FINAL REPORT
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Influence of Environmental Factors on Fruiting of Edible, Mycorrhizal Mushrooms

Prepared for
California Department of Forestry and Fire Protection

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Please note: A requirement for obtaining the Bachelor's degree in Biology or Botany at Humboldt State University is the completion of at least one unit of research. Ms. Brenda Engirt volunteered to complete the biomass study for her requirement. In Fall 1993, we have six students involved in this project who are completing their senior theses: one at Jackson Demonstration State Forest, Cythnia Willis, two at Lanphere-Christensen Dunes, Jason Cooley and Michael Stephenson, and three at Patrick's Point State Park, John Meriwether, Sam Brennan, and Kathy Kimm.

INTRODUCTION

Extensive commercial harvesting of wild, edible mushrooms continues to be prevalent throughout the forested areas of northern California and increased during the 1992 season because of the wet weather pattern. However, in 1993 commercial harvesting of wild, edible mushrooms decreased due to the warm, dry weather patter. Foresters, biologists and others interested in the vitality of the forests and wildlife of the Pacific Northwest, including northern California, are concerned about potential impacts of commercial harvesting of wild mushrooms (Bengston, 1993 a, b; Molina et. al. 1993).

Most of the fungi producing mushrooms that are targets of commercial and recreational pickers form complex relationships such as mycorrhizae with forest trees and plants. The impact of different intensities and methods of mushroom picking on existing fungal populations is unknown. If mushroom picking does have an effect on fungal populations, will this effect result in a difference in the health and vigor of the trees that depend upon their mycorrhizal associations with the fungi? Some small mammals and deer also eat the same mushrooms chosen by pickers; will mushroom harvesting have an effect on their populations? Some harvesting techniques may result in habitat degradation. This may ultimately have an effect on species of plants and animals in the forest, such as fish and birds, that are not directly dependent on the mushrooms.

Because of these concerns, foresters, biologists, university researchers and mycological societies have cooperated on several projects in California and the Pacific Northwest that study the biology of target species and effect of commercial harvesting on wild edible mushrooms:

1. The Oregon Mycological Society began a biomass and population study of the yellow Chanterelle (*Cantharellus cibarius*) September 1986 in cooperation with USDA Forest Service. This study, supervised by Lorelei Norvell from the University of Washington, utilizes permanent plots secured behind locked gates in the Mt. Hood region in Oregon. (Norvell, 1992)

2. Two research projects that involve biomass productivity of the matsutake (*Armillaria ponderosa*) and environmental correlation began in Fall 1993. These projects, supervised by the Forestry Sciences Laboratory in Corvallis, are situated in Winema National Forest and Siskiyou National Forest, both in Oregon. (Fischer et. al., 1993)

3. A research project involving biomass productivity and environmental correlation of *Armillaria ponderosa* began in Fall 1993. This project, located in Klamath National Forest in northern California, involves Humboldt State University and is supervised by Max Creasy, Uknonom Ranger District, Klamath National Forest. (Millar et. al., 1993)

4. A research project involving population and biomass studies of *Armillaria ponderosa* began in 1991 in Six Rivers National Forest in northern California. This project, supervised by David Largent, Humboldt State University (HSU), utilizes permanent plots and is based upon protocols developed during earlier studies funded by the California Department of Forestry and Fire Protection (CDFF).

5. The research projects discussed in this report, underway since Fall 1990 in three locations in northern California: Jackson Demonstration State Forest (Fort Bragg), Patrick's Point State Park (Trinidad) and Lanphere-Christensen Dunes Preserve (Arcata). These projects are supported by CDFF, supervised by David Largent and involve the Humboldt Bay Mycological Society. These projects focus on weather conditions, population, biomass, and phenology of six target species depending on site location:

Jackson Demonstration State Forest: *Armillaria ponderosa*, *Boletus edulis*, *Cantharellus cibarius*, *Craterellus sp.*, *Hydnum repandum*, *Leccinum manzanitae*.

Lanphere-Christensen Dunes Preserve: *Armillaria ponderosa*, *Boletus edulis*, *Cantharellus cibarius*, *Leccinum manzanitae*.

