Macrofungi of the altitudinal gradient, Northern Rocky Mountains

by John Henry Keck

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science . in Biological Sciences
Montana State University

Abstract:
Macrofungal communities of four altitudinal zones of the Northern Rocky Mountain region are described and compared with respect to species richness, production (g/100m2/yr), functional structure (mycorrhizal vs. decomposer), seasonality of activity and relationship to temperature and rainfall. Two study sites of 100m2 were established in grasslands, Douglas-fir forest, subalpine fir (spruce-fir) forest and in the alpine. Each study site was visited fortnightly during the collecting season (May-September) in 1997 and 1998, monthly in 1999, with a limited number of trips to the alpine. All fungal sporocarps were collected, dried, weighed, and identified to species when possible. Soil moisture and soil temperature readings were taken at each visit during 1997 and 1998. Species richness varied with the elevational gradient from three species collected in grasslands, 60 species collected in Douglas-fir forests, 61 species collected in subalpine fir forests, and zero species collected in the alpine. Sixty-five species (out of 100 total species) fruited only during the wettest year of the study, 1997. Standing crop estimates ranged from 0.0002 to 0.005 g/100m2 in grassland, 0.01 to 2.16 g/100m2 in Douglas-fir forests, 0.04 to 1.63 g/100m2 in subalpine fir (spruce-fir forests) and no sporocarps were collected in the alpine. Standing crop was greatest in the grassland and forest sites in the wettest year, 1997. Species richness and production peaked earlier in the Douglas-fir forests (June), than in subalpine fir forests (August and September). With the majority of fungal species in the study fruiting only in the wettest year (1997), one might conclude that collecting sporocarps in a wet year provides a better indication of species richness than collecting in several typical (dry) years. The 100m2 plot size used in this study may bias for the sampling of saprophytic species, and may under-sample the more patchily distributed mycorrhizal species.

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of

Master of Science

in

Biological Sciences

MONTANA STATE UNIVERSITY-BOZEMAN
Bozeman, Montana

April 2001

APPROVAL

of a thesis submitted by

John Henry Keck

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ACKNOWLEDGEMENTS

I wish to thank the members of my committee: Dr. Cathy Cripps, Dr. Don Mathre, Dr. Rich Stout and Dr. Tad Weaver. A special thanks goes to Dr. Tad Weaver for giving me the idea for this project and chairing my committee. A special thanks also to Dr. Cathy Cripps for the hours spent teaching me and helping me with mushroom identification.

I also wish to thank my wife, Jennifer, for her support and assistance throughout the project.

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ABSTRACT

Macrofungal communities of four altitudinal zones of the Northern Rocky Mountain region are described and compared with respect to species richness, production ($g/100m^2/yr$), functional structure (mycorrhizal vs. decomposer), seasonality of activity and relationship to temperature and rainfall. Two study sites of $100m^2$ were established in grasslands, Douglas-fir forest, subalpine fir (spruce-fir) forest and in the alpine. Each study site was visited fortnightly during the collecting season (May-September) in 1997 and 1998, monthly in 1999, with a limited number of trips to the alpine. All fungal sporocarps were collected, dried, weighed, and identified to species when possible. Soil moisture and soil temperature readings were taken at each visit during 1997 and 1998. Species richness varied with the elevational gradient from three species collected in grasslands, 60 species collected in Douglas-fir forests, 61 species collected in subalpine fir forests, and zero species collected in the alpine. Sixty-five species (out of 100 total species) fruited only during the wettest year of the study, 1997. Standing crop estimates ranged from 0.0002 to 0.005 $g/100m^2$ in grassland, 0.01 to 2.16 $g/100m^2$ in Douglas-fir forests, 0.04 to 1.63 $g/100m^2$ in subalpine fir (spruce-fir forests) and no sporocarps were collected in the alpine. Standing crop was greatest in the grassland and forest sites in the wettest year, 1997. Species richness and production peaked earlier in the Douglas-fir forests (June), than in subalpine fir forests (August and September). With the majority of fungal species in the study fruiting only in the wettest year (1997), one might conclude that collecting sporocarps in a wet year provides a better indication of species richness than collecting in several typical (dry) years. The $100m^2$ plot size used in this study may bias for the sampling of saprophytic species, and may under-sample the more patchily distributed mycorrhizal species.

CHAPTER 1

GENERAL INTRODUCTION

Fungi are an important functional component of ecosystems which has been neglected in ecological studies of the Northern Rocky Mountain region. Fungi perform the functions of decomposition and nutrient cycling, maintaining the health of forest trees through mycorrhizal associations, and providing food for a variety of animals including humans. The scarcity of research papers on fungal ecology is due, in part, to the difficulty of quantifying fungal presence. In general, the fungal organism is composed of the mycelium, mycorrhizae (for some species) and the fruiting body, which is the reproductive structure and the only part of the fungus readily accessable for study. While the mycelium and mycorrhizae are the primary component of the fungus (Fogel and Hunt 1979), and quantifying them would provide a valuable characterization of fungal communities, there is presently no practical method for doing so. Instead the conventional approach is to collect, identify and weigh fruiting bodies as an index to their presence.

Due to the unpredictable production and short duration of fruiting bodies, ecologists usually establish permanent study plots and visit them repeatedly over time to collect fruiting bodies. Many studies of this nature have been conducted in forests due to the high abundance of sporocarps found there and the importance of fungi to the health of forest trees (Hering, 1966; Bills, et. al. 1986; Jansen, 1988; North, et. al. 1997).

The present study describes the change in fungal diversity and abundance as measured by sporocarp presence, frequency and biomass along an elevational gradient from grasslands through dry and moist forests and into the alpine of the northern Rocky Mountains. Examination of mushroom production along a transect of changing environmental conditions has been done with respect to rainfall (Eveling et. al. 1990; O'Dell et. al. 1999), and rainfall and temperature (Wilkins & Harris, 1946; Hering, 1966; Eveling et. al. 1990). Site selection and description is usually based on the type of dominant overstory vegetation (i.e. spruce-fir forest) and is therefore somewhat vague as to the specific environmental type studied. In contrast, this study uses the habitat typing system developed by Daubenmire (1968) to categorize the sites based on the dominant overstory and dominant understory vegetation present at climax, so that "all land areas potentially capable of producing similar plant communities at climax may be classified as the same habitat type" (Daubenmire, 1968). The diverse environments of the Northern Rocky Mountains have been classified (Daubenmire 1968) and those environments have been compared with respect to climate and soils (Weaver 1980, 2001). Climax communities occupying them have been compared with respect to composition, plant standing crop/production and animal associates. While the habitat typing system is well established in the study and management of forest and rangeland it has not been widely employed in the research and mangement of fungi (Pilz 1996).

Objectives

The objectives of this thesis are to describe and compare fungal communities of major ecosystems found in the Northern Rocky Mountain landscape: grassland environments, low-elevation Douglas fir environments, higher subalpine fir environments, and alpine environments. Chapters of this thesis will describe species composition and diversity (richness), standing crop and production, functional structure (mycorrhizae vs. decomposer), relationship to temperature and rainfall and how these factors trend up the elevational gradient. Use of Daubenmire's (1968) habitat typing system introduces this approach to ecologists and land mangers who wish to extend mycological data from unique sites to vast landscape segments they represent.

General Methods

Study Site Selection

To determine the common species and measure sporocarp productivity of macrofungi along an elevational gradient from grasslands to the alpine in the northern Rocky Mountain region, eight study sites were selected in four zones common to the area. The eight study sites included two grassland, two dry forest, two moist forest and two alpine sites (Table 1). The two grassland types represent relatively dry grassland (BS) and mid-range moisture grassland (AB). Moving up the elevational gradient, the forest sites chosen represent lower elevation Douglas fir (PS,b and PS,g) and higher elevation subalpine fir (AV,b and AV,g) conifer forests common to this region. The two alpine sites were chosen in a similar manner with *Dryas octopetala* (D) representing the

Table 1. Habitat type, location and abbreviation codes for eight study sites.

Habitat Type and Location	Site Abbreviation
Bouteloua gracilis/Stipa comata – Missouri Headwaters State Park	BS
Agropyron spicatum/Bouteloua gracilis – East side of Bozeman	AB
Pseudotsuga menziesii/Symphoricarpos albus – Gallatin Range (Kirk Hill)	PS,g
Pseudotsuga menziesii/Symphoricarpos albus – Bridger Range (Olson Cr.)	PS,b
Abies lasiocarpa/Vaccinium scoparium – Gallatin Range (History Rock Tr.)	AV,g
Abies lasiocarpa/Vaccinium scoparium – Bridger Range (Bracket Cr.)	AV,b
Dryas octopetala -- Bridger Range (Sacajawea Tr.)	D
Carex spp. -- Bridger Range (Sacajawea Tr.)	C

lower elevation and *Carex spp.* (C) representing the higher alpine. A map of the study area is given in figure 1.

Two other considerations in the choice of specific sites included accessability (close proximity to a road, trailhead and other study sites to minimize travel time) and location on public land.

Site Descriptions

Six study sites were established in September of 1996: two in grasslands, two in Douglas fir forests and two in subalpine fir forests. Two alpine sites were added in August of 1998. Each site conains four permanent plots measuring 1 meter by 25 meters for a total of 100 square meters per site. Plots within a site run parallel and are approximately 5 meters apart. A typical study site is diagrammed in figure 2. Each plot is divided into four sub-plots of equal size to produce a total of sixteen sub-plots per site. Use of elongate plots allowed for meticulous surveying without trampling in the plots. Site description information is given in table 2.

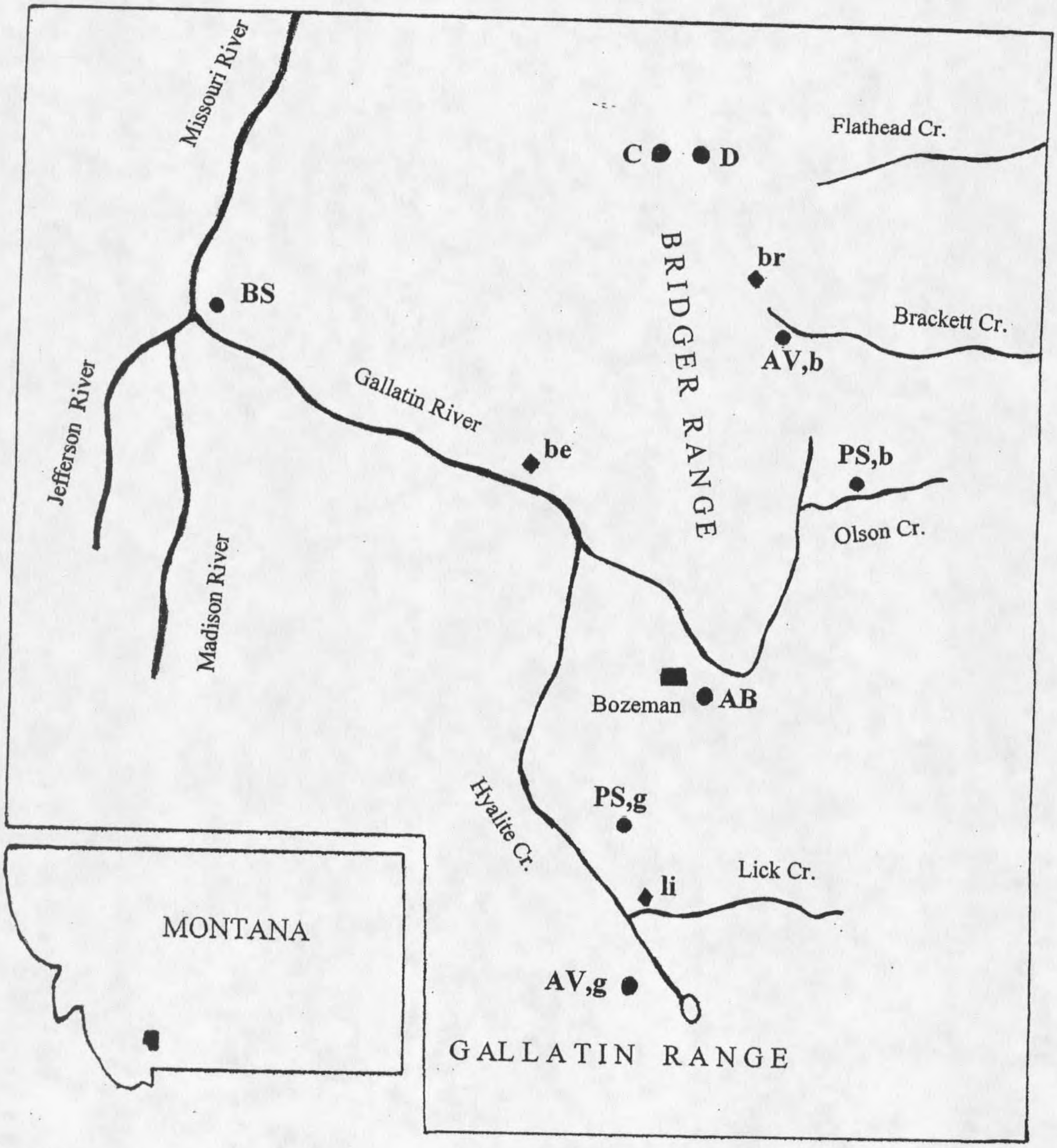

FIGURE 1. Map of study area.
Site locations: **BS** = *Bouteloua gracilis/Stipa comata* grassland; **AB** = *Agropyron spicatum/Bouteloua gracilis* grassland; **PS,g** = *Pseudotsuga menziesii/ Symphoricarpos albus* (Gallatin Mtns); **PS,b** = *Pseudotsuga menziesii/Symphoricarpos albus* (Bridger Mtns); **AV,g** = *Abies lasiocarpa/Vaccinium scoparium* (Gallatin Mtns); **AV,b** = *Abies lasiocarpa/Vaccinium scoparium* (Bridger Mtns); **C** = *Carex spp.* (alpine); **D** = *Dryas octopetala* (alpine). Weather stations (◆): **be** = Belgrade airport; **li** = Lick Cr.; **br** = Brackett Cr.

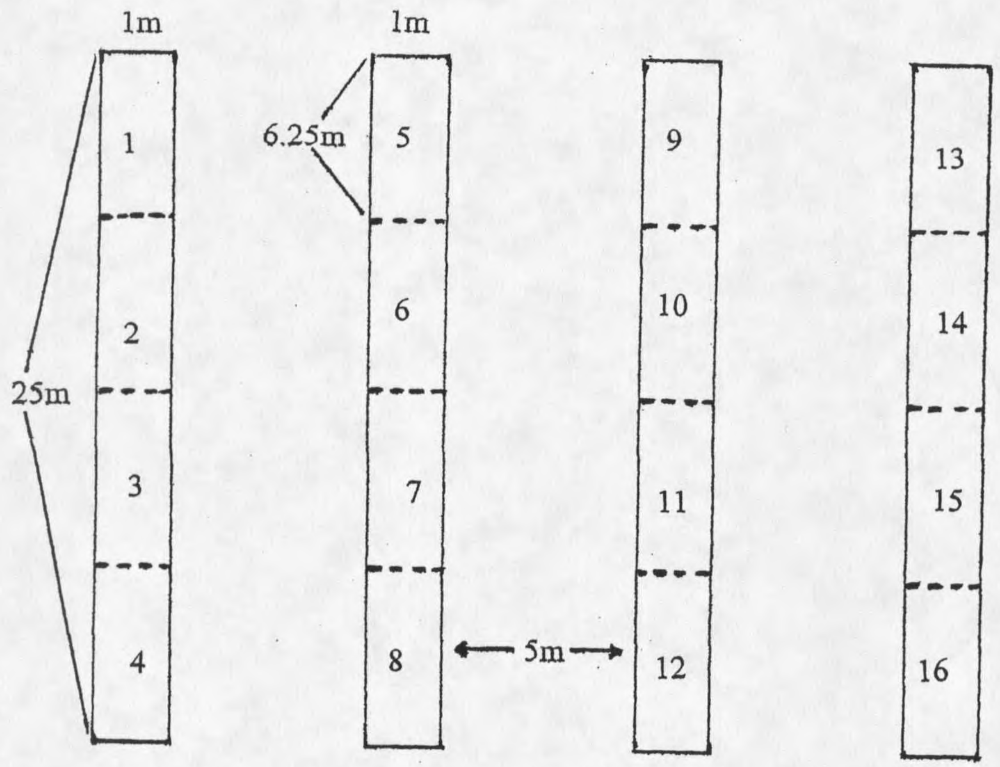

Figure 2. Study site design. Each site contains four 1m X 25m plots. Each plot is divided into four 1m X 6.25m subplots. Plots run parallel and are spaced approximately 5m apart. Subplots are numbered 1 – 16.

Sampling Methods

Study sites were visited every 2 weeks during the 1997 and 1998 field seasons and monthly during the 1999 field season. The two alpine sites were established and sampled in August of 1998 and were sampled only twice in 1999. Table 3 shows dates at which each site was visited.

At each sampling, all macrofungi found within a plot were collected, dried, weighed and stored. Field notes at the time of collection included: date, location (site, sub-plot)

Table 2. Environmental characteristics of eight sites representing four northern Rocky Mountain biomes.

Biome	Grassland		Dry Conifer		Moist Conifer		Tundra	
Site	BS,	AB	PS,b	PS,	AV,g,	AV,b	D	C
Energy & water availability indices								
Altitude (ft)	4100	4875	5700	5700	6300	6600	8400	8900
Altitude (m)	1262	1500	1754	1754	1938	2030	2584	2738
Aspect (°)	/	122	270	300	80	/	9	230
	level	SSW	W	NW	E	level	E	SW
Slope (°)	0	20	25	22	23	0	17	22
Soil temperature indices								
Warmest ST								
1997	18.8	-	15.5	14.4	11.1	14.4	-	-
1998	28.8	-	16.1	14.4	11.7	13.3	-	-
Fortnights > 10C								
1997	>7	-	5	4	4	4	-	-
1998	>9	-	5	5	4	4	-	-
Soil water indices (-bars)								
Driest soil								
1997	8.3	-	3.7	2.1	0.4	0.4	-	-
1998	15	-	15	15	15	15	-	-
Fortnights <								
1997	3	-	1	1	0	0	-	-
1998	5	-	3	4	2	3	-	-
Energy availability for saprobes, indices								
Soil Org. Cont. %	1.81	3.39	2.82	2.44	2.69	2.96	9.71	9.54
Litter, gm/m²								
Est dpth, cm	0	0	1.3	2.5	7.5	10.0	-	-
Dead wood,								
X, gm/m²	0	0	150	300	690	1230	0	0
SD, gm/m²	0	0	110	220	180	930	0	0
Energy availability for ectomycorhizae, indices								
Live needle mass								
X, gm/m2	0	0	1390	2210	1290	1670	0	0
SD	0	0	620	730	520	670	0	0
Host availability for ectomycorrhizal fungi								
Abies lasiocarpa,%			0	0	48	44		
Pinus contorta,%			0	0	26	33		
Picea spp, %			0	0	27	25		
Pinus albicaulis			0	0	+	-		
Pseudotsuga menziesii, %			100	100				
Nutrient availability indices								
Organic C, %	1.81	3.39	2.82	2.44	2.69	2.96	9.71	9.54
total N, %	0.19	0.28	0.17	0.15	0.12	0.13	0.55	0.81
total S, %	0.003	0.014	0.007	0.005	0.008	0.009	0.022	0.064
CaCO3 %	12.5	0	0	0	0	0	30.5	5.0
pH	8.1	7.4	5.7	5.9	4.5	4.3	7.2	7.0

[1] Environmental series are Bouteloua gracilis/ Stipa comata, (BOGR), Agropyron spicatum/ Bouteloua gracilis (AGSP), Pseudotsuga menziesii/ Symphoricarpos albus (PSME), Abies lasiocarpa/ Vaccinium scoparium (ABLA), Dryas octopetala (DROC), and Carex spp (CARX).

[2] Locations are all in Gallatin County, MT. Trident and Bozeman are in the valley, Kirk Hill and History Rock are in the Gallatin Range, Olsen Creek, Bracket Creek, and Sacajawea are in the Bridger Mountains.

[3] Live needle mass (representing potential photosynthate) is a correlate for root area, ie for mycorrhizal niche.

[4] pH measured by MSU Soil testing lab on a 1 soil: 2 water slurry.

Total organic carbon is calculated as total carbon minus carbonate carbon.