogomphus</i>	1		1
<i>Cortinarius</i>	63 (7)	95 (5)	81 (61)
<i>Craterellus</i>	1	1	
<i>Gomphidius</i>	2	2	2
<i>Gomphus</i>	2	1	2
<i>Hebeloma</i>	1	9 (1)	3
<i>Hydnellum</i>	1		
<i>Hydnum</i>	2	2	1
<i>Hygrophorus</i>	3	5	6
<i>Inocybe</i>	17	62 (1)	41 (31)
<i>Laccaria</i>	3	3	3
<i>Lactarius</i>	8	8	10
<i>Limacella</i>		1	
<i>Paxillus</i>			1
<i>Phaeocollybia</i>		15	1
<i>Phellodon</i>	3	1	
<i>Phylloporus</i>	1	1	1
<i>Ramaria</i>	1	21 (1)	15 (6)
<i>Rozites</i>	1		
<i>Russula</i>	12 (1)	50 (1)	25
<i>Sarcodon</i>	1		
<i>Suillus</i>	3	2	2
<i>Thelephora</i>		2	1
<i>Tricholoma</i>	11	13 (1)	7
<i>Xerocomus</i>	2	1	4
Total	146	309	216

¹Original species names from the Olympic and Cascade studies have been adjusted to conform to current generic or species concepts for *Cortinarius*, *Craterellus*, and *Xerocomus*. *Clavariadelphus*, *Clavulina*, *Hygrocybe*, and *Tapinella* are omitted from all study totals, as their mycorrhizal associations are suspect. Numbers reflect names as listed in original lists, with species reported as “sp.” or totaled in unnamed species complexes enclosed in parentheses.

²O’Dell et al. 1999.

³Norvell & Exeter (current preliminary).

⁴Smith et al. 2002.

PERMANENT VS. MOVABLE TRANSECTS AND THE SPACE-TIME CONTINUUM (Does Time = Area in fungal species richness studies?): The Oregon Coast Range study’s high EEB species richness (309) was recorded from an area one-third (“Olympic”, with 146 EEB species) to one-thirteenth (“Cascade”, with 216 EEB species) the size of the other two studies. This suggests that higher richness is tied not to an expanded target area, but instead to a greater number of stand samples per fruiting season. The Olympic study covered only two

years, used movable transects totaling 10,400 m², and sampled each stand 6 times for 48 total stand samples (O’Dell et al., 1999). The Cascade study covered four years to date, used both movable and permanent transects totaling 43,700 m², and sampled each stand nine times for 81 stand samples (Smith et al., 2002). The present Oregon Coast Range study covered four years, uses permanent transects totaling 3,200 m², sampled three stands 20 times and one stand 18 times for 78 stand samples. Both the Olympic and Cascade studies inves-

tigated species abundance, and the Cascade study also monitored hypogeous ectomycorrhizal fungi (O’Dell et al., 1999; Smith et al., 2002).

Differences in EEB species richness between studies may be variously explained. The Olympic study, for instance, covered only two complete fruiting cycles, comprised fewer stand visits, and included some relatively dry “depauperate” forests (O’Dell pers. comm., 2001). Nonetheless, one salient difference may be the use of permanent transects combined with a higher sampling frequency in the present study. Even considering that total species may decrease once species concepts are fully refined in the current studies, it would appear that an increased sampling of permanent transects has contributed significantly to the high EEB species richness total. Familiarity with a site, more accessible locations, and less time setting up transects all confer advantages. O’Dell et al. (1999), who suggested that movable transects may have contributed to higher EEB species–richness records compared to other studies that resampled permanent (and contiguous) quadrats, stressed that methodological differences greatly complicate cross-study EEB species richness comparisons. Nonetheless, they stated that sampling “noncontiguous plots distributed along transects resulted in sampling new areas,” thereby possibly contributing to their higher totals. They also noted that “even though our stand samples were modest in size, they were dispersed over a greater surface area than those from studies using adjacent and resampled plots. Higher richness may result from sampling a new transect at each sampling time or from the non-continuous spacing of plots.” To this should be added that Smith et al. (2002), who used both movable and permanent transects, observed no significant differences in species richness per stand visit. In the final analysis, however, a longer growing season is potentially

the single most important factor contributing to the higher fungal diversity noted for the Oregon Coast Range.

THE DOUGLAS-FIR/WESTERN HEMLOCK CONNECTION (Table 7): O’Dell et al. (1999) and Smith et al. (2002) both tied their relatively high EEB species–richness values to the high ectomycorrhizal potential of *Pseudotsuga menziesii* and *Tsuga heterophylla* originally hypothesized by Trappe and Fogel (1977). O’Dell et al. (1999) sampled 150 EEB species from 10,400 m² in two years, and Smith et al. (2002) sampled 215 EEB species from 43,700 m² in four years. O’Dell et al. (1999) contrasted their EEB species richness from a single western hemlock forest zone in western North America to the much lower EEB species richness from eastern North American *Fagus*- and *Picea*- (54 species/6144 m²; Bills et al., 1986) and *Abies*-, *Betula*-, and *Picea*-forests (84 species/6000 m²; Villaneuve et al., 1989). With respect to the ectomycorrhizal potential for *Picea*, however, it should be noted that Gulden et al. (1992) cited an EEB species richness of 132/2250 m² for *Picea* for their three–year study of a spruce forest in northern Norway, a total only slightly lower than that reported by O’Dell et al. (1999) and from a much smaller area than the eastern North American studies.

Within the three western hemlock zone studies, the current four–year Oregon Coast Range studies encompass a smaller area than the two–year Olympic and four–year Cascade studies. Based on 309 EEB species/3200 m², Oregon Coast Range forests appear richer, with 400 m² stand samples reaching up to 60 EEB species per stand visit and 150 EEB species per 400 m², recording 2 times the Olympic and 1.4 times the Cascade totals. Inclusion of data from different forest age classes may explain the unusually high species richness for the Oregon Coast and Cascade Range studies. Current data imply a higher

TABLE VII
PERCENTAGE (%) OF HIGHER EEB TAXA IN PACIFIC NORTHWEST DOUGLAS-FIR FORESTS.

Orders	Olympic Peninsula WA ¹	COAST RANGE OR ²	CASCADE RANGE OR ³
Agaricales 1: Cortinariaceae	56.2	58.6	58.3
Agaricales 2: Non-Cortinariaceae	15.1	10.0	10.2
Boletales	6.2	2.6	5.6
Cantharellales	3.4	1.9	1.4
Phallales	2.1	7.1	7.9
Russulales	13.7	18.8	16.2
Thelephorales	3.4	1.0	0.5

¹O’Dell et al. 1999.

²Norvell & Exeter (current preliminary).

³Smith et al. 2002.

TABLE VIII

KEYING MACROFUNGI IN WESTERN NORTH AMERICA: NUMBER OF REFERENCES CONSULTED IN PRELIMINARY IDENTIFICATION OF *CORTINARIUS*, *INOCYBE*, AND *RUSSULA* SPECIES FROM OREGON DOUGLAS-FIR FORESTS.

Genus	Total refs	Reg. flora/ monogr.	Other tax. papers	Europe/ Asia	PNW refs	Total spp indexed	Total refs indexed	Total spp identified
<i>Cortinarius</i>	96	17	44	43	24	613	23	95
<i>Inocybe</i>	58	14	38	19	25	246	26	62
<i>Russula</i>	88	15	55	23	17	125	13	50

EEB species richness for Douglas–fir forests in general, and for Oregon coastal montane Douglas–fir forests in particular.

REFERENCES IN DISARRAY: HOW DO WE KNOW WHAT IT IS WE FOUND? (Table 8; Taxonomic References): Perhaps the single greatest problem confronting Pacific Northwest forest myco–ecologists is the paucity of regional monographs or keys to important large genera. The western North American mycota is large and diverse and covers several different forest zones. As these and other studies have shown, the number of EEB species associated with Douglas–fir is indeed high. The present authors outline literature research protocols as a guide for what should be the very first consideration *before* launching a project dependent upon fungal fruit-body identification. A survey of early and contemporary ecological studies (none cited here) suggests that many ecological researchers maintain the delusion that because macrofungi are visible to the naked eye, they are readily identified from macrocharacters alone, making them somehow appropriate for novice mycologists with little or no rigorous taxonomic background. Fungi that produce visible sporocarps are not readily keyed from field guides using the unaided eye or a hand lens; “macro” fungi remain microorganisms that must be identified using a compound microscope. Field guide-based myco–ecological studies contribute only superficial information, because even the most comprehensively written guide is a secondary reference that cannot provide sufficient detail for identification to species. In the future, unknowns may be economically identified using molecular probes, but until Genbank has sequences of all known and (as yet) unknown species on file, recourse to the technical literature and the microscope remains the only reliable way to identify fungi. Because differing levels of taxonomic expertise or species refinement between independent studies can greatly complicate cross–study comparisons, those conducting rigorous myco–ecological studies—particularly those attempting to assess species richness or abundance—are

well advised to ensure active participation of expert taxonomists who understand the scope of the problem at the onset. These trained taxonomists are, in turn, advised to amass as much taxonomic literature on the target species as possible, paying particular attention to the larger genera, such as *Cortinarius*, *Inocybe*, and *Russula*, the three great western Douglas–fir forest problem genera.

Only after a nomenclature is correlated to a concept can a taxonomist hope to develop informative keys and descriptions. Because information from out–of–date American monographs, “antique” and modern research papers, and modern European monographs need to be blended into a viable keying base, the senior author’s first task (performed, unfortunately, on the run) was to develop species concepts that would remain somewhat consistent during the keying process. Using extralimital keys to identify Oregon collections was particularly vexing, because many fungi appeared to represent endemic and possibly undescribed taxa. Therefore, it became necessary to build three giant (and several smaller) cross-referenced nomenclatural indices that linked one species concept to several names used by different workers. This activity sapped much needed time from microscopic examinations and identifications, but the alternative of attempting to identify each unknown using multiple descriptions and different keys in a species concept vacuum proved both inefficient and pointless. For that reason, a major goal of both studies has become the development of keys to Douglas–fir associated fungi in the Pacific Northwest coniferous region.

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This paper is dedicated to Orson K Miller Jr., one of the first American mycologists to weld taxonomy and ecology into a viable science and who has devoted much of his working life to agarics in western forests. His North American *Chroogomphus*, *Gomphidius* and *Xeromphalina* monographs and his contributions to the knowledge of *Amanita*, gastromycetes, and snowbank, alpine, & montane fungi have proved invaluable to generations of serious mycologists. He has trained a host of vital, outstanding mycological taxonomists, ecologists, geneticists, and evolutionary scientists. With warmth and approachability, Orson has forged an enviable alliance between field ("amateur") and academic ("professional") mycologists and written a number of excellent field guides for use by both alike. As one of the first post-war American mycologists to rekindle the scientific liaison between North America and Europe forged by Curtis and Berkeley, Orson has given American mycology an important gift: hope. For all his contributions, he is owed much gratitude.

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- . 1994b. Record of decision [ROD] for amendments to Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl & standards and guidelines for late-successional and old-growth forest related species within the range of the northern spotted owl. U.S. Govt. Printing Office, Washington DC.
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Appendix: Taxonomic Literature Consulted (Primary References Only)

Citations include family name of first author in boldface type, publication year, and in parentheses the abbreviated title/ journal citation.

AGARICALES - EEB Cortinariaceae: *CORTINARIUS* - Ammirati 1972 (*Michigan Bot.* 11: 13-25; Univ. Michigan Ph.D. diss.), 1977 (*Mycotaxon* 5: 381-397), 1978 (*Mycotaxon*

- 7: 256–264), 1984 (Mcllvainia 6: 54–64), 1985 (Poisonous Mushr. of N. U.S. & Canada), 1988 (Mycotaxon 33: 437–446; Mcllvainia 8: 49–59), 1998 (unpubl. NWFP descr.); **Brandrud** 1992 (Nordic Macromycetes), 1990–2001 (Cortinarius Flora Photographica); **Breitenbach** 2000 (Fungi of Switzerl. 5); **Kauffman** 1905 (Bull. Torrey Bot. Club 32: 301–325), 1925 (Pap. Michigan Acad. Sci. 5: 115–148), 1929 (Pap. Michigan Acad. Sci. 9: 151–210), 1932 (N. Am. Flora 10: 282–348); **Moser** 1960 (Gattung *Phlegmacium*), 1983 (Keys to Agarics & Boleti), 1987 (Arctic Alpine Mycol. 2: 219–317), 1994–2002 (Farbatlas), 1995 (Mycotaxon 55: 301–346), 1996 (Mycotaxon 58: 387–412, Sydowia 49: 25–48), 1997 (Sydowia 49: 25–48), 1999 (Mycotaxon 72: 289–321), 2000 (Mycotaxon 74: 1–36); **Norvell** 1995 (NWFP Strat. 1 unpubl. descr.); **Seidl** 2000 (Univ. Wash. Ph.D. diss.); **Smith** 1939 (Contrib. Univ. Michigan Herb. 2: 5–42); 1942 (Bull. Torrey Bot. Club 69: 44–64); 1944 (Lloydia 7: 163–235), 1950 (Mycologia 42: 80–134), 1972 (Mycologia 64: 1138–1153); **Stuntz** 1980's (unpubl. Macrokey to Wash. *Cortinarius* spp.); **Thiers** 1969 (Mycologia 61: 526–536). **HEBELOMA** – **Breitenbach** 2000 (Fungi Switzerl. 5); **Moser** 1983 (Keys to Agarics & Boleti), 1994–2002 (Farbatlas); **Norvell** 1995 (NWFP Strat. 1 unpubl. descr.); **Smith** 1983 (Veiled spp of *Hebeloma* W. U.S.). **INOCYBE** – **Alessio** 1980 (Iconogr. Mycol. 29: *Inocybe*); **Breitenbach** 2000 (Fungi Switzerl. 5); **Cripps** 1997 (Mycologia 89: 670–688); **Grund** 1968 (Mycologia 60: 406–425); 1970 (Mycologia 62: 925–939); 1975 (Mycologia 67: 19–31); 1977 (Mycologia 69: 392–408); 1980 (Mycologia 72: 670–688); 1981 (Mycologia 73: 655–674); 1983 (Mycologia 75: 257–270); **Heim** 1933 (Genre *Inocybe*); **Horak** 1980 (Persoonia 11: 1–37, Sydowia 33: 145–151), 1981 (Persoonia 11: 303–310); **Jacobsson** 1989 (Windahlia 18: 15–24); **Kauffman** 1921 (New York State Mus. Bull. 223–224: 43–59); 1924 (N. Amer. Flora 10(4): 227–260); 1925 (Pap. Michigan Acad. Sci. 4: 311–344); 1930 (Pap. Michigan Acad. Sci. 11: 151–210); **Kuyper** 1985 (Persoonia 12: 375–400), 1986 (Revis. *Inocybe* in Europe); **Matheny** 2001 (Sydowia 53: 93–139); 2002 (Amer. J. Bot. 89: 688–698, Prelim. Key to PNW *Inocybes* unpubl.); **Moser** 1983 (Keys to Agarics & Boleti), 1994–2002 (Farbatlas); **Nishida** 1988 (Mycotaxon 33: 213–222), 1989 (Mycotaxon 34: 181–196); **Printz** 1992 (Nordic Macromycetes); **Redhead** 1979 (Univ. Toronto Ph.D. diss.); **Smith** 1938 (Pap. Michigan Acad. Sci. 24: 93–106), 1941 (Mycologia 33: 1–18), 1950 (Mycologia 42: 80–135); **Stangl** 1989 (Gattung *Inocybe* in Bayern); **Stuntz** 1940 (Yale Univ. Ph.D. diss.), 1947 (Mycologia 39(1): 21–55), 1954 (Pap. Michigan Acad. Sci. 39: 53–84), 1965 (*Inocybe* subg. *Inocybium* sec. *Inocybium* Stuntz, unpubl. man.), 1978 (PNW Key Council *Inocybe* skeletal key); **Vauras** 1986 (Karstenia 26: 65–72). **PHAEOCOLLYBIA** – **Norvell** 1998 (Univ. Wash. Ph.D. diss.).
- AGARICALES - EEB Non-Cortinariaceae: AMANITA** – **Breitenbach** 1995 (Fungi Switzerl. 4); **Jenkins** 1986 (Amanitas N. Amer.); **Lindgren** 1997 (PNW Key Council *Amanita* key); **Moser** 1983 (Keys to Agarics & Boleti), 1994–2002 (Farbatlas); **Thiers** 1982 (Agaricales of Calif. 1, Mycotaxon 15: 166); **Tulloss** 1992 (Mycotaxon 45: 373–387), 1994 (Mycotaxon 51: 179–190). **HYGROPHORUS** – **Breitenbach** 1991 (Fungi Switzerl. 3); **Hesler** 1963 (NAm. spp. of *Hygrophorus*), **Largent** 1985 (Agaricales of Calif. 5), **Miller** 1984 (Mycologia 76: 816–20); **Moser** 1983 (Keys to Agarics & Boleti), 1994–2002 (Farbatlas); **Norvell** 1995 (NWFP Strat. 1 unpubl. descr.). **LACCARIA** – **Mueller** 1992 (Syst. *Laccaria* Cont. U.S. & Canada). **LIMACELLA** – **Breitenbach** 1995 (Fungi Switzerl. 4); **Moser** 1983 (Keys to Agarics & Boleti), 1994–2002 (Farbatlas); **Smith** 1945 (Pap. Michigan Acad. Sci. 30: 125–147). **TRICHOLOMA** – **Ammirati** 1985 (Poisonous Mushr. of N. U.S. & Canada); **Breitenbach** 1991 (Fungi Switzerl. 3); **Kauffman** 1918 (Agaricaceae Mich.), **Moser** 1983 (Keys to Agarics & Boleti), 1994–2002 (Farbatlas); **Norvell** 1995 (NWFP Strat. 1 unpubl. descr.); **Ovrebø** 1980 (Univ. Toronto Ph.D. diss.), **Shanks** 1997 (Agaricales Calif. 11: *Tricholoma*).
- BOLETALES: BOLETUS, CHALCIPORUS, SUILLUS, XEROCOMUS** – **Both** 1983 (Boletes N. Amer.); **Bessette** 2000 (N. Amer. Boletes); **Donk** 1966 (Gen. names Hymenomyc. 4); **Smith** 1971 (Boletes Michigan); **Thiers** 1975 (Calif. Mushr.: F.G. to Boletes), 1976 (Mycologia 68: 976–983); **Watling** 1970 (British Fungus Fl. 1); **Suillus** – **Smith** 1964 (Contrib. Monogr. N. Amer. spp. *Suillus*). **CHROOGOMPHUS & GOMPHIDIUS** – **Miller** 1964 (Mycologia 56: 526–548), 1966 (Mycologia 58: 855–861), 1970 (Mycologia 62: 831–836), 1971 (Mycologia 43: 1129–1163); **Singer** 1949 (Mycologia 41: 462–489); **Thiers** 1985 (Agaricales Calif 3); **Watling** 1970 (British Fungus Flora 1). **PAXILLUS & PHYLLOPORUS** – **Smith** 1972 (Mycologia 64: 1138–1153); **Thiers** 1985 (Agaricales Calif 4).
- CANTHARELLALES: CANTHARELLUS** – **Corner** 1966 (Monogr. Cantharelloid Fungi); **Donk** 1966 (Gen. names Hymenomyc. 9); **Norvell** 1995 (NWFP Strat. 1 unpubl. descr.); **Redhead** 1997 (Mycotaxon. 65: 285–322); **Smith** 1947 (Mycologia 39: 497–534), 1968 (Michigan Bot. 7: 143–183); **Thiers** 1985 (Agaricales Calif 2); **Tylutki** 1987 (Mushr. Idaho 2). **CRATERELLUS** – **Bigelow** 1978 (Mycologia. 70: 707–756), **Corner** 1966 (Monogr. Cantharelloid Fungi); **Petersen** 1979 (Nova Hedwigia 31: 1–23); **Redhead** 1979 (Univ. Toronto Ph.D. diss.); **Smith** 1968 (Michigan Bot. 7: 143–183), 1981 (How to Know Non-gilled Mushr.); **Thiers** 1985 (Agaricales Calif 2); **Trappe** 2001 (Oregon State Univ. M.S. thesis); **Tylutki** 1987 (Mushr. Idaho 2). **HYDNUM** – **Donk** 1966 (Gen. names Hymenomyc. 5); **Hall & Stuntz** 1971 (Mycologia 63: 1099–1128); **Harrison** 1964 (Canad. J. Bot. 42: 1205–1233), 1971 (Mycologia 63: 1067–1072), 1987 (Mycotaxon 28: 419–426; 28: 426–435); **Tylutki** 1987 (Mushr. Idaho 2).
- PHALLALES: GOMPHUS** – **Bigelow** 1978 (Mycologia 70: 707–756); **Corner** 1966 (Monogr. Cantharelloid fungi); **Petersen** 1968 (J. Elisha Mitchell Sci. Soc. 84: 373–381), 1971 (Genera *Gomphus* & *Gloeocantharellus* in N. Amer.), 1973 (The Fungi: Aphyllorales II), 1979 (Nova Hedwigia. 31: 1–23); **Smith** 1947 (Mycologia 39: 497–534), 1968 (Michigan Bot. 7: 143–183); **Thiers** 1985 (Agaricales Calif. 2); **Tylutki** 1987 (Mushr. Idaho 2). **RAMARIA** – **Corner** 1950 (Monogr. *Clavaria* & Allied Gen.), 1966 (Trans. Brit. Myc. Soc. 49: 101–111); 1970 (Suppl. to Monogr. of *Clavaria* & Allied Gen.); **Donk** 1966 (Gen. names Hymenomyc. 3); **Doty** 1944 (*Clavaria* in Oregon & PNW); **Exeter** 2000–2002 (Keys to PNW *Ramaria*, unpubl.), 2002 (*Ramaria* subg. *Laeticolora* & subg. *Ramaria*,

unpubl.); **Leathers** 1956 (*Mycologia* 48: 278–287); **Marr** 1973 (*Ramaria* of W. Wash.); **Petersen** 1967 (*Mycologia* 59: 767–802), 1969 (*Bull. Torrey Bot. Club* 96: 457–466), 1974 (*Amer. J. Bot.* 61: 739–748), 1975 (*Ramaria* subg. *Lentoramaria*), 1976 (*Amer. J. Bot.* 63: 309–316), 1979 (*Nova Hedwigia* 31: 25–38), 1981 (*Ramaria* subg. *Echinoramaria*), 1982 (*Sydowia* 35: 176–205), 1985 (*Mycologia* 77: 903–919), 1986 (*Canad. J. Bot.* 64: 1786–1811), 1987 (*Sydowia* 40), 1988 (*Mycologia* 80: 223–234), 1988 (*Mycotaxon* 33: 101–144), 1989 (*Persoonia* 14: 23–42), 2000 (*Karstenia* 40: 139–142), **Scates** 1981 (PNW Key Council *Ramaria* trial key).

RUSSULALES: LACTARIUS—**Bills** 1986 (*Mycologia* 78: 70–79); **Burlingham** 1913 (*Mycologia* 5: 305–311); **Hesler** 1979 (N. Amer. spp. *Lactarius*); **Korhonen** 1984 (Suomen Rouskut); **Leuthy** 1981 (PNW Key Council *Lactarius* trial field key); **Methven** 1992 (*McIlvainea* 10: 29–40), 1992 (*McIlvainea* 11: 26–34), 1997 (*Agaricales Calif.* 10); **Moser** 1983 (Keys to Agarics & Boleti), 1994–2002 (*Farbatlas*). **RUSSULA**—**Burlingham** 1915 (N. Amer. Flora 9: 201–236), 1944 (*Mycologia* 36: 104–120); **Einhellinger** 1987 (Gattung *Russula* in Bayern); **Fatto** 1999 (*Mycotaxon* 70: 167–175); **Grund** 1965 (Univ. Wash. Ph.D. diss.), 1979 (*Mycologia* 69: 93–113); **Kauffman** 1925 (Pap. Michigan Acad. Sci. 5: 115–148), 1929 (Pap. Michigan Acad. Sci. 9: 151–210); **Kibby** 1990 (Keys to Northe. N. Amer. Russulas); **Knudson** 1992 (Nordic Macromycetes); **Kuyper** 1985 (*Persoonia* 12: 447–455); **Moser** 1983 (Keys to Agarics & Boleti), 1994–2002 (*Farbatlas*); **Romagnesi** 1967 (Russules d'Europe et d'Afrique du Nord); **Ruotsalainen** 1994 (*Karstenia* 34: 21–34); **Sarnari** 1998 (Monogr. illustrata Gen. *Russula* in Europe I); **Schaeffer** 1962 (1979) (*Russulae*); **Shaffer** 1962 (*Brittonia* 14: 255–284), 1964 (*Mycologia* 56: 202–31), 1970 (*Lloydia* 33: 49–96), 1972 (*Mycologia* 64: 1008–1053), 1989 (Mem. New York Bot. Gard. 49: 348–354), 1990 (Contr. Univ. Michigan Herb. 17: 295–306); **Singer** 1942 (*Mycologia* 34: 64–93), 1986 (*Agaricales in Mod. Tax.*); **Thiers** 1994 (*Mycol. Helv.* 2: 107–120), 1997 (*Agaricales Calif.* 9); **Woo** 1993 (PNW Key Council *Russula* key).

THELEPHORALES (Only *Phellodon* and *Thelephora* are represented in the current studies; other ectomycorrhizal genera are *Boletopsis*, *Hydnellum*, *Polyzellus*, *Sarcodon*.)—**Baird** 1986 (*Mycotaxon* 23: 297–304), 1986 (Stipitate Hydnums S. Appalach. Mts.); **Breitenbach** 1986 (*Fungi Switzerl.* 2); **Corner** 1989 (Ad Polyporaceae V); **Donk** 1966 (Gen. names Hymenomyc. 5, 7); **Hall** 1971 (*Mycologia* 63: 1099–1128), 1972 (*Mycologia* 64: 15–37, 560–590); **Harrison** 1964 (*Canad. J. Bot.* 42: 1205–1233), 1968 (*Michigan Bot.* 7: 212–264), 1984 (*Michigan Bot.* 23: 76); 1987 (*Mycotaxon* 20: 95–99, 28: 419–426); **Moser** 1994–2002 (*Farbatlas*); **Norvell** 1995 (NWFP Strat. 1 unpubl. descr.); **Smith** 1947 (*Mycologia* 39: 497–534), 1981 (How to Know Non-gilled Mushr.); **Stalpers** 1993 (Aphyllorhizaceous Fungi 1); **Thiers** 1985 (*Agaricales Calif.* 2); **Tylutki** 1987 (Mushr. Idaho 2).

NEB TARGETS: GENERAL—**Castellano** 1999 (NWFP Strat. 1 Handb.), 2003 (Add. NWFP Fungi). **ASTEROPHORA**—**Breitenbach** 1991 (*Fungi Switzerl.* 3); **Moser** 1983 (Keys to Agarics & Boleti), 1994–2002 (*Farbatlas*); **Redhead** 1995 (*Canad. J. Bot.* 72: 1812–1824), 2000 (Taxon); **Smith** 1949 (Mushr. in their Natural Habitats). **CLAVARIADELPHUS**—**Corner** 1950 (Mon-

ogr. of *Clavaria* & Allied Gen.), 1970 (Suppl. to Monogr. *Clavaria* & Allied Gen.); **Donk** 1966 (Gen. names Hymenomyc. 9); **Methven** 1989 (*Mycotaxon* 34: 153–179), 1990 (Gen. *Clavariadelphus* in N. Amer.); **Petersen** 1972 (*Mycologia* 64: 137–153); **Wells** 1968 (*Michigan Bot.* 7: 35–57). **CLAVULINA**—**Breitenbach** 1986 (*Fungi Switzerl.* 2); **Corner** 1950 (Monogr. *Clavaria* & Allied Gen.), 1970 (Suppl. to Monogr. of *Clavaria* & Allied Gen.); **Donk** 1966 (Gen. names Hymenomyc. 3); **Petersen** 1998 (NWFP Strat. 3 descr. unpubl.). **CLITOCYBE**—**Bigelow** 1982, 1985 (*Clitocybe* I & II); **Breitenbach** 1991 (*Fungi Switzerl.* 3); **Moser** 1983 (Keys to Agarics & Boleti). **GALERINA**—**Breitenbach** 2000 (*Fungi Switzerl.* 5); **Gulden** 1971 (*Norweg. J. Bot.* 18: 1–46), 1992 (Nordic Macromycetes), 2000 (*Acta Bot. Isl.* 13: 3–54.), 2000 (Nordic J. Bot. 19.), 2001 (*Mycol. Res.* 105: 432–440); **Horak** 1993 (*Sydowia* 44: 346–376), 1992 (*Canad. J. Bot.* 70: 414–433) **Moser** 1983 (Keys to Agarics & Boleti), 1994–2002 (*Farbatlas*); **Senn-Irlet** 1990 (Arctic Alpine Fungi: *G. terrestris*); **Singer** 1955 (*Trudy Bot. Inst. Akad. Nauk* 6: 472), 1964 (*Mycologia* 38: 500–523); **Smith** 1953 (*Mycologia* 45: 894–915); 1955 (*Mycologia* 47: 557–596), 1957 (*Sydowia* 11: 447), 1958 (*Mycologia* 50: 470–487), 1964 (Monogr. Gen. *Galerina*); **Watling** 1993 (British Fungus Fl. Agarics & Boleti 7: Cortinariaceae); **Wells** 1969 (*Lloydia* 32(3): 369–387). **GYMNOPIUS**—**Hesler** 1969 (*Gymnopilus* Monogr.); **Norvell** 1995 (NWFP Strat. 1 unpubl. descr.); **Smith** 1944 (*Amer. Midl. Naturalist* 32: 694–696). **LICHENOMPHALLA** (*Omphalina*, *Phytoconis*)—**Norvell** 1994 (*Mycotaxon* 50: 379–407), 1998 (NWFP Strat. 3 descr. unpubl.); **Redhead** 1987 (Arctic Alpine Mycol. 2: 319–348), 1988 (*Mycotaxon* 31: 221–223); 2002 (*Mycotaxon* 83: 19–57). **MYCENA**—**Breitenbach** 1991 (*Fungi Switzerl.* 3); **Maas Geesteranus** 1992 (*Mycenas* N. Hemisphere); **Moser** 1983 (Keys to Agarics & Boleti), 1994–2002 (*Farbatlas*); **Perry** 1999 (*Mycotaxon* 70: 87–97); **Redhead** 1989 (*Canad. J. Bot.* 67: 3003–3062), 1993 (*Mycotaxon* 46: 97–105), 1999 (unpubl. prep. key); **Smith** 1947 (N. Amer. spp. *Mycena*), 1950 (*Mycologia* 42: 80–134), 1953 (*Madroño* 12: 103–109). **PHOLIOTA**—**STROPHARIA**—**Farr** 1980 (*Mycotaxon* 11: 241–249); **Norvell** 2000 (*Mycotaxon* 76: 315–320), **Smith** 1968 (N. Amer. spp. *Pholiota*), **Stuntz** 1962 (*Mycologia* 54: 272–298). **SPARASSIS**—**Breitenbach** 1986 (*Fungi Switzerl.* 2); **Burdsall** 1988 (*Mycotaxon* 31: 199–206); **Martin** 1976 (*Mycologia* 68: 622–639).

COMPEHENSIVE TEXTS OR GUIDES: Arora 1986 (Mushr. Demystified); **Barron** 1999 (Mushr. Ont. & E. Canada); **Bessette** 1995 (Mushr. N. Amer. in color), 1997 (Mushr. Northe. N. Amer.); **Breitenbach** 1983–2000 (*Fungi Switzerl.* 1–5); **Courtecuisse** 1999 (Mushr. Brit. & Eur.); **Dähncke** 1979 (700 Pilze in Farbfotos); **Evenson** 1997 (Mushr. Colorado); **Flora Agaricina Neerlandica** 1991–2002 (Vols. 1–5); **Lincoff** 1981. (Audubon F.G. to N. Amer. Mushr.); **McKenny** 1987 (New Savory Wild Mushr.); **Miller** 1972 (Mushr. N. Amer.); **Moser** 1983 (Keys to Agarics & Boleti), 1994–2002 (*Farbatlas*); **Nordic Macromycetes** 1992–2002 (Vols. 1–5); **Nylén** 2000 (Svampar inorden och Europa); **Phillips** 1981 (Mushr. Great Brit. & Eur.), 1991 (Mushr. N. Amer.); **Singer** 1986 (*Agaricales in Mod. Tax.*); **Smith** 1949 (Mushr. in their Nat. Habitat), 1975

(F.G. to Western Mushr.), 1979 (How to Know Gilled Mushr.), 1980 (Mushroom Hunter's F.G.), 1981 (How to Know Non-gilled Mushr.).

NOTE: Supplementary taxonomic keys to and descriptions of Pacific Northwest conifer-associated basidiomycetes

developed during the current studies include microscopic and macroscopic keys to *Ramaria* (Exeter, 1999–2002) and species indices and/or microscopic keys to *Cortinarius*, *Galerina*, *Hydnum*, *Hydnellum*, *Inocybe*, *Mycena*, *Russula*, and *Sarcodon* (Norvell, 1998–2003).