LA-13384-MS

A Survey of Macromycete Diversity at Los Alamos National Laboratory, Bandelier National Monument, and Los Alamos County

A Preliminary Report

Los Alamos
NATIONAL LABORATORY

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Cover: *A fire road leading away from the Pajarito Ski Hill area where high-altitude surveys took place. (Photo by Fran J. Rogers.)*

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Los Alamos, New Mexico 87545

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DEDICATION: BILL ISAACS

Mentor, teacher, gentleman. "When a person of this quality dies, a library burns."

Illustration by John Tenniel

PROLOGUE

All through recorded history, macromycetes, the large visible fruiting bodies of fungi (or more commonly: mushrooms), have influenced our culture in a curious variety of ways. Alice, above, meets a caterpillar who uses a mushroom on which to smoke his hookah. In addition, the mushroom provides Alice a way of growing or shrinking depending on which side of the mushroom she eats. In real life, though not quite as dramatic, mushrooms play a role of ecological importance not readily understood.

A Survey of Macromycete Diversity at Los Alamos National Laboratory, Bandelier National Monument, and Los Alamos County A Preliminary Report

by

Nelson Jarmie and Fran J. Rogers

ABSTRACT

We have completed a 5-year survey (1991–1995) of macromycetes found in Los Alamos County, Los Alamos National Laboratory, and Bandelier National Monument. We have compiled a database of 1048 collections, their characteristics, and identifications. The database represents 123 (98%) genera and 175 (73%) species reliably identified. Issues of habitat loss, species extinction, and ecological relationships are addressed, and comparisons with other surveys are made.

1.0 INTRODUCTION

Few systematic surveys of the diversity of fungi—the third great eukaryotic kingdom of living organisms—had been conducted in North America (and not at all in New Mexico) before 1990. This neglect of fungi is common. "Out of sight-out of mind." The fungal vegetative form is often microscopic or in thin microscopic filaments (hyphae), hidden in the soil or in its animal or plant host. Indeed, the study of fungal taxonomy and interrelations with other life forms is perhaps many years behind botany and zoology. Since 1990, there has been an increase in surveys of macrofungi in the United States (Murphy 1996 and the references therein). See also Nishida et al. (1992) and Ammirati et al. (1994).

Despite our relative ignorance of their affairs, fungi are extraordinarily widespread, diverse, abundant, and ecologically important. Roughly 70,000 species of fungi have been identified out of the one to two million fungal species conservatively estimated to exist (Raven 1994). The importance of fungi to the ecosystem is well expressed by Arnolds (1992). He says, "Wild mushrooms are fascinating organisms, not only because of their tremendous variations in color and shape, but also in view of their unpredictable time of appearance, the scarcity of so many species, and their enormous ecological differentiation. Fungi are not only decorative, but are also essential components of our environment. Without them, there would be no long-term survival of the forests."

As indicated by Arnolds' statement, the ecological importance of fungi is being recognized. Macroscopic fungi have been found to be good indicators of environmental change (Deka and Mishra 1981; Kinnes 1982; Wright and Tarrant 1957; Klopatek et al. 1987; Jansen and Dighton 1990; Arnolds 1992). In Europe, researchers have become alarmed at the disappearance of edible species such as the chantrelle (Lizon 1995a, 1995b). Dieback of forests in Europe has been correlated with dieback of certain symbiotic fungi. Researchers such as Cherfas (1991) believe the disappearance is not due to over collecting but to subtle environmental impacts such as the use of nitrogen fertilizer in farming, as well as a general increase of air pollution. An astonishing example of dieback is given in Figure 1, which shows the decrease of the choice edible Chantrelle (*Cantharellus cibarus*) harvest, in weight of sporocarps (per thousand kg) over a 20-year period in Europe at a certain market in Saarbrüken, Germany (Arnolds 1991 and Derbsch 1987).

To understand environmental change in the environment, we must know what species occur in an area, which habitats they live in, and the conditions of those habitats (Kosztarb 1984). Some types of fungi can be indicative of certain environmental factors and may be indicators of unique or sensitive habitats. In our surveys we encountered the rare Jemez Mountains salamander (*Plethodon neomexicanus*) in an area where we located an uncommon (rare to some) fungal species (*Xerula americana*). It is important to understand the species diversity and species dependence on habitats, particularly those habitats which support species that are threatened, endangered, or of concern. Understanding the fungal component of the ecosystem will help in management decisions related to other trophic levels: plant and animal. It is becoming widely recognized that the effort should not be just to preserve *P. neomexicanus* and *X. americana*, but to preserve the entire habitat they live in, along with the tens of thousands of other living entities residing there.

This survey began in 1991 when Teralene Foxx of the Ecology Group (ESH-20) of the Los Alamos National Laboratory (LANL), in collaboration with Craig Allen of the National Park Service at Bandelier National Monument (BNM), sponsored this study as part of botanical and zoological surveys of Park and Laboratory areas. Most of the inventoried portions of Bandelier are within Los Alamos County, and all of these lands are situated on the Pajarito Plateau on the east flank of the Jemez Mountains in north-central New Mexico. The area within Los Alamos County and BNM offers a unique opportunity to study the fungal species and their diversity. The Laboratory represents a 112-km^2 (43-mi^2) area that is remote but does have the potential for contaminants to enter the environment through various activities. BNM had experienced a large forest fire in 1977, and smaller controlled burns at various times, providing areas to study fire disturbance and succession. A large altitude variation with a variety of volcanic soils provides a number of habitats and biomes.

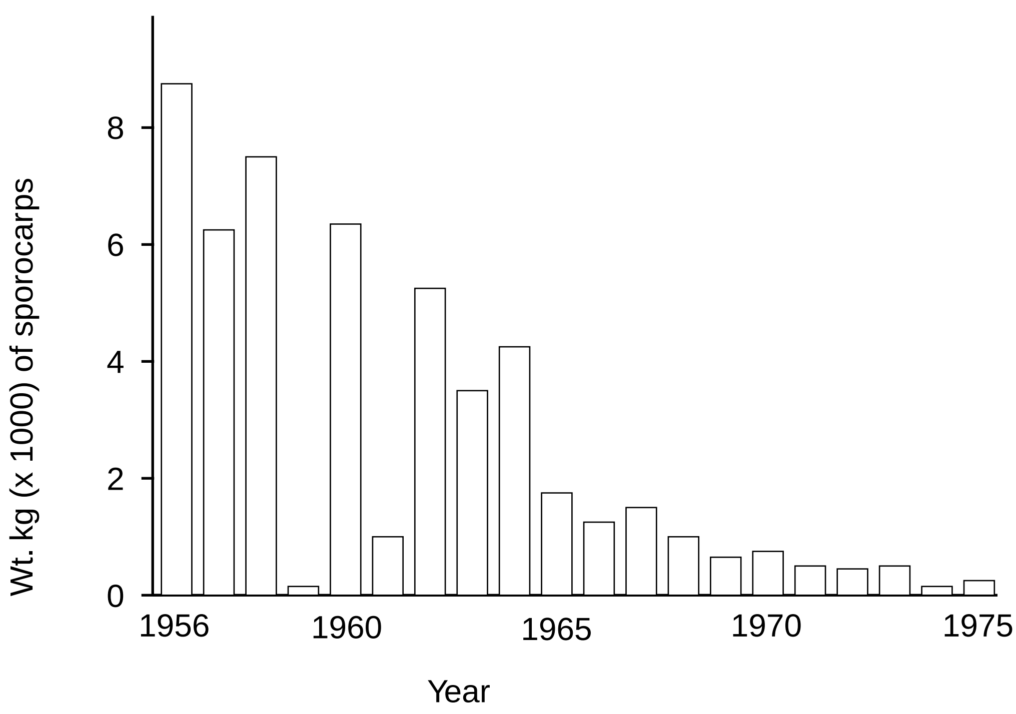

Figure 1. Weight of sporocarps of *Canthrellus cibarus* (Chantrelle) supplied to the Saarbrücken, Germany, market between 1956 and 1975 in units of 1000 kg.

Therefore, in 1991, we began a systematic survey of Los Alamos County and BNM for fungi. Figure 2 shows the location of Los Alamos County and BNM.

The basic goal of this survey has been to collect, identify, and record (at least to genus) as many macroscopic fungi species as possible, and thus, inventory the diversity of such fungi in our area.

Additional goals for a study related to fungi include the following:

A) to observe species distribution patterns within the County and Bandelier as a function of habitat and time,

B) to record any rare or unusual species of the area,

C) to contribute to ESH-20's land cover classification projects,

D) to begin to understand the ecology of the species within these environments, and

E) to cooperate with and support other studies mapping the distribution of fungi in North America and throughout the world.

This paper documents the collections made from 1991 to 1995 and the databases developed from these surveys. With this baseline information and modeling of this baseline data, we can begin to understand more about the fungal flora of the area.

An intermediate report of this work has been published (Jarmie and Rogers 1996).

2.0 TAXONOMIC AND ECOLOGICAL INFORMATION

2.1 Ecology

Fungi, plants, and animals comprise the three great eukaryotic kingdoms of living matter. The vegetative form of macromycetes is a thin segmented microscopic filament (hypha), usually hidden in the soil or the host. The visible fruiting body is the "mushroom." Specific characteristics of fungi include the presence of chitin in the cell walls, indeterminate growth form (hyphae), absorbothrophic feeding mode using a wide range of enzymes, and complex genetic systems: reproducing sexually (spores) or asexually.

Based on their functions, macromycetes are divided into three main ecological groups: saprotrophic, parasitic, and ectomycorrhizal.

Approximately one-half of the species are saprotrophic and are involved in the decomposition of dead organic matter, including leaf litter, wood, dung, and dead sporocarps of other fungi. The species of the subdivisions Basidiomycotina and Ascomycotina (of the division Dikaryomycota), which dominate this survey, are the only organisms with effective enzyme systems for the breakdown of lignin and cellulose–the main components of woody plant material. They also can consume chitin and keratin.

The parasitic fungi are few in number, but are very destructive. They feed on living tissues of plants, animals, and other fungi, often killing their hosts, which are mainly weakened trees and other vascular plants.

The ectomycorrhizal fungi, also about one-half of the species, are in a beneficial symbiotic relationship with trees and other plants. This mutualist relationship is an intimate union of fungal hyphae and the feeding rootlets of the tree dominated by the hyphae (Kendrick 1992). Each rootlet is attached to hundreds or thousands of hyphae. It has been estimated that there are roughly 1000 kg (2200 lb) of hyphae per acre of typical forest. A fungus provides large quantities of water and nutrients to the vascular plant in exchange for sugars and other carbohydrates. Co-evolving over the ages, many trees are obligately ectomycorrhizal (Arnolds 1992) including in our area: pines (*Pinus* spp.), spruce (*Picea* spp.), Douglas fir (*Pseudotsuga* spp.), white fir (*Abies* spp.), oak (*Quercus* spp.), birch (*Betula* spp.), juniper (*Juniperus* spp.), cottonwood (*Populus* spp.), and willow (*Salix* spp.). Other types of mycorrhizae exist but are not relevant for this report.

2.2 Taxonomy

The taxonomy of this type of fungi important to our report is straightforward but, typically, everchanging. An example of the higher taxa for this survey is shown in Figure 3. Some of the common names of frequently found specimens are given in Table 1.

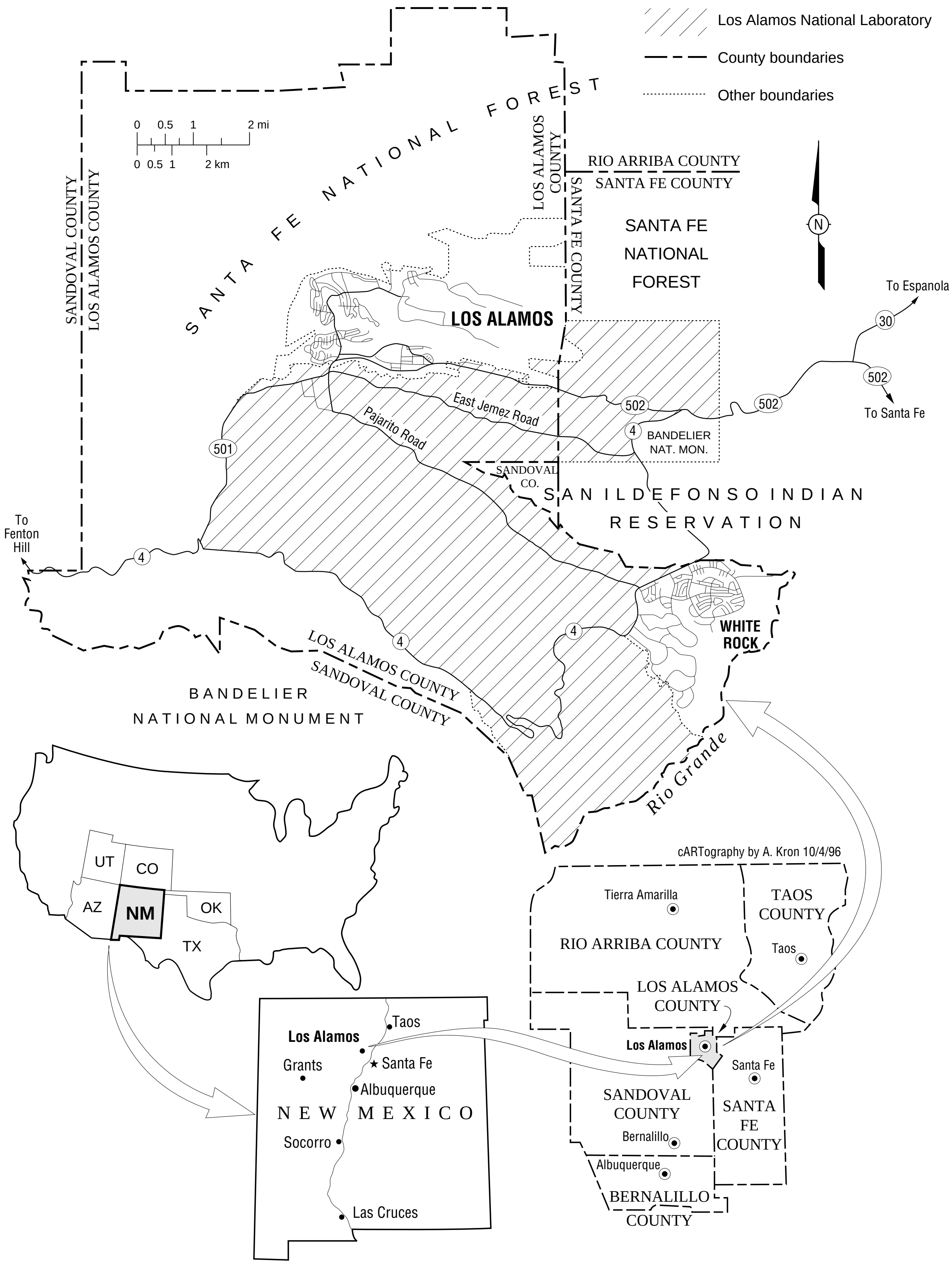

Figure 2. Location of Los Alamos National Laboratory.

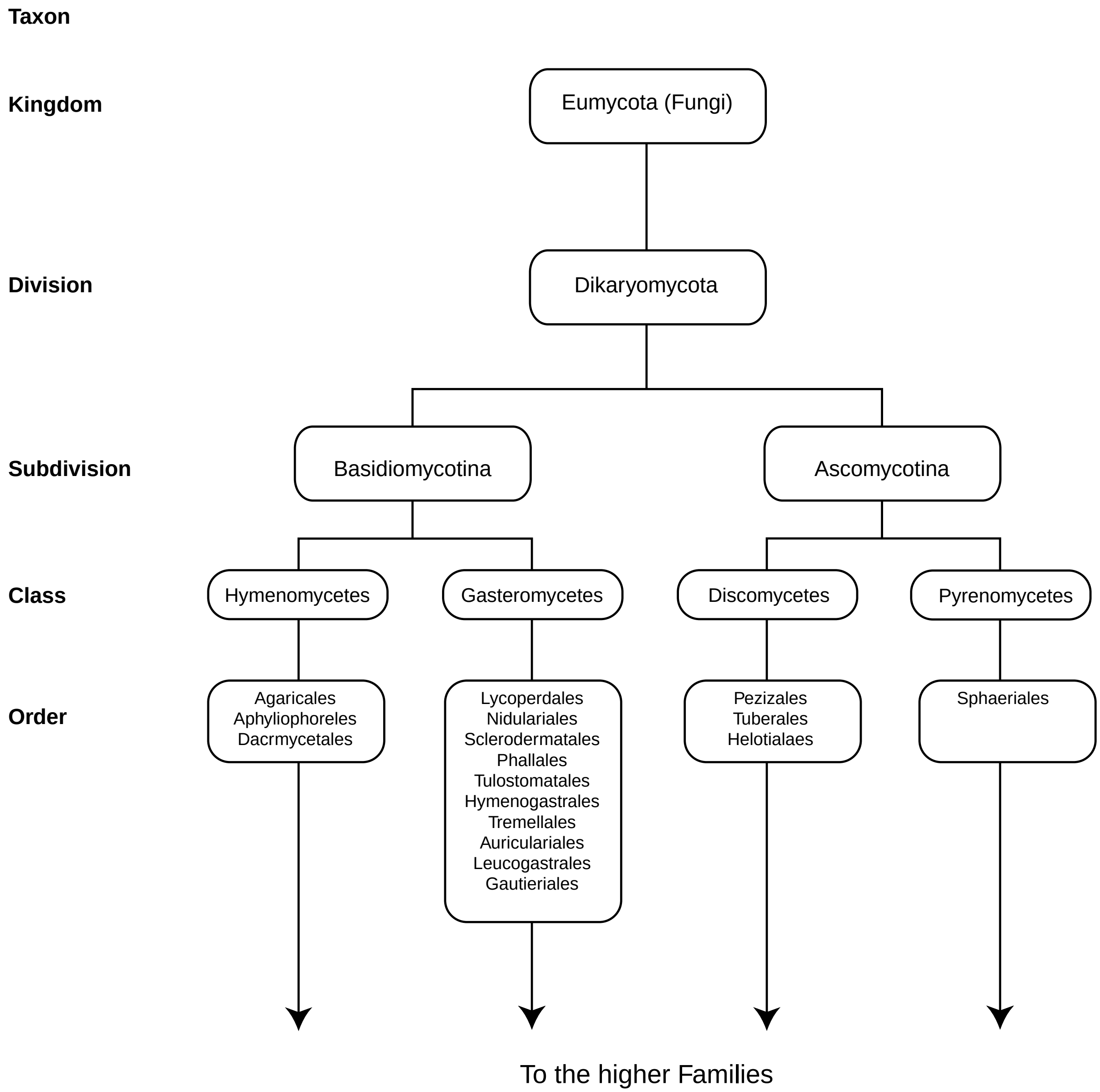

Figure 3. An outline of the higher taxonomic levels of fungi.

Table 1. Common representatives of the taxonomic hierarchy of "Order" for the macroscopic fungi (note that Gasteromycetes is a Class).

Argaricales	Aphyllophorales	Gasteromycetes	Pezizales
Boletes	Polypores	Puffballs	Morels
Gilled fungi	Corals	Bird's nest	False morels
	Chantrelles	Stinkhorns	Cups
	Spiny fungi	False puffballs	Truffles
		Stalked puffballs	
		False truffles	

3.0 METHODS

3.1 Collection Techniques

Specimens were collected from Los Alamos County in north-central New Mexico and the adjacent Bandelier National Monument. On Laboratory property, emphasis was placed on areas where other botanical surveys were being conducted. BNM was especially interested in forest areas burned by fires, particularly the 1977 La Mesa fire. Fungal fruiting depends heavily on soil moisture and atmospheric humidity, which, in Los Alamos, is dependent on altitude. Thus, habitats varied markedly with altitude. We searched in areas at different elevations and within different vegetative zones from 1700 to 2900 m (5500 to 9500 ft).

The fungal fruiting season runs normally from May through October, with most of the fruiting occurring in the rainy season from July through September. Most of our collections were from July through September.

We established 39 collection locations in three general areas: Bandelier, LANL, and Santa Fe National Forest within Los Alamos County. Collections were made within Laboratory technical areas (TAs) including TA-0, -3, -18, -67. We included burn sites in BNM near the Juniper Campground, Park Headquarters; parts of the 1977 La Mesa fire at Burnt Mesa and the Apache Springs Road area; at controlled burns in Frijoles Canyon; and the Dome Road/Highway 4 intersection area. Santa Fe National Forest sites were mostly off the Pajarito Ski Area road, which provided access to higher altitudes.

A collection site was defined as roughly a 100-meter-diameter circle (unless a definite habitat change took place within). We attempted to informally scan each site several times during the season. The use of the term "collection" or "item" in this report refers to either a single fungus fruit or to a group of identical fruits from a local and gregarious stand of fungi. Universal transverse mercator coordinates were determined for each site, and a code name was assigned (Figure 4).

In the diversity surveys of Nishida et al. (1992) and Ammirati et al. (1994), certain taxa were excluded; this is also true with our report. The objects we collected and cataloged were macroscopic "fleshy" fungi—fungal fruits of the sexual phase (teleomorphs) visible to the naked eye in the field (some hypogeous species were included). Almost all the specimens collected were in the kingdom Eumycota (Fungi). We found several species of "slime molds" now thought to be in the animal kingdom, as well as a common juniper rust, and included them in the list for interest. Most mycorrhizal and many saprophytic fungi put up visible fruits making them easier to find and identify. A study of the many species of microscopic fungi (smuts, rusts, mildews, yeasts, blights, and soil fungi, etc.) was not attempted due to the difficulties associated with their identification and our lack of resources, although these fungi are extremely important in the ecology and management of vascular plants (e.g., forest trees and agricultural crops).

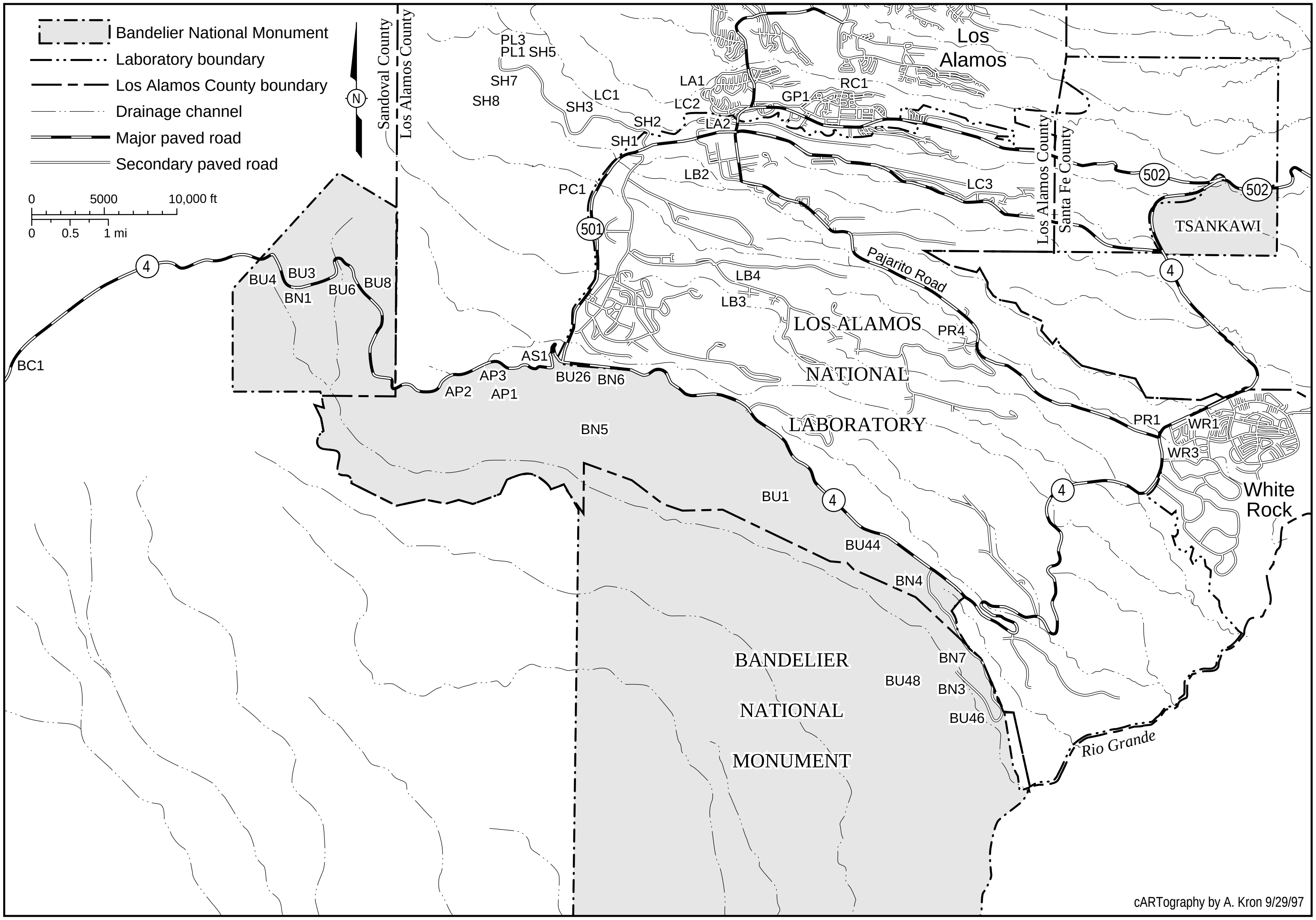

Figure 4. Location map ollection sites, Bandelier/Los Alamos macromycetes survey.

Our original goal was to conduct a fruiting density study as is done with vascular plants, using a dedicated plot of ground, such as a botanical transect. However, it soon became clear that a "famous fickle fungi fruiting factor" exists* that results in erratic fruiting of fungi year by year and site by site. Given the limits of available personnel and resources, a meaningful density study proved impossible. In addition, contrary to most plants, the vegetative body of fungi is almost always hidden in the soil, inside living or dead wood or dead animals. Furthermore, many of the fruits perish rapidly, generally within a few days. Thus, our survey is essentially a "presence log" which simply says: "Yes, this species does exist in this habitat in this location, at this time," and includes a subjective statement that it is abundant, common, uncommon, or rare.

3.2 Field Protocol and Herbarium Preservation

We kept field notes and, after identification and assignment of an accession number, dried and preserved many specimens for storage in our fungal herbarium. See Appendix A for our collection and herbarium procedure.

Vouchers for three-fourths of all specimens with at least one voucher for each species are stored.

Several genus specialists have asked for herbarium specimens. Mycologists have visited with us at Bandelier and in Los Alamos County. Others have been available to us at major statewide or national forays to help with identifications. The primary effort was to identify specimens to genus because many of the ecological factors (e.g., mycorrhizae) are common to the genus, or even family.

3.3 Identification and Identification Reliability

A taxonomic identification was made from personal knowledge, reference to various monographs, field guides and texts, microscope work, chemical indicators, and suggestions from experts. Again, <u>the primary effort was to reliably identify specimens to genus</u>. A number of species especially in difficult genera (e.g., *Agaricus*, *Amanita*, *Cortinarius*, and *Russula*) await further expert study by specialists. Ninety-three percent of the 1048 specimens were identified to genus.

Our isolation from mycological academic centers and the lack of a local professional or one available for the 90 field trips we took raises a question of the reliability of the identifications. To help answer this question, we initiated a numerical grade for identification reliability (Appendix B): grade #1 = species taxon sure, no question; grade #2 = fairly sure, e.g., by a mycologist for a species perhaps not in his specialty or region; grade #3 = some hint of species identification, what a field guide might call a "group" or "complex" and placing a "cf." with the species name in the data lists. A grade #4 = genus only, grade #5 = family only and so forth. Within this system we attempted to be very conservative.

3.4 Species Essays

Based on our field notes, and before we get into the nitty-gritty of explaining the particulars of our database, we present a collection of 12 essays, each one focusing on a particular species; each one illustrating unique characteristics of a unique species and of isolated episodes and reminiscings contained within five years of field work.

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* This was a private communication from H. Burdsall (USDA Forest Service Forest Products Laboratory, Madison Wisconsin) in 1991. Well, of course, Burdsall did not put it quite this way, but he certainly emphasized that a healthy fungus-tree partnership could live happily without fruiting for maybe 10 to 15 years. This fickle fungi fruiting factor implies that an accurate abundance measurement may require more than collecting by walking around and looking.

Coprinus comatus
accession numbers: 163, 243, 677

The "Shaggy Mane" is a beginner's best friend—easy to learn to identify with hardly anything that could be called a look-alike. It is a choice edible, so delicate that it needs to be steamed or used to make a soup. It is common to find it in its favorite habitats: on the edges of dirt roads or wherever the soil has been disturbed for a year or three and occasionally on a lawn or in a meadow.

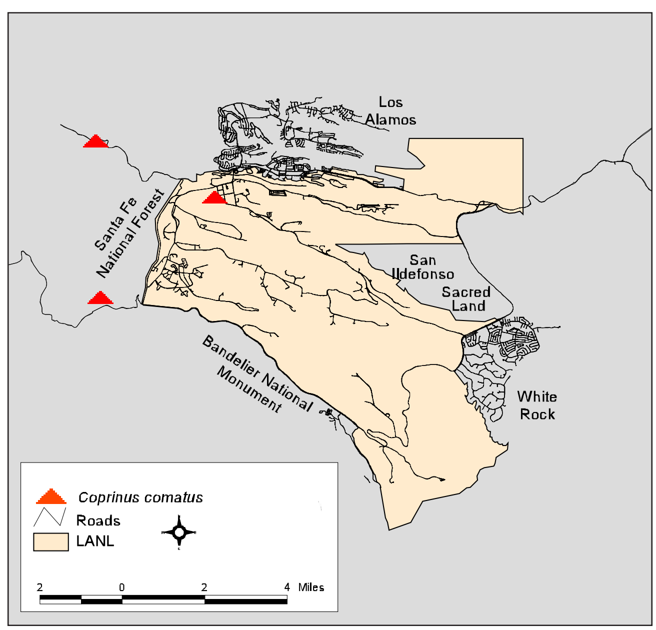
Species in the genus *Coprinus* have gills that deliquesce into a black ink as they age; *comatus* in particular. The juice can be used as a writing ink. The fungus is a saprobe and is ubiquitous. We were startled to see a stand of about 2000 fruiting bodies on a large lawn in the Emperor's Gardens in Tokyo, Japan, all self-digesting to an inky black mess. *Coprinus* belongs to the Family Coprinaceae of the Order Agaricales of the Class Hymenomycetes in the Subdivision Basidiomycotina and Division Dikaryomycota then Kingdom Eumycota (Fungi).

Out in the field, when you see gills of a mushroom black and deliquescing, immediately you know to start an identification search with the genus *Coprinus*, a reward for learning the scientific names.

Coprinus comatus

Photo by Fran Rogers

The reason for the common name is obvious.



***Chalciporus* sp.**

accession numbers: 1051, 1123, 114

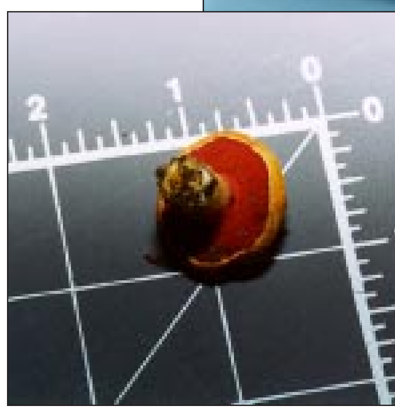
In 1994, the New Mexico annual foray was held in the thriving metropolis of Weed in the south-central region of the state. A group of us were surveying a piñon/juniper habitat where fungal fruitings are not common without heavy rains. We came upon a small unimposing specimen growing under a piñon pine that immediately reminded us of the genus *Suillus*, a group, also unimposing, of soft-pored fungi that often keep company with ponderosa pine.

Upon investigation, we saw that the pore surface was a bright purple, a color none of us had seen in this type of mushroom. Jack States, an Arizona mycologist, took it home and identified the Genus as *Chalciporus* (Family Boletaceae). Bill Isaacs of Santa Fe agreed, noting he had collected them in the piñon/juniper area north of Santa Fe.

How about our survey? The next week we visited friends in our area who had mentioned mushrooms fruiting under piñon pine. Indeed, the purple-pored *Bolete* was present, and was found there twice more. Now the question, is it rare or common? Rare to the world and common to us? We plan to send the berbarium voucher to a specialist.

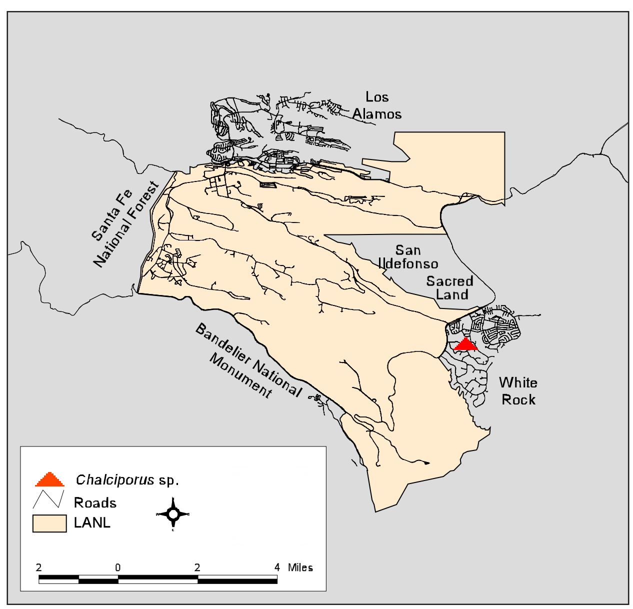
Chalciporus is in the Family Boletaceae of the Order Agaricales. A tentative indentification of the species is *amarellus* (cf.).

***Chalciporus* sp.**



Photos by Fran Rogers

Focused to bring out the color, and to show the pores underneath. The grid lines show inches.



Calvatia booniana

accession number: 1150 (not in the formal survey)

Most of the time surveying, we concentrated on forest habitats and wild meadows where the density of fruits is greatest. We looked a little at football field grass and residential lawns to check on some old favorite LTMs (little tan mushrooms).

There is a danger of including species brought in manure or wood chips that come from distant sources. But we couldn't resist an excited neighbors call: "There's a monster in our back yard! Is it a mushroom?" We went to see. There, in a domestic lawn in a slight depression, which stayed moist from the lawn watering, were several gorgeous medium-sized *Calvatia booniana.* The photo at right shows co-author, FJR, with a couple examples. Note the polygonal surface pattern.

Unfortunately they were a little past their prime or they would been good for dinner. We know also the ripe brown powder has been used in times past as a styptic for treatment of wounds and for other medicinal purposes. We had never seen this species in our survey or in our local region. Did the neighbors use packaged manure? Yes, they did. The problem was to include *booniana* or not. We chose not to include it in the survey until a second collection shows that it has taken hold in the regional habitat.

The fungus is a good example of the Class Gastromycetes; where the spores ripen inside an enclosed body. The Order is Lycoperdales.

Calvatia booniana

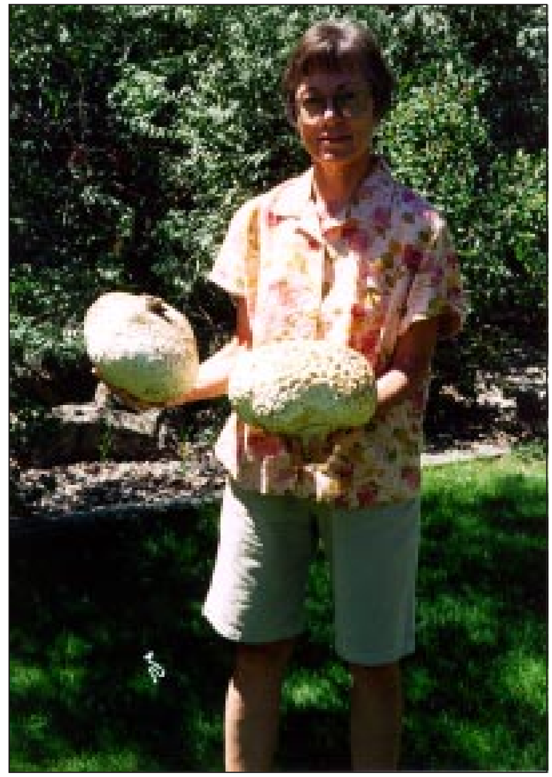
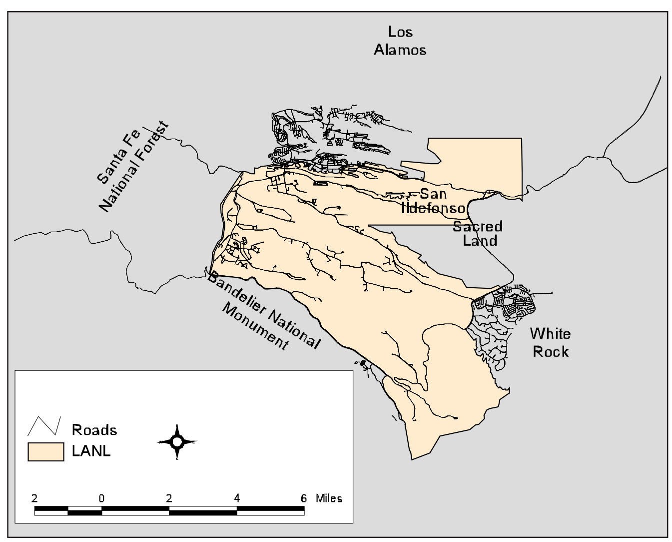


Photo by Nelson Jarmie

Note that the map does not give away the location of these monsters.



Chlorociboria aeruginascens

accession numbers: 236, 1147

This tiny cup (3 to 5 mm wide) is the fruit of a fungus that is common but not noticed very often. The mushroom is the fruiting body of a fungus whose hyphae stain the inner bark of dead wood, often oak, a distinct blue (to some a green). Some of the field guides call it blue stain and some green stain; a good example of the dangers of common names. The Latin binomial gives clues of the color and nature of the specimen, and can be used to impress your friends when this long name rolls off your tongue.

This hints of a famous conundrum of inductive logic known as the Grue-Bleen paradox. The Bleen hypothesis is that the blue stain of the fungus (or your house, if it is blue) will suddenly change to green at exactly the last second of the twentieth century. Frequent observations inductively support the hypothesis, so that after many observations there can be no doubt of the truth of the hypothesis.

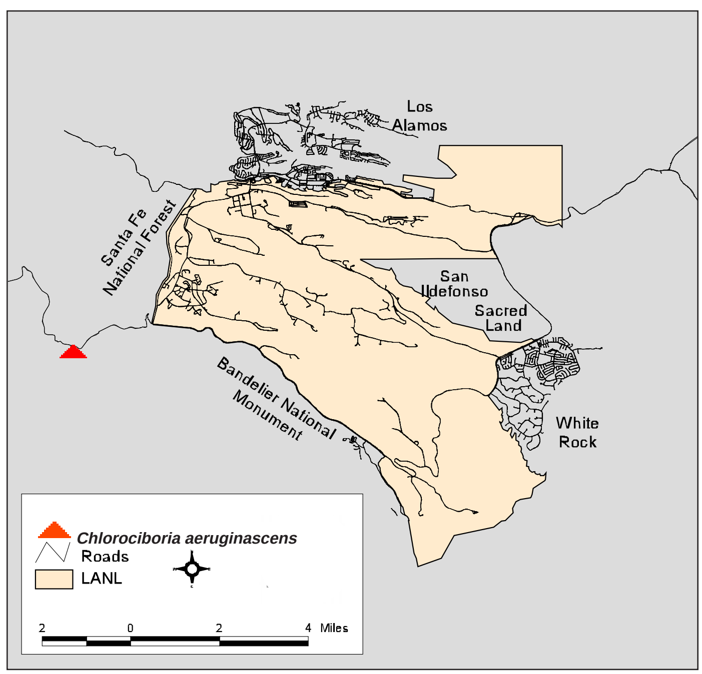
We had only two collections, but would have many more if we had pulled the bark off rotting oak logs. *Aeruginascens* is of the Family Dermatiaceae, of the Order Helotiales (Earth Tongues) of the Class Discomycetes, and thus, is an example of the Subdivision Ascomycotina, whose spores are grown in a small sack of eight. The Asco's are smaller than the Basidiomycetes, I think that is because few members are mycorrhizal with plants.

If you see a stained log, look on the bottom surface and you may find a few tiny blue-green (grue?) cups.

Chlorociboria aeruginascens

Photo by Fran Rogers

The cups are too small to see, but the bleen stain on this rotten wood is brilliant.



Xerula americana

accession numbers: 258, 961, 1121

We found three collections of this rare (?) (but see below) member of the Tricholomataceae (Agaricales). We had seen no literature report of one in the western United States. One of ours was under ponderosa pine at 7500 ft (site BN6). The other two were in moist duff of mixed conifer at 9000 ft (site SH5). The latter site was a stones (easy) throw from the lair of a Jemez Mountains salamander (*Plethodon neomexicanus*), truly rare, whose home we found while looking for fungi under a wet, rotting conifer log.

The young *americana* specimens are strikingly beautiful, both stipe (stem) and pileus (cap) are coated with a thick blue-black velvet when young. The cap fades to a medium tan in age. The stipe cover in age splits in a spiral fashion counterclock-wise, revealing a white interior. The fungus has a long yellowish root.

Understandably, its edibility has not been tested. We found that its taste was mild.

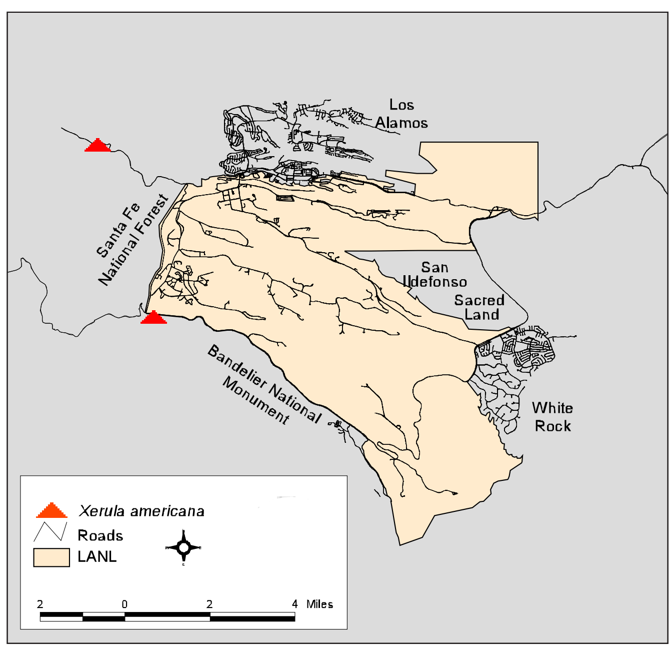
Also unknown is the type. It seemed to be growing on rotten wood although it could be mycorrhizal since some fungi in the Family Tricholomataceae are. This family is a catch-all for white-spored mushrooms that do not easily separate into groups based on an evident morphology.

The first expert we showed it to said it was the second sighting in North America. We had a rare one!? We kept finding more local specimens–not all that rare. Then our visits to national conferences made it clear that there were experts who were familiar with the mushroom which, though uncommon, would be expected in our habitats. Our truly rare fungi are probably buried in our list of "unknowns."

Xerula americana

Photo by Fran Rogers

Look carefully. The smaller fungus is on its side showing the root.



Hypomyces lactiflourum

accession numbers: 101, 189, 264, 287, 312, 387, 496, 617, 788, 1035, 1110

The “Lobster” is an oddity in the woods. You see it almost always in the company of ponderosa pine, in late summer at an elevation of 7000 to 8000 feet. It pokes its nose up through the pine duff and exposes a bright red-orange lobster-colored distorted monster. So! An odd fungus mycorrhizal with *Pinus ponderosa*?

No way, sorry. A little more searching exposes a number of a gilled mushroom, *Russula brevipes*, in the area usually shoving up a load of pine needles and dirt on its cap (pileus), a typical one of many *Russula* with whitish spores and a brittle flesh (context). The short stalk (stipe) and its load of soil and pine needles gives a clue to the species.

The *Hypomyces* infects a *Russula* and turns it into that colorful, rough, ridged, ugly, non-gilled shape. It grows its sacks of spores on the surface of the former *brevipes* in tiny pimples or “flasks” that can be seen with a sharp eye aided by a powerful hand lens.

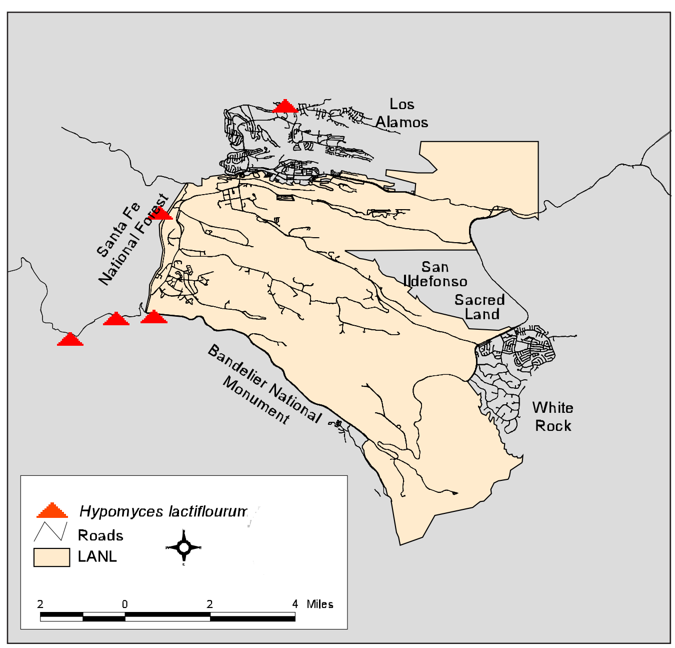
The *brevipes* is reported to have a poor taste but the Lobster is choice eating. All the field guides warn you that the underlying mushroom might be toxic, but I have never seen an expert hesitate to enjoy the feast.

Other species of *Hypomyces* infect Amanitaceae, and Boletaceae, as well as the Russulaceae. *Hypomyces* belongs in the Class Pyrenomycetes in the Subdivision Ascomycotina.

Hypomyces lactiflourum

Photo by Fran Rogers

Some of the host’s cap is still visible. The color is often more orange.



Xeromphalina campanella
accession numbers: 219, 423, 447, 457, 479, 510, 533, 548, 584, 595, 627, 638, 702, 759, 809, 974, 990, 1071

We often felt an aesthetic pleasure, a joy, from walking in the woods and discovering fungi new to us. The AP1 site at Apache Springs in Bandelier was a fungi showcase in 1992. In this moist narrow cleft, surrounded by expanses of drier ponderosa pine/mixed conifer forest, is a small riparian habitat that provided a profuse fairyland of mushrooms. There were troops of tiny orange *Xeromphalina campanella* on fallen logs, guarded by flanks of the purpled-pored cups of *Humaria hemisphaerica*, and orange corals (*Clavicorona pyxidata*) amidst red "eye-lash" cups (*Scutellinia scutellata*). We collected 40 different species in all from that one site in August and September 1992.

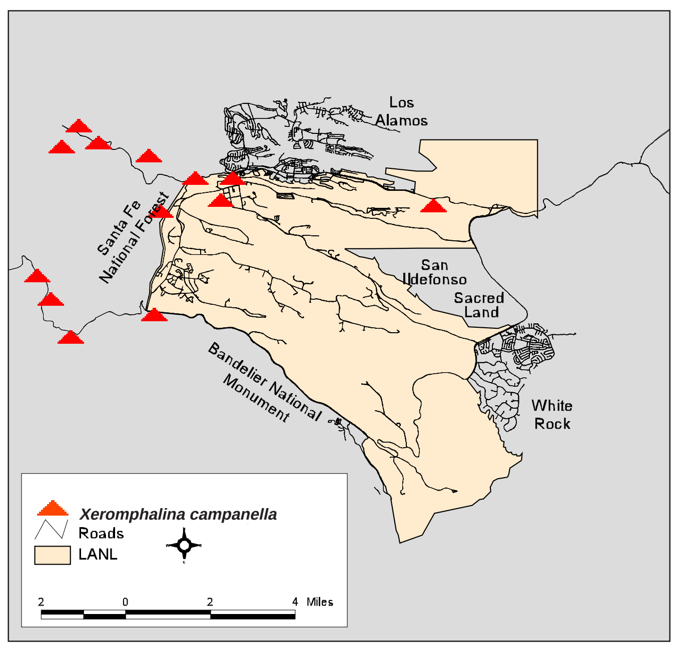
"Troops" of small mushroom fruits are usually saprobic, exuding enzymes to digest the components of dead wood, standing or as fallen logs. Mycorrhizal fungi are often larger. I surmise that their "standard of living" is higher, the host tree or plant providing the carbohydrates and various complex chemicals (in return for water, minerals, and other basic nutrients).

X. campanella is in the catch-all family Tricholomataceae, in the Order Agaricales, Class Hymenomycetes, Subdivision Basidiomycontina, and Division Dikariomycota.

Xeromphalina campanella

Photo by Fran Rogers

As the map below shows, *X. campanella* is widespread as well as abundant.



Amanita muscaria* var. *muscaria

accession numbers: 119, 416, 445, 569, 600, 619, 648, 790, 1037

This famous, beautiful, ubiquitous mushroom fruit is without doubt the most well known mushroom in the opinion of mycologists and non-mycologists alike. It is seen in Egyptian hieroglyphics, sacred Hindu texts, Christmas cards, and has been observed as the seat of a hookah-smoking caterpillar! It is large as gilled mushrooms go, with a bright red cap tufted with white remnants of a universal veil, a floppy snow-white annulus (ring), and a tight volva at the base of the stem.

As might be suspected with a member of the *Amanita* genus, the *muscaria* is poisonous with a collection of gastric irritants, central nervous system toxins, and hallucinogens—not recommended for experimentation!

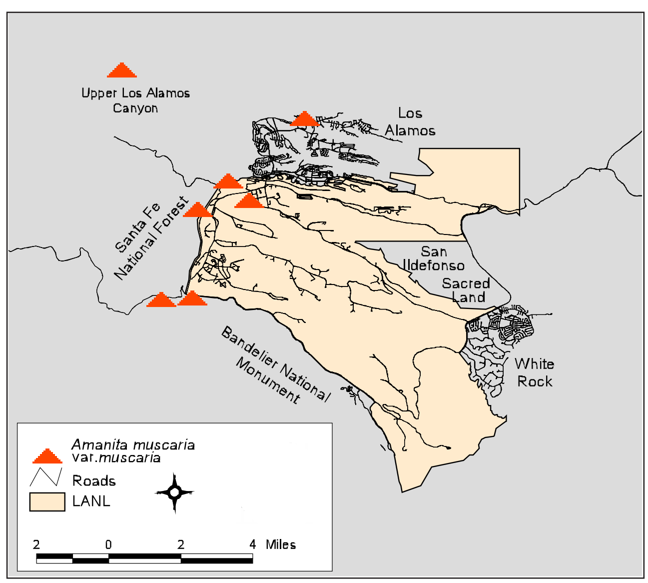
Like other *Amanitas*, *muscaria* is mycorrhizal. It is “promiscuous” in its choice of symbiotic partners. We have seen it fruit under ponderosa pine, aspen, and mixed conifer, from high mesa to riparian habitat, sometimes in a partial fairy ring. Different color varieties exist, especially var. *formosa*, which has an orange-yellow cap and is found in the eastern United States. The family Amanitaceae is a member of the Order Agaricales of the Class Hymenomycetes.

We have also collected specimens of the all-white super-deadly *Amanita*, *Amanita bisporigea*, in a variety of habitats from 7000 to 9000 ft.

Amanita muscaria* var. *muscaria

Photos by Fran Rogers

Note the flaring skirt (annulus) above and the cup (volva) on the left.



Phaeolus schweinitzii

accession numbers: 434, 482, 508, 643, 714, 943, 963

This large, perennial, tree-eating, multilobed, multicolored polypore is a dangerous parasite, whose hyphae invade a tree, often a conifer, and produce an internal brown rot that weakens the plant so much that it breaks and falls. The major contents of wood are cellulose (whitish) and lignin (brown). So if the fungus eats the cellulose mostly, then the remainder is brown–hence, a brown rot.

The paper-making industry now uses acids and other undesirables to separate the lignin and leave the white cellulose for paper production. The appetite by white-rot fungi for lignin may eventually help do the job without using the chemicals.

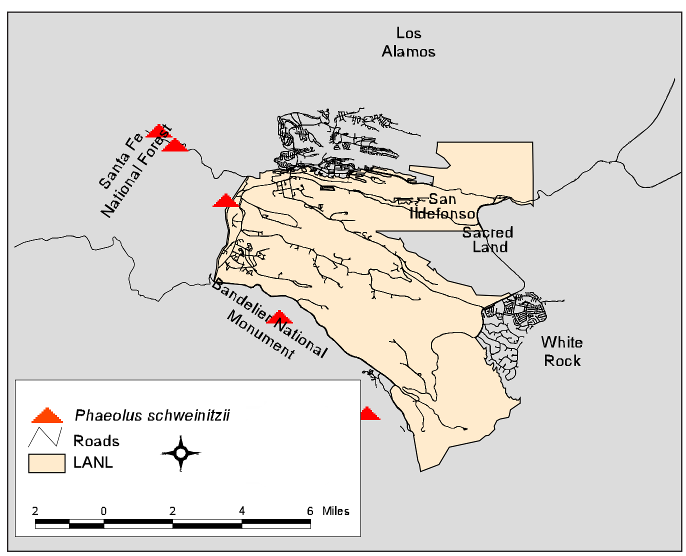
The mushroom is sometimes hard to see–almost camouflaged–passing through stages of yellow to green to brown to black, and by growing slowly, engulfing grass, twigs, and debris. Its color properties are prized by artists who dye wool using natural sources. Art papermaking sometimes uses the pulped *schweinitzii* for color, but must add other sources to provide structural strength.

Yes, there was a mycologist named Schweinitz.

Phaeolus schweinitzii

Photo by Joy Spurr

About a foot across.



Boletus barrowsii

accession numbers: 107, 421, 497, 501, 645, 675, 739, 783, 785, 807, 973, 1012, 1036, 1084, 1116

Boletus barrowsii was named for Chuck Barrows, an early fungi hunter in New Mexico who sent a number of new species to a well-known mycologist, Alex H. Smith, in Michigan. Smith sent one of his best students, Bill Isaacs, to New Mexico to assess the situation. Bill came and never left, much to the benefit of New Mexico.

A close cousin, *Boletus edulis*, is famed as a choice edible the world over–called Steinpilz, Cep, Penny Bun, or Porcini, depending on what country you are in. King Bolete is the official American common name, but I have never heard it called that. The main field difference is a whitish-buff color cap on *barrowsii*, while *edulis* has medium to dark red-brown tones.

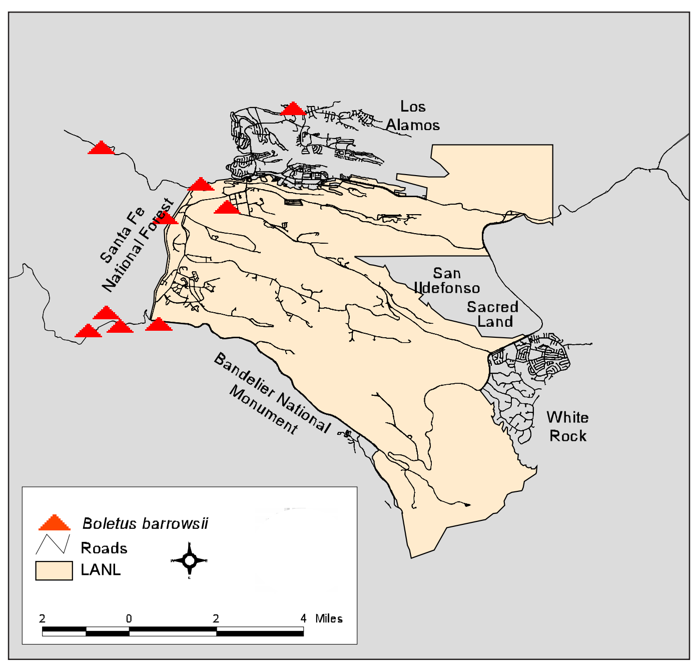
B. barrowsii is a challenger for the best taste. The problem is getting to it before the maggots do (and other *barrowsii* hunters). They (the maggots) burrow up the stalk, and, if you forget to slice the stalk off right away, will have toured the cap flesh. Not so yummy unless you don't mind the extra protein.

The attendees of the latest New Mexico annual foray came upon a huge fruiting of both *B. edulis* and *Cantharellus cibarius*, the Chanterelle. The nature of the foray changed. There were mushrooms by the hundreds, sliced and drying in dryers, on beds, desks, banisters, and on any flat, warm surface in the cars or hotel.

Boletus barrowsii

Photo by Fran Rogers

Usually not pink. Note the fine reticulum (webbing) on the stipe (stalk).



LBMs and their allies

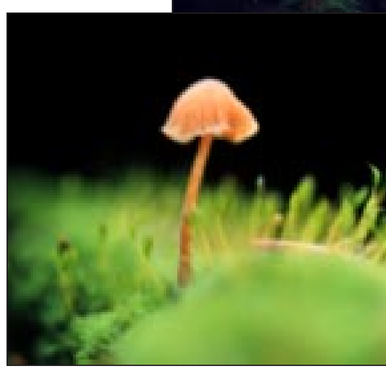
accession numbers: several, 303 for example

A very frustrating section of macromycete taxonomy are the little brown mushrooms (LBMs). Identification characteristics are often hard enough to ascertain with a large mushroom. A spore print for color and to provide spores for microscopic measure, and observation of the attachment of the gills to the stalk are hard to get from a gilled mushroom that is 1 cm tall and 2 mm wide. Oops, it dried up already? Squashed in your basket? Often LBMs have a lack of distinguishing features like a volva or a ring or shaggy cap; they just stare at you from the safety of the clump of moss that is their home.

Many families and genera contribute a few species that are small and featureless. Some are not so small, perhaps several cm tall and/or wide. The genus *Cortinarius* has an estimated species number between 800 to 1000. Many of them are featureless, brown, and small enough to be labeled LBM. Other LBMs are found in the genera *Collybia*, *Galerina*, *Marasmsiius*, *Mycena*, *Pholiota*, *Psathyrella*, and *Tubaria*. Actually, it is tempting to label any mushroom you can't identify as a LBM. Looking for LBM edibles requires caution. Some *Inocybe* species are unpleasantly toxic, and *Galerina autumnalis*, which actually has a wisp of a ring, is deadly.

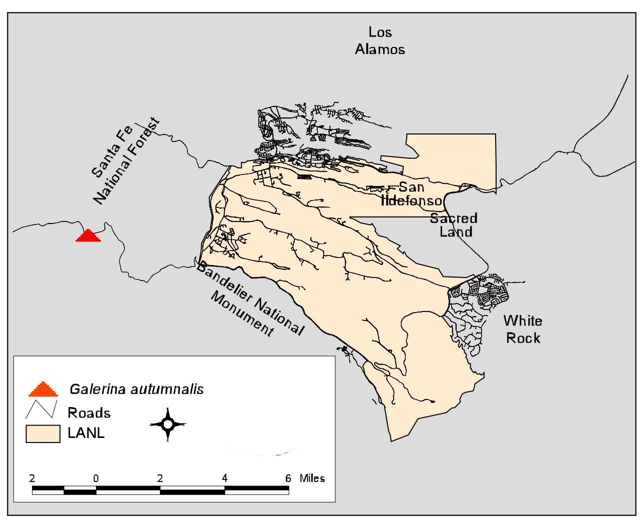
Also in wide use are: LBJ (little brown job), LTM (little tan mushroom), LWM (little white mushroom), JAC (just another *Cortinarius)*, JAR (just another *Russula*), IBBM (itsy bitsy brown mushroom). TWIBBM…

LBMs and their allies



Photos by Fran Rogers

LBMs, LTMs, JACs, JARs? You're never really sure.



Fuligo septica

accession numbers: 415, 608, 808, 848, 1132

When enjoying hiking in the woods looking for fungi to collect, we found a number of "slime molds." The name professional people use is Myxomycetes; which will probably change after it is taken out of the Eumycota Kingdom and put, I don't know where. One of the important differences is that slime molds engulf their food, whereas fungi exude enzymes to digest their food, and then reabsorb the products. In this regard, a slime mold is on the animal branch of taxonomy, splitting off soon after the invention of the nucleated cell that spawned animals, plants, and fungi. The life history of a slime mold is complex, but usually ends up with a group of cells that join together, dissolving their cell walls to form a plasmodia. This amoeba-like creature oozes along, eating bits of plant and debris, and, when the time is ripe, forms a spore-making machine (sporocarp). The residual sporocarp is often very beautiful, and can be seen with a fairly low-power system, a hand lens or dissecting stereoscope.

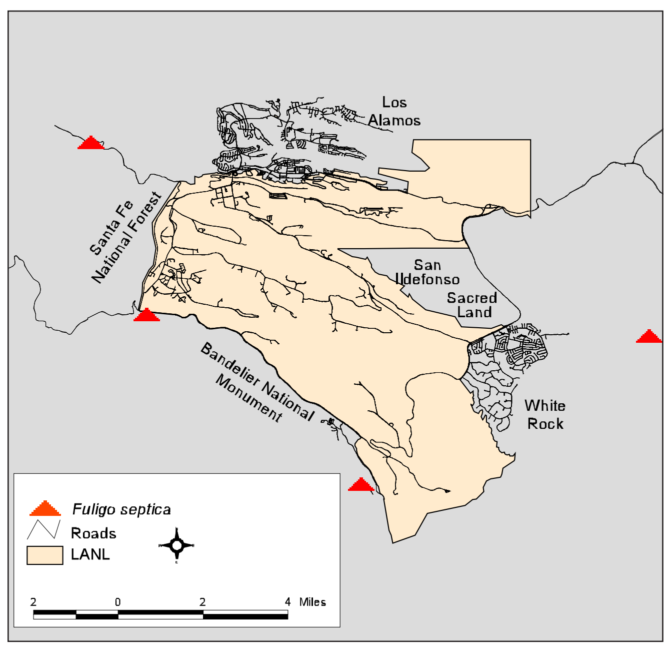
Fuligo septica isn't beautiful, it settles down to form a blob that sometimes is yellow or orange, crusting to a white blob with a black spore mass inside. Under the right conditions, the fruiting can be enormous. Once, in a Texas town, the molds grew all over the place, frightening the inhabitants who thought they were from outer space.

F. septica is in the Family Physacacae, Order Physarales, Class Myxomycetes, and Division Myxomycota. Maybe.

Fuligo septica

Photo by Fran Rogers

Typically enmeshed in a cluster of small twigs.



4.0 RESULTS

The results are given in the Appendices: Appendix C (Species List sorted, genus alphabetic), Appendix D (Species list sort by Order), Appendix E (New to the New Mexico state list), and Appendix F (28FnABC complete Short Form). Information in the long form can be accessed through the database, which will be established as a link to the geographic information system software, ARC INFO, or by request to the authors.

4.1 Computer Database

We entered our findings into a relational database program. FoxBASE+/MAC was chosen for versatility and compatibility with other databases. There is a database record with a unique accession number for every specimen collected. The 34 database field codes are explained in Appendix B. The accession number also identifies a "memo" field that accepts additional comments for a given record.

The master database is labeled 28FnABC; where 28 is the final version number, Fn = fungi, ABC stands for the complete alphabetized list.

This basic database for years 1991 through 1995 has been completed and alphabetically sorted by Genus, Species, Date, and Accession Number. The "short form" stands alone as a concise list of the 11 most useful fields. The "long form" adds 20 additional fields (mostly habitat, location, growth habit, etc.) to form a "complete list" (see field codes in Appendix B).
Here is a summary of the lists given in this report. (The Appendix is shown in parenthesis.)

1. Species list: 28FnSpList. One type record for each species identified plus 6 entries with a known genus, but unknown species. Thus, the species list also acts as a genus list, listed alphabetically by genus. (11 fields) (C)
2. Species list sorted by Order: 28FnSpOrder. (9 fields) (D)
3. Species list sorted as in #1 but new to the state (NM) list: (9 fields) (E)
4. Short form of 28FnABC: concise (11 fields) complete list of specimens. (F)

Also available among the many possible ways of sorting, but not given here, are:

5. Long form of 28FnABC: holds all records and most of the fields. (31 fields)
6. Short form 28FnNum: Sorted by accession number. (ncode) (11 fields)

4.2 Summary Information from the Complete Database (All Collections)

Table 2 shows the results of the information in the complete database 28FnABC.

4.3 Summary Information for Species List (28FnSpList)

We sorted the database by each species being represented once. This meant that specimens of the same species were lumped together for one entry as a "type." 28FnSpList is alphabetized by genus (Appendix C). Table 3 shows the information related to identified species.

4.4 Summary Information for Species List Sorted by Order (28FnSpOrder)

Since this is just a re-sort of 28FnSpList, the summary information is the same. Note the dominance of the Subdivision Basidiomycotina, especially the Order Agaricales (Appendix D). The small number of Ascomycetes is expected here, but remember that the survey only contains specimens seen by eye. There are very large numbers of Ascomycotina fungi involved with lichens, and in many other ecological niches, often of microscopic size.

Table 2. Results of the Surveys and Collections sort in the Complete (Main) Database: 28FnABC (See Appendix F).

Number of Specimens	**Item**
1048	Total number of records (specimens)
673	Total number of specimens whose species taxon could be identified reliably
34	Total number of unknown families
796	Total number of voucher specimens
11	Microscopic studies
79	Total number of specimens new to the New Mexico Mycological Society List
64%	Percentage of specimens identified to species
93%	Percentage of specimens identified to genus
21	Number of specimens judged rare
169	Number of specimens judged uncommon
649	Number of specimens judged common
39	Number of specimens judged abundant

Table 3. Database information sorted by species. (Appendices C, D, E)

Number of Species or Genera		**Comment**
241		Total species (all grades of identification reliability)
175	(73%)	Of the species identifications, 175 are considered reliable (Grades 1 and 2)
123	(98%)	Genera identifications are considered reliable
51		Species are new to the New Mexico Mycological Society list
211	(88%)	Species are of the Subdivision Basidiomycotina
25	(10%)	Species are of the Subdivision Ascomycotina
6	(3%)	Species are slime molds

4.5 Summary Information for Species List with condition of not being on the State Master List (28FnSpNotNM)

The new species have since been added to the master list of accessions for New Mexico (Appendix E).

5.0 DISCUSSION

The results are an important contribution to the Ecology Group (ESH-20) for their grid of plant, animal, and geologic information. The results are also of use to BNM for their ongoing ecological studies, especially contributing information about conditions in burned areas.

5.1 Importance to Mycological Diversity Mapping

As mentioned in the introduction, several surveys have been done or are in progress in North America in the last few years. The goal to complete a nationwide mesh of database information about living entities and their habitats will find our results useful (Pennisi 1993). Survey information is not standardized in content or format. Consider three excellent recent surveys of macromycetes that have sites in the western mountain chain of forests (three diversity surveys: Ammirati et al. 1994, Nishida et al. 1992, and this work and an abundance study, Norvell 1995). Conditions for their surveys are shown in Table 4.

5.2 Correlations

Collections in burn areas sparked an ongoing interest in the taxonomic Class Discomycetes (of the Subdivision Ascomycotina), whose small members appeared to have a greater density in burned areas–more evident, possibly, because of the lack of the usual large mycorrhizal fungi. Typical genera found were *Gyromitra*, *Cudonia*, *Coriolellus*, *Scutellinia*, *Spathularia*, *Helvella*, and *Peziza*. Again, the erratic fruiting times makes correlation studies difficult.

Table 4. A comparison of pertinent characteristics between four different surveys in western mountain forests.

FUNGI SURVEYS

	Barlow Pass (Ammirati et al. 1994)	**Chiricahua (Nishida et al. 1992)**	**Chantrelle (Norvell 1995)**	**Los Alamos (This Work)**
# Species	~200	362	1	241
# Plots or Sites	1	43	250	~30
Freq. of Visit	Often	Not Often	Often	Often
Type: Diversity or Abundance	Limited Diversity	Diversity	Abundance	Diversity
# Professionals	11	6	14	2?
# Amateurs (Volunteers)	24	0	35	2?
# Other Personnel	0	0	13	0
Area m^2 Total	$\sim 10^4$	(Prob. Large) Unknown	10^3	$\sim 10^4$
Span, Years	3	3	10	5
Biome Varied?	No	Yes	No	Yes
Vouchers?	Yes	Yes	Yes	Yes
Correlations	Time Habitat	Habitat	Many	Time Habitat

This table is not definitive, but is an example of the differences possible in surveying and recording. If computer mapping of all biological species (Pennisi 1993) is the long-term goal, (which should produce information to help identify endangered species and point to the need of specific habitat protection), then standardization of surveying technique is badly needed (Arnolds 1992, Murphy 1996).

A simple correlation is shown in Figure 5. Plotted is the number of collections versus month. This shows the narrow fruiting season expected for the short summer period at altitudes surveyed.

The “fickle fungi fruiting factor” certainly operates in the Jemez Mountains. For example, while only 11 taxa were collected at site BN3 in 1991 and 1992 combined, 34 were found there in 1993. In contrast, at Apache Springs (AP1) this pattern was reversed, with 38 species collected in 1991 and 1992 and none in 1993. A fruiting of a given species may happen erratically, with a 10- to 15-year barren interval possible between fruitings. These fluctuations are not well understood. At the least, they are a complex function of rains and rain history, humidity, soil and air contamination, nutrients, length of day, temperature, competition (for nitrogen and other nutrients) with other organisms, and the health of the symbiont partner if there is one. With such variable factors involved, we found it difficult to correlate local fruiting patterns with environmental conditions–the only distinct correlations are with precipitation and moist soil conditions and time of the year. More correlation studies are planned.

In general, more fungi and more taxa were seen at the higher, moister elevations, especially in mixed-conifer habitats. However, we also observed heavy, intermittent fruiting in typically barren piñon-juniper habitats at lower-elevation sites, but usually not until extended rainfall created moist soil conditions for a week or two. Some species, especially in the genera *Agaricus* and *Amanita*, seem to favor piñon-juniper habitats (Klopatek et al. 1987, 1988). Attempts to make meaningful correlations were again frustrating. For example, 29 specimens were collected from piñon-juniper habitats, but 15 of the specimens could not be reliably identified to species. One identified specimen, *Agaricus pinyonensis*, is known only to occur with piñon and juniper in New Mexico. We identified also *Amanita constricta* that favored the piñon-juniper habitat, yet this species is found mostly under oak or like hardwoods in California (Jenkins 1986). *Chalciporus* spp. were collected only in piñon-juniper. *Laccaria laccata* and *Leccinum aurantiacum* were seen only in a mixed-conifer environment—the latter usually seen in aspen groves. In contrast, two species, *Russula brevipes* and *Lycoperdon perlatum*, were collected in all the habitat types. Again, a detailed study of the database is needed. Apparent symbiotic relationships

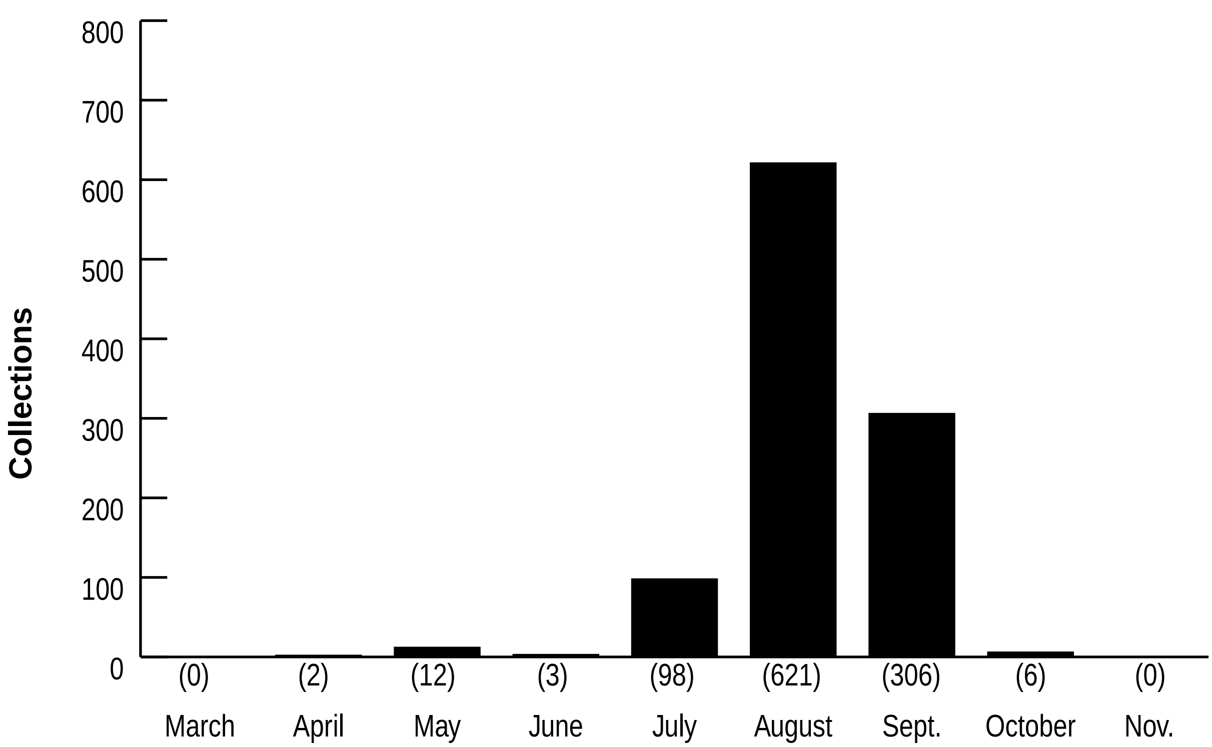


Figure 5. Number of collections (all five years) vs. month.

between trees and fungi were consistently observed. Intensely burned areas where trees did not survive the 1977 La Mesa fire lacked the fruits of mycorrhizal fungi. For example, site BN6, a ponderosa pine grove near the “Backgate,” produced expected mycorrhizal genera (*Amanita*, *Russula*, *Lactarius*), whereas the nearby site BU1, burned clear of ponderosa pine trees in the La Mesa fire, produced none of these genera or others known to be mycorrhizal.

Fungi species unique to burn habitats, such as *Coriolellus carbonarius*, were found in recently burned areas. There also seemed to be a higher than normal fruiting density of fungi in the class Discomycetes.

We often felt an aesthetic pleasure, a joy, from walking in the woods and discovering fungi new to us. The AP1 site at Apache Springs in Bandelier (Figure 4) was a fungi showcase in 1992. In this moist, narrow cleft surrounded by expanses of drier ponderosa pine/mixed conifer forest, a small riparian habitat existed providing a profuse fairyland of mushrooms. There were troops of tiny orange *Xeromphalina campanella* on fallen logs, guarded by flanks of the purpled-pored cups of *Humaria hemisphaerica*, and orange corals (*Clavicorona pyxidata*) amidst red “eye-lash” cups (*Scutellinia scutellata*). We collected a total of 40 species from that one site in August and September 1992.

Another favorite walk is the Pipeline Trail site (PL1) near the Los Alamos Ski Hill at an altitude of 2700 to 2850 m (9000 to 9500 ft). Cross-country ski trails provide paths edged with downed aspens and conifers. These logs retain moisture even when seasonal rains are sparse and provide a habitat for many wood-loving fungi. Here can be found the Ascomycetes: Morels and *Helvellas* (elfin saddles), tiny blue-green fruiting cups of *Chlorociboria aeruginascens* on like-colored pieces of wood stained by it, and the tongue fungi of genus *Spathularia*. The Basidiomycetes are here too–*Auricularia auricula* (tree ears), corals of *Ramaria* and *Clavulina*; clubs of *Clavariadelphus truncatus*, *Poria spissa*, and crusts; the crinkled bright orange jelly, *Dacrymyces palmatus*. Myxomycete, *Stemonitis splendens*, lives here, a slime mold first showing a white bubbly structure, next, tiny brown waving stems with even tinier brown caps, with the last stage a pink burgundy spotted “cap.” As the walk continues, we see large fruitings of parasitic *Armellaria* at work, with polypores of *Ganoderma applantum* and *Fometopsis pinicola* reducing dead and dying trees to forest mulch. The so-called rare mushroom, *Xerula americana*, is also evident, grayish-black felty cap, white gills, spiraling stem, and radicating root. Curiously, what is <u>not</u> seen is also of interest. Where are the common Russulaceae, Amanitaceae, or any of the *Boletus* species? With the aspens all round, why aren’t *Leccinums* evident? Mysteries in the forest.

6.0 SUBSIDIARY INFORMATION

Information gained from the literature search and from contact with fungi experts seemed at times as important for the education of the sponsors of the project’s funding as the data itself. For example:

1. An obligate mycorrhizal relationship with plants is very common; over 90% of higher plants have fungal symbionts. Major boreal tree families, such as Pinaceae, are thought to be 100% mycorrhizal (Kendrick 1992). This relationship is an important parameter in forest fires (Dhillion et al. 1987, Pilz and Perry 1983). Mycorrhizal relationships apparently help maintain vascular plant diversity (Grime et al. 1987).
2. A variety of studies provide glimpses of the ecological complexity of fungal activity in soils after fires. For example, an increase in soil temperature results in a <u>decrease</u> in the density of higher fungi, but with an associated <u>increase</u> in bacteria and actinomycetes (Wright and Tarrant 1957). It is apparent that complete studies, which include all forms of fungi, bacteria, and other life forms, are necessary to fully understand the ecological interactions of fire and fungi (Moffat 1993, Rose and Hutchins 1988, Wicklow-Howard 1989, Harvey et al. 1976, and the many references therein). Local diversity inventories such as the present effort will support more sophisticated fungi-fire research.
3. Tree seedlings used in reforestation must be inoculated with a mycorrhizal partner for survival past one year (Trappe 1977). There is a succession through time of different symbiotic fungal partners as the trees mature (Visser and Danielson 1990, States 1993).
4. There are subtle factors involved in the choice of fungi in post-fire restorations. For example, in reforestation efforts, attention should be paid to fungal health. Parameters like soil moisture and

temperature–and thus the time of the year–and the amount of shade in the area, will affect the use of clear cutting and other management techniques (States 1993). Soil nitrogen depletion after fire is an important factor for fungi growth and mycorrhizae (Freeman 1984, Kinzig and Socolow 1994).

5. Interesting ecological cycles involving fungi exist, including many that are poorly known. For example, there is a strong relation between ponderosa pine trees, truffles (mycorrhizal Gastromycetes or Discomycetes that are hypogeous [occurring underground]), and Abert squirrels (*Sciurus aberti*). These truffles exude aromas to attract the squirrels, who dig up and eat these fungi. They spread the spores through their feces, which is especially important for nearby ponderosa pine seedlings that need to be inoculated with these mycorrhizal fungi (Trappe 1977, States et al. 1988). This coevolutionary relationship likely developed over a long time. Near Bandelier headquarters in 1993, an Abert squirrel noisily scolded us for digging up its truffle dinner in ponderosa pine needle duff where it had previously been foraging. The squirrels provide food for the local goshawk (*Accipiter gentilis*) who, with the truffle, have evolved to need a certain density of pine tree for optimum survival.
6. In Europe, mycologists have made major fungi diversity surveys for many years, far ahead of American studies, and have charted the changes of fruiting boundaries of various species through time, developing "red lists" compilations of species that are extinct/missing or threatened with extinction (Arnolds 1989, Lizon 1993, 1995a, 1995b). Detrimental changes in the environment, such as acidic rain, have been correlated with major retreats in the geographic distributions of both fungal species and associated forest plants (Arnolds 1992). Which symbiont partner dies first? Again see Figure 1.
7. In Washington state it has been suggested that there is more commercial value in a possible mushroom harvest than from timber (Molina et al. 1993), a remarkable statement given that this is one of the most productive forestry areas in the world.

7.0 CONCLUSIONS

<u>The main conclusion of our survey is simply the database itself. It shows that a broad diversity of macroscopic fungi exists locally in a variety of habitats.</u> The efforts to collect, identify, and develop a database for the macroscopic fungi of Los Alamos County has provided a listing of 1048 collections, 241 species, 123 genera, 52 families, 22 orders, 5 classes, 2 subdivisions, and 1 division of the kingdom Eumycota (Fungi). Fifty-one of the 241 identified species were new to the New Mexico lists and 11 species are considered rare, although this number critically depends on one's definition of rare. The content of our complete database will provide additional details on diversity in the future as correlations in the data are studied. The studies and survey reinforce the importance of habitat in fungal life.

7.1 Future Work

1. Of priority will be improving the identification of unknown and poorly identified collections by using our voucher specimens, making special field trips, and by consultation with experts.
2. Detailed study of correlations in the data should give interesting results. For example, the fungi database we have developed could be used to decipher additional relationships between local fungal distributions and environmental conditions and habitats, such as the associations between intense La Mesa fire burn sites, and the recent large Dome fire in 1996, with certain fungi noted above. It should be useful to compare detailed climatic data (e.g., rainfall patterns) with our fungal fruiting data.
3. Cooperation and collaboration with groups desiring to use the databases and herbarium samples; especially with ESH-20 installing the data into their master database programs and with the ongoing ecological studies at Bandelier National Monument.

Eventually, soil and wood cores will be taken to identify the hyphal vegetative states of fungi using DNA sequence analysis. These new techniques can also help identify single- or few-celled fungi and bacteria, which are very important components of local soil and forest ecosystems. Such a project is far beyond the scope of the present work. Still, we can achieve a significant advance in the knowledge of local fungi diversity and ecology by improving identifications and studying correlations.

8.0 ACKNOWLEDGMENTS

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APPENDIX A

Herbarium and Collection Technique for Fleshy Fungi

1. Collection, in the field:
   a. Specimens, hopefully of various ages, include stipe base and piece of host, if possible.
   b. Spore print started.
   c. Fresh characteristics noted: colors, textures, odors, size, veils, taste, bruising, gill attachment etc.
   d. Note habitat, host, location, general conditions.
   e. Early identification made, if possible.
2. Notation, in the laboratory:
   a. Write up a “first note” with all available descriptive information. Make the best identification, and assign a reliability “grade” to this.
   b. Assign an accession number. Enter relevant information into a formal database (we use FoxBASE+/Mac for Macintosh).
3. Preservation:
   a. Spore print completed or made.
   b. Shortest possible time to dryer. Dry at low temperatures (105 F or 41 C) till crisp, may take days. Also dry small envelopes, spore print card, and small pasteboard boxes if used in storage.
   c. When dry, put folded print card in labeled envelope, and specimens, if small or fragile, into small labeled pasteboard box.
   d. Put a few grains of paradichlorobenzene (“Moth Ice”) in the envelope and small box. Mark pint size (or larger) Ziploc heavy-duty freezer storage bag 2.7 mil)with accession number and name of specimen. Put all items in the bag with a few more grains of paradichlorobenzene. Seal bag. Take care! The fumigant is toxic. Work in a ventilated place.
   e. Put bags in order of accession number into a Rubbermaid “Keepers-Latch Box” 2.6 gal size #2147, 14.5 x 9.25 x 7 inches (with no open gaps). Usually can fit 20-30 bags/plastic latch box (don’t overfill).
   f. A cabinet is needed that accepts the shape of the latch boxes.

      Saprobic fungi, insects, and rodents should then be controlled. In four years without further attention, we have not lost a specimen.

      All physical supplies were obtained from local hardware, grocery and stationery stores. The plastic bags are transparent to, but not damaged by, the fumigant.

      Filled boxes and bags should be handled gently.

APPENDIX B1

Field Abbreviations for Los Alamos Fungi Databases

July 16, 1997

Not all of these fields are given in the Short Form and Species lists in this paper.

ncode	Number code = mcode = our accession and herbarium number.
lcode	Letter code: first two letters of genus and species. Not often used.
genus	Taxonomic Genus of specimen.
species	Species.
family	Family.
order	Order.
commonname	Only given if really universal. Omitted in some versions.
grd	"Grade" Identification Reliability, see Reliability code list and text.
ref	Reference: Book and page number. See Reference code list.
loct	Location. See Location code list.
date	Date of acquisition.
habi	Habitat, compatible with ESH-20 code. See Habitat code list.
bndlr	.T. = Located in Bandelier National Monument.
nmlst	.T. = specimen is on New Mexico list of 10/13/94 +1995 update.
ta	LANL Technical area. "00" means not on LANL land.
(typ)	Type S/M/P/X/U = Saprobe/Mycorrhiza/Parasite/Mixed/Unknown.
vchr	.T. = Voucher sample made. Dried and stored in local herbarium.
pho	Photograph, P/S/N = Print/Slide/None.
(eat)	Edibility (various sources). A guide only, beware! See Edibility code list.
col/id	Collector/identifier. See code list. Single set of initials is both.
alt	Altitude in kilofeet. See Location code list.
zone	"Life zone" See code list.
host	Mycorrhizal and/or immediate habitat. See code list.
grthb	Growth habit (e.g., "scattered") See code list.
ocr	Occurrence code (e.g., "common"). See Occurrence code list
utmn	Universal Transverse Mercator coordinates, north. See location code.
utme	Universal Transverse Mercator coordinates, east. See location code.
day	Day of acquisition.
mon	Month of acquisition.
year	Year of acquisition.
mcro	.T. = Microscopic work has been done.
(cmnts)	Comment memos written in database. See comments printout.
mcode	= ncode = Jarmie's accession and herbarium number.
version	Version date or number identifies latest date of editing. Not on some versions.

A Field Abbreviation in parentheses denotes an unfinished field.

APPENDIX B2

loct: Location and Elevation Code for Los Alamos Fungi Database

Location site, about ±100 m — July 15, 1997

Code	Elev. (Feet)	utmn 39xxxx0 (m)	utme[a] 3xxxx0 (m)	Location Description
AP1	8444	6526	7424	Apache Springs itself, in little cañon. BNM #UF-23[a].
AP2	8500	6556	7480	Apache Springs, Ponderosa grove to the NE. BNM #UF-23.
AP3	8500	6584	7481	Apache Springs, MC between Springs and Hwy 4. BNM #UF-23.
AS1	8200	6650	7550	American Springs Rd. N. of SR 4.
BN1	8949	6773	9158	Bandelier, S of intersection of Dome Rd and Hwy 4. BNM #UF-10.
BN3	6066	5998	8419	Bandelier, Headquarters ± 400 m. BNM #HQ-47.
BN4	6200	6140	8343	Bandelier, Ceremonial Cave area.
BN5	7023	6414	7706	Bandelier, Upper Crossing.
BN6	7600	6606	7742	Bandelier, Back Gate/Ponderosa C.G. BNM #UH-27.
BN7	6689	6187	8439	Bandelier, Juniper C.G.
BU1	7200	6452	8015	Bandelier “Burnt Mesa” Plots BM1, BM 2, BM 3. BNM #UF-35.
BU3	8960	6800	7160	Bandelier NE of Dome Rd/Hwy 4. BNM #UF-3.
BU4	8960	6800	7100	Bandelier W of Dome Rd/Hwy 4. BNM #UF-4.
BU6	9000	6760	7300	Bandelier S of Frijoles Cr. headwater. BNM #UF-6.
BU8	9000	6670	7350	Bandelier E of BU6, BNM #UF-8.
BU26	8100	6600	7600	Bandelier Gully SE of Hwy 4 and Armstead Sp. Rd. BNM #UF-26.
BU44	6300	6180	8260	Ban. Frijoles Cr. 2 mi. up from Ceremonial Cave. BNM #HQ-44.
BU46	6000	5950	8550	Bandelier SE of Rainbow House ruin, BNM #HQ-46.
BU48	6580	5940	8270	S. of HQ betwn Lummis and Alamo Canyon. BNM #BW-48.
GP1	7000	7400	8250	Guaje Pines, in trees.
LA1	7400	7278	8056	Los Alamos, Urban Park, and other mid-Los Alamos.
LA2	7200	7122	8048	Los Alamos, Canyon bottom near Ice Rink.
LB2	7400	7037	8000	LANL TA-3 area.
LB3	7300	6806	8282	TA 67 mid-mesa..
LB4	7100	6823	8276	TA 67 Pajarito Canyon.
LC1	7700	7210	7730	Los Alamos Canyon, 1 mile W. of reservoir.
LC2	7400	7124	7905	Los Alamos Canyon, just W. of “West Road.”
LC3	6500	7007	8810	Los Alamos Canyon, about 2 mi. W. of SR 4.
PC1	7900	7020	7750	Pajarito Canyon N. of SR 501.
PL1	9200	7330	7465	Pipeline Road shunt CC trails near Ski Hill.
PL3	9540	7625	7440	Pipeline Road, junction with shunt.
PR1	6540	6500	8900	Pajarito Canyon, N. of Pajarito Rd. (.1 mi to SR 4)
PR4	6700	6646	8611	Pajarito Canyon, near entrance to TA-18 (2.4mi to SR 4)
RC1	6500	7447	8544	Rendija Canyon.
SH1	7500	7072	7880	Ski Hill Road, Ponderosa grove near base.
SH2	8000	7117	7828	Ski Hill Road, So. Ponderosa grove. 1st flat stretch.
SH3	8600	7241	7641	Ski Hill Road, “Install Chains” turnout.
SH5	9200	7263	7538	Ski Hill Road, 1/2 mile below Spruce lift.
SH7	9260	7305	7427	Ski Hill Road, Spring area near Mother lift.
SH8	10000	7250	7400	Ski Hill, Spruce Forest SW of end of road, ridge.
WR1	6500	6466	9025	La Vista subdivision. White Rock area.
WR3	6440	6400	9040	Mid-La Senda (PJ).

[a]Universal Transverse Mercator Coordinates, Zone 13, in meters.
[b]BNM# is Bandelier area number code.

APPENDIX B3

grd: Identification Reliability Code for Los Alamos Fungi Database

July 15, 1997

The grade is subjectively determined by the identifier.

grd	
1	Well known, no doubt, species sure, no close unknown brothers.
2	Well identified, but slight possibility of being a species in a close group, that a specialist would be needed to separate.
3	Genus sure, species possible, but not sure. Often designated as a “Group” or “Complex” in the literature or in a field guide, “cf.” in species field.
4	Genus sure only.
5	Family sure only.
6	Order sure only.
7	Unknown.

APPENDIX B4

August 14, 1997

ref: Reference Codes for Los Alamos Fungi Database

A variety of books and monographs were used in the initial identification; but often we chose to put the best field description of the following list in the ref field.

AMD Arora, D. 1986. Mushrooms Demystified. 2nd Ed. Ten Speed Press, Berkeley, CA.

BSF Breitenbach, J. and E. Kränzlin. Fungi of Switzerland. 4 Volumes. Luzern. Verlag, Mycologia.

BSM Bessett, A. and W. J. Sundberg. 1967. Mushrooms, A Quick Reference Guide to Mushrooms of North America. Macmillan Field Guides. Macmillan Pub. Co., New York, NY.

GLT Glick P. G. 1979. The Mushroom Trailguide. Henry Holt, New York, NY.

GAP Gilbertson R. L. and L. Ryvaarden. 1986. North American Polypores, Vol 1 & 2. Fungiflora, Oslo.

HMD Huffman D. M., L. H. Tiffany, and G. Knaphus. 1989. Mushrooms & Other Fungi of the Midcontinental United States. Iowa State University Press, Ames, IA.

LIG Largent D. L. and T. J. Baroni. 1988. How to Identify Mushrooms to Genus VI, Modern Genera. Mad River Press, Eureka.

LAS Lincoff, G. H. 1981. The Audubon Society Field Guide to North American Mushrooms. A. A. Knopf, Inc., New York, NY.

MNA Miller, O. K. 1977. Mushrooms of North America. E. P. Dutton & Co., Dubuque, IA.

MSM McKenney, M. and D. N. Stuntz. 1987. The New Savory Wild Mushroom. Revised and Enlarged by Joseph Ammirati. University of Washington Press, Seattle, WA.

PNA Phillips, R. 1991. Mushrooms of North America. Little, Brown and Co. Boston, MA.

SWM Smith, A. H. 1975. A Field Guide to the Western Mushrooms. University of Michigan Press, Ann Arbor, MI.

SGM Smith, A. H., H. V. Smith, and N. S. Weber. 1979. How to Know the Gilled Mushrooms. The Pictured Key Nature Series. Wm. C. Brown Co. Pub., Dubuque, IA.

SNG Smith, A. H., H. V. Smith, and N. S. Weber. 1973. How to Know the Non-Gilled Mushrooms. Wm. C. Brown Co. Pub., Dubuque, IA.

SSW States, J. S. 1990. Mushrooms and Truffles of the Southwest. University of Arizona Press, Tucson, AZ.

APPENDIX B5

host: Mycorrhizal Host and Immediate Habitat Code for Los Alamos Fungi Database

July 14, 1997

The host, if any, is estimated by the collector on the spot, within the "dripline" or within about 5 m from a large tree. This is a guess at best.

JU	Juniper, One-seed, Juniperus monosperma.
RJ	Rocky Mt. Juniper, Juniperus scopulorum.
PI	Piñon Pine, Pinus Edulis.
PP	Ponderosa Pine, Pinus ponderosa.
LP	Limber Pine, Pinus flexilis.
DF	Douglass Fir, Pseudotsuga menziesii.
WF	White Fir, Abies concolor.
ES	Englemann Spruce, Picea engelmanii.
AS	Aspen, Populus tremuloides.
CO	Cottonwood, Populus fremontii var. wislizenii.
OK	Gambel (Scrub) Oak, Quercus gambelii.
OD	Other Deciduous, see "memo."
OC	Other Conifer, see "memo."
MC	Mixed Conifer. Usually mix of firs and some pine and spruce.
MT	Mixed Trees. Many varieties close.
RW	Rotten unidentified wood.
BW	Burned wood.
DW	Dead deciduous log.
DC	Dead conifer log.
MG	Meadow/grasses. No trees or obvious host.
DU	Dung.
DI	Dirt.
SA	Saprophyte.
HU	Humus.
FU	Fungus.
NA	None of the above, see "memo."
UN	Unknown

.

APPENDIX B6

ocr: Occurrence Code for Los Alamos Fungi Database

August 15, 1997

Factors other than number of collections sometimes affect the choice.

ABN	Abundant, (Ubiquitous). At least 10 collections.
COM	Common. From 2 to 10 collections.
UNC	Uncommon, (Infrequent). One collection.
RAR	Rare.
UNK	Unknown.

APPENDIX B7

habi: Habitat Codes for Los Alamos Fungi Database

June 14, 1997

JG	Juniper Grassland
PJ	Piñon/Juniper
PJPP	Piñon/Juniper/PonderosaPine
PP	Ponderosa Pine
PJMC	Piñon/Juniper/Mixed Conifer
MC	Mixed Conifer
ES	Engelmann Spruce
SAM	Subalpine Meadow
CB	Canyon Bottom
CBPJ	Canyon Bottom/Piñon/Juniper
CBPP	Canyon Bottom/Ponderosa Pine
CBMC	Cañon Bottom/Mixed Conifer
BQ	Bosque
W	Wetland
MG	Meadow or Grass