Patrick's Point State Park: *Boletus edulis*, *Cantharellus cibarius*.

All of these studies should provide information on how to best manage forest fungal resources and are extremely important because of reports of declining macrofungi in Europe. (Cherfas, 1993; Lizon, 1993)

Location: Jackson Demonstration State Forest (JDSF), near Fort Bragg, California

BACKGROUND

This area is located on both sides of Highway 20 between Willits and Fort Bragg, California. As JDSF is a demonstration forest, a variety of timber management strategies are utilized on the forest making it possible to study mushroom fruiting in different, managed ecosystems. The forest stretches from very near the Pacific coast to thirty-five miles inland with elevations ranging from sea level to about 2500 feet. Long term rainfall data show that some regions of the forest can get more than 60 inches of rainfall per year. More average rainfall in most areas is between 25 and 30 inches per year but the forest has been subject to California's persistent drought of the last seven years.

Timber species are primarily Redwood (*Sequoia sempervirens*) and Douglas-fir (*Pseudotsuga menziesii*) with other tree species including Pacific Madrone (*Arbutus menziesii*) and Tan Oak (*Lithocarpus densiflorus*). The area has many creeks and small streams and is bisected by the Noyo River that serves as the source of drinking water for the community of Fort Bragg. A fish egg collecting station is located in the center of the forest on the Noyo. During spawning season, salmon make their way up many of the small shallow streams into pond areas.

The forest is popular with recreational users. There are several camping and day use areas including a group camp area near Camp One. There are gravel and dirt roads throughout the forest that are passable to most vehicles in all but the wettest periods of the year and many popular hiking, bicycle and horse trails. Mushroom picking is a traditional outdoor hobby for ethnic European, Asian and Native American groups that reside in the area. The area has an active mycological society and is also well known to commercial buyers. During mushroom season, vehicles with signs offering to buy mushrooms can be seen all along Highway 20 and in the communities of Fort Bragg and Willits. Anecdotal evidence shows that many former timber workers have turned to mushroom picking as a way to support their families as other jobs in the woods have disappeared. Many areas closer to the San Francisco Bay area have been closed to mushroom picking of any kind so JDSF has become the closest area where mushroom collecting is allowed.

In 1990 season, the Forest Supervisor, Forest Tilley, set aside an area designated as a mushroom study region. The research project began that year with a mushroom survey and sporocarp longevity study throughout the forest using a combination of plots and fixed transects in seven locations within and outside the designated study area. Some sporocarps were lost to animals. It was another drought year so mushroom productivity was poor. Commercial and recreational pickers continued to pick in the study areas. We learned that the size of the forest coupled with good vehicle accessibility to good mushroom sites and shortage of recreational patrol officers to police the designated study area made it impossible to maintain permanent plots unless they were very well hidden.

In 1991 season, Forest Supervisor Tilley requested that we attempt to confine our sites to the designated area in an effort to control access by pickers. Efforts during this season focused on locating plot areas that would be accessible for monitoring on weekly visits (JDSF is a seven-hour round trip from HSU), that had a good variety of target mushrooms and timber species, and that were hidden or inconvenient enough to be uninviting to pickers. A suitable plot was located near Camp One and intensively mapped for all vegetation during the 1991 season. Two other sites were identified near Bear Gulch and Gulch 16. All three sites were sampled during site visits for numbers of target species. The 1991 season was another drought year with reduced mushroom productivity. As was the case during the 1990 season, there was frequent evidence of commercial picking (although not in the mapped plot): piles of discards and trimmings near the road edge, areas of raking, trampling, digging and other disturbance, and encounters with groups of pickers carrying pails and bags of mushrooms.

STUDY PERIOD: SEASON OF 1992

JDSF generally remained dry and warm until the end of October when rains began. This season was the first to experience a normal amount of rainfall after seven years of drought conditions in northern California. Mushroom fruiting was prolific in comparison to last year for both target and non-target species. Fruiting was not observed for any target species until the first week in November when all the mushrooms began to fruit simultaneously. Fruiting of many species other than the target mushrooms was heavy; at times it was impossible to walk within the plots without stepping on mushrooms. Fruiting persisted in some sheltered spots through January.

Three study areas were used in the designated mushroom research area north of Highway 20 during this season: Gulch 16, a site in the eastern portion of the forest off Chamberlain Road; Bear Gulch, a site located near the central portion of the forest between Camp One and Parlin Fork Camp; and Camp One, a site also located in the central portion of the forest. The Camp One site, mapped during 1991 season, is uphill from a locked gate on an unused road. Bear Gulch is also controlled by a locked gate but is subject to vehicular use by authorized persons. The Gulch 16 site is near the old target shooting range adjacent to a heavily used road open to the general public. All of the sites are accessible by foot or bicycle; hikers and mushroom collectors were frequently encountered during site visits, particularly in the Gulch 16 and Bear Gulch areas.

1. Bear Gulch: From the months of January through May, twenty new 10m x 10m plots were established and mapped at Bear Gulch. All vegetation was mapped on each of these plots and accurately located on each map. All corners of the subplots were indicated by flags and stakes purchased with funds available for this study. The total number of worker hours involved was approximately 250. Unfortunately, sometime between late May and late July this site was vandalized; all stakes and flags were removed and thrown away. Therefore these plots have been eliminated; estimated cost to the project of $3500.00.

2. Gulch 16: Five new 4m x 10m plots were established and mapped at Gulch 16. Unfortunately, vandalism is quite prevalent at this site with the signs posting the area as "Closed to mushroom picking" as well as plot tags removed by someone during the period between November 12 to November 20. This area continues to show evidence of visits by commercial pickers. It is very close to a well-traveled road and also near a target-shooting range. Plots were not re-established during this season and a decision has been made to discontinue this site in the future.

3. Camp One: Site study plot is an intensively mapped area of 484 square meters. Separate subplot maps for each four square meters were reproduced and used during each site visit to locate species under study as well as potential indicator species. The Camp One site is a Douglas-fir and Tan Oak habitat.

Field workers on sampling visits during this season collected data to define relationships, if any, between target species of mushrooms and existing trees and shrubs. Locations of target species sporocarps were mapped to follow season to season changes in the intensively mapped plot at the Camp One site.

During 25 sampling visits, the following numbers of sporocarps were observed and noted on subplot maps of the three sites (Table 2). Data from 1990 and 1991 seasons are shown for comparison for Bear Gulch and Gulch 16:

Table 2. Numbers of sporocarps at three study sites, JDSF

	Camp One	Bear Gulch			Gulch 16		
	1992	1990	1991	1992	199	1991	1992
C. cibarius	23	0	0	29	0	0	10
B. edulis	3	0	0	12	0	0	0
L. manzanitae	0	0	0	2	~~0~~	3	0
A. ponderosa	0	0	0	0	0	0	0
H. repandum	17	0	0	41	0	25	7
Craterellus sp.	52	0	0	23	0	0	4

The data presented in this table reflects differences in numbers of target species sporocarps for the two previous drought years as compared to the wet 1992 season. However, the true number of sporocarps was probably more than recorded because of the heavy incidence of mushroom harvesting in these areas.

Generally there were more mushrooms from target species this year than in previous years. The sporocarps were very large in some cases with one specimen of *Cantharellus cibarius* measuring 28 cm across the top. (Other aspects of this study suggest sporocarp size is important for estimates of total biomass and for estimates of total spore number; see below.) Sporocarps of other than target species were also very plentiful and fruiting in general was much more prolific than during previous years. Without exception, all sporocarps encountered in previous years of this study were small; less than 4 cm at largest diameter across the top for young *Hydnum repandum*. Small size and general absence of target species are thought to be because of the extended drought conditions. A brief period of heavy rain in January 1992 may have encouraged the large flush of *H. repandum*.

COMMON VASCULAR PLANT ASSOCIATIONS FOR THE TARGET SPECIES

Information from the subplot maps still needs to be entered into a mapping program for a full statistical analysis but a preliminary review of the map data indicates that *Cantharellus cibarius* is most commonly associated with Douglas-fir less than five inches in diameter. *C. cibarius* was also found close to Tan Oaks. In all but one instance, the Douglas-fir or Tan Oak was close to huckleberry (*Vaccinium ovatum*).

Boletus edulis tended to be located in spots where the canopy was open with no clear preference for any particular species of tree or shrub. The total number of *B. edulis* was rather small (as was *Leccinum manzanitae*) this year; clearer associations may be demonstrated by more prolific fruiting of these species.

Hydnum repandum was as likely to be found near true firs and Douglas-firs as it was near Tan Oaks; frequently groups of fruiting bodies of this species were found under fern fronds. *Craterellus* fruited most often near Madrone and small (diameter less than five inches) Tan Oaks that were in close proximity to rotting logs.

STUDY PERIOD: SEASON OF 1993

This is the fourth year of study at this site. Because of difficulties in maintaining permanently marked plots, this year the project staff, Sally Hewitt and Cindy Willis, used random transects within large areas delimited by relatively permanent human-made or natural structures. Monitoring took place in two plots of approximately five hectares each. Both plots are located in the Bear Gulch area. Each plot was divided into six subplots during September. A random 50 meter transect in each subplot was traversed weekly, making 12 transects per visit. In addition, fourteen collections of mycorrhizae below fruiting bodies of *Cantharellus cibarius* were made and described.

When target species were encountered on the transects, age of the sporocarp was noted (button, mature, over-mature), and the species of the nearest tree or shrub. DBH was also noted for the nearest tree or shrub.
Results are presented in Table 3.

Discussion

There were very few mushrooms of any species during most of this season at JDSF. We believe this is due to a period of warm, dry winds that persisted for several weeks during October. Sporocarps of target and other species had abortive growth and were dried up in the button stage. The 1993 season was also another drought year for California; what rain there was came too little and too late. Visits to JDSF during January and February following the late rains revealed some very late season mushrooms but none of the target species.

The study pattern of large, unflagged plots with random transects did serve to alleviate the problems caused by vandalism in the past. We intend to continue to use this study pattern in the next year and add more large plots at different locations on the Forest, including some in areas picked intensively by commercial and recreational pickers.

Table 3. Summary of data gathered in JDSF during Fall of 1993

Plot and Date		# Target Species	Age of Sporocarp	Species tree/shrub	DBH of Tree, Inches
1A	10/9/93	None	NA	NA	NA
1A	10/16/93	None	NA	NA	NA
1A	10/23/94	None	NA	NA	NA
1A	10/30/93	None	NA	NA	NA
1A	11/6/93	None	NA	NA	NA
1A	11/20/93	None	NA	NA	NA
1A	11/27/93	None	NA	NA	NA
1A	12/4/93	None	NA	NA	NA
1A	12/12/93	None	NA	NA	NA
1A	12/18/93	None	NA	NA	NA
1B	10/9/93	None	NA	NA	NA
1B	10/16/93	None	NA	NA	NA
1B	10/23/94	None	NA	NA	NA
1B	10/30/93	None	NA	NA	NA
1B	11/6/93	None	NA	NA	NA
1B	11/20/93	None	NA	NA	NA
1B	11/27/93	2 C. subalbidus	1 mat 1 overmat	LiDe Tan Oak	8
1B	12/4/93	None	NA	NA	NA
1B	12/12/93	1 C.cibarius	overmat	PsMe Douglas-fir	17
1B	12/18/93	None	NA	NA	NA
1C	10/9/93	None	NA	NA	NA
1C	10/16/93	None	NA	NA	NA
1C	10/23/94	None	NA	NA	NA
1C	10/30/93	None	NA	NA	NA
1C	11/6/93	None	NA	NA	NA
1C	11/20/93	None	NA	NA	NA
1C	11/27/93	None	NA	NA	NA
1C	12/4/93	None	NA	NA	NA
1C	12/12/93	None	NA	NA	NA
1C	12/18/93	None	NA	NA	NA
1D	10/9/93	None	NA	NA	NA
1D	10/16/93	None	NA	NA	NA
1D	10/23/94	None	NA	NA	NA
1D	10/30/93	None	NA	NA	NA
1D	11/6/93	4 C. cibarius	1 mat 3 overmat	LiDe Tan Oak	3
1D	11/20/93	None	NA	NA	NA
1D	11/27/93	11 C. cibarius	7 mat 4 overmat	LiDe Tan Oak	24.7
1D	12/4/93	None	NA	NA	NA
1D	12/12/93	None	NA	NA	NA
1D	12/18/93	None	NA	NA	NA
1E	10/9/93	None	NA	NA	NA
1E	10/16/93	None	NA	NA	NA
1E	10/23/94	None	NA	NA	NA
1E	10/30/93	5 C. subalbidus	5 overmat	LiDe Tan Oak	24
1E	11/6/93	1 C. cibarius	overmat	Vac Huckleberry	< 1
1E	11/20/93	None	NA	NA	NA
1E	11/27/93	None	NA	NA	NA
1E	12/4/93	None	NA	NA	NA
1E	12/12/93	None	NA	NA	NA
1E	12/18/93	None	NA	NA	NA
1F	10/9/93	None	NA	NA	NA
1F	10/16/93	None	NA	NA	NA

Plot and Date		# Target Species	Age of Sporocarp	Species tree/shrub	DBH of Tree, Inches
1F	10/23/94	None	NA	NA	NA
1F	10/30/93	None	NA	NA	NA
1F	11/6/93	5 C. cibarius	5 overmat	LiDe Tan Oak (2)	2, 4
1F	11/20/93	None	NA	NA	NA
1F	11/27/93	None	NA	NA	NA
1F	12/4/93	None	NA	NA	NA
1F	12/12/93	None	NA	NA	NA
1F	12/18/93	None	NA	NA	NA
2A	10/9/93	None	NA	NA	NA
2A	10/16/93	None	NA	NA	NA
2A	10/23/94	None	NA	NA	NA
2A	10/30/93	None	NA	NA	NA
2A	11/6/93	None	NA	NA	NA
2A	11/20/93	None	NA	NA	NA
2A	11/27/93	None	NA	NA	NA
2A	12/4/93	None	NA	NA	NA
2A	12/12/93	None	NA	NA	NA
2A	12/18/93	None	NA	NA	NA
2B	10/9/93	None	NA	NA	NA
2B	10/16/93	None	NA	NA	NA
2B	10/23/94	None	NA	NA	NA
2B	10/30/93	None	NA	NA	NA
2B	11/6/93	1 C. cibarius	overmat	PsMe Douglas-fir	14
2B	11/20/93	None	NA	NA	NA
2B	11/27/93	None	NA	NA	NA
2B	12/4/93	None	NA	NA	NA
2B	12/12/93	None	NA	NA	NA
2B	12/18/93	None	NA	NA	NA
2C	10/9/93	None	NA	NA	NA
2C	10/16/93	None	NA	NA	NA
2C	10/23/94	None	NA	NA	NA
2C	10/30/93	None	NA	NA	NA
2C	11/6/93	None	NA	NA	NA
2C	11/20/93	None	NA	NA	NA
2C	11/27/93	None	NA	NA	NA
2C	12/4/93	None	NA	NA	NA
2C	12/12/93	None	NA	NA	NA
2C	12/18/93	None	NA	NA	NA
2D	10/9/93	None	NA	NA	NA
2D	10/16/93	None	NA	NA	NA
2D	10/23/94	None	NA	NA	NA
2D	10/30/93	None	NA	NA	NA
2D	11/6/93	None	NA	NA	NA
2D	11/20/93	None	NA	NA	NA
2D	11/27/93	None	NA	NA	NA
2D	12/4/93	None	NA	NA	NA
2D	12/12/93	None	NA	NA	NA
2D	12/18/93	None	NA	NA	NA
2E	10/9/93	None	NA	NA	NA
2E	10/16/93	None	NA	NA	NA
2E	10/23/94	None	NA	NA	NA
2E	10/30/93	None	NA	NA	NA

Plot and Date		# Target Species	Age of Sporocarp	Species tree/shrub	DBH of Tree, Inches
2E	11/6/93	None	NA	NA	NA
2E	11/20/93	None	NA	NA	NA
2E	11/27/93	None	NA	NA	NA
2E	12/4/93	None	NA	NA	NA
2E	12/12/93	None	NA	NA	NA
2E	12/18/93	None	NA	NA	NA
2F	10/9/93	None	NA	NA	NA
2F	10/16/93	None	NA	NA	NA
2F	10/23/94	None	NA	NA	NA
2F	10/30/93	None	NA	NA	NA
2F	11/6/93	None	NA	NA	NA
2F	11/20/93	None	NA	NA	NA
2F	11/27/93	None	NA	NA	NA
2F	12/4/93	None	NA	NA	NA
2F	12/12/93	None	NA	NA	NA
2F	12/18/93	None	NA	NA	NA

Location: Lanphere Dunes, located 5 miles west of Humboldt State University, Arcata, California.

BACKGROUND

The Lanphere-Christensen Dunes Preserve is a fenced and protected preserve located on the Pacific coast near the northern reaches of Humboldt Bay. Because of location, Lanphere receives moisture from rain and heavy coastal fog and has moderate temperatures: maximum temperatures average 13 degrees with occasional rises to 20 degrees in the Fall months; relative humidity averages 70%, does not fall below 60%, and has periods of several days above 80% (from data collected during 1991 season). Soil temperatures remain above freezing year round; air temperatures may fall below freezing during winter months, particularly during late December and early January (from data collected during 1990 and 1991 seasons). Coastal Lodgepole pines (*Pinus contorta* var. *contorta*) predominate at this site.

Because the Preserve is a protected area that has been set aside for preservation of several endangered plant species, any research has to exist within certain restrictions: setting up and surveying of plots must use existing trails, the visual impact of plots to other visitors to the Preserve must be minimized, and no trampling of existing vegetation is permitted. Since the Preserve is located close to the HSU campus, frequent monitoring visits to the site are possible making this a valuable location for biological studies of the target species.

Investigation of the Lanphere-Christensen Dunes mycoflora essentially began in 1979 and 1980 with research conducted by Sue Van Hook for her Master's degree. Van Hook used scattered circular plots of two meter diameter located at trail edge throughout the Preserve. She focused on the concept of indicator species and tried to determine if any particular species reliably heralded or accompanied fruiting of any other species.

Current research at the Lanphere-Christensen Dunes Preserve emphasizes an understanding of the reproductive biology of four local, edible mushrooms indicated in the introduction. In 1990, this project, using plot protocols developed by van Hook, set up fifty semi-permanent plots and four weather stations in the Preserve. Each weather station has four rain cans and a maximum-minimum thermometer; two stations are under forest canopy and two are in the open. These stations are visited every time sampling occurs or when rainfall accumulates. Relative humidity is measured with a portable hygrometer; soil temperature with a standard soil thermometer placed at a depth of 7-9 cm. Plots are marked with a wooden stake at the center and are circular with a diameter of two meters. Each plot is numbered and a map of the preserve with plot locations indicated has been generated. Additional plots have been added in each project year.

In order to accurately evaluate the life strategies of these fungi, the following studies have been accomplished: recording the individual life span of each mushroom, the duration and pattern of spore release, the period of time during the season that each type of mushroom fruits, the pertinent environmental data throughout the season, and the identification of other macromycete species that indicate the onset of fruiting of the edible mushrooms.

The concept of indicator species was considered by Sue van Hook in 1980 and in 1992-1993 attempts were made to continue to establish which mushrooms, if any, fruited approximately two weeks prior to the study fungi. A catalog of mushroom species and their respective times of fruiting was kept. Information of this sort is particularly valuable to the forest land managers, as indicator mushrooms will enable them to patrol more efficiently.

A more exact method of locating sporocarps within a plot was developed in 1992 and was continued in 1993. The process is a simple one: with a meter stick or a tape originating at the plot center, orient it toward the mushroom and measure the distance to the center of the mushroom. With a compass attached to the stick and oriented in the same direction, take the compass reading. In this fashion the field worker generates a numeric name for each mushroom. The orientation is listed first, followed by the distance in centimeters. An example name might be 145-51.

Sporulation studies are done by placing microscope slides in metal holders (spore traps) below the fruiting bodies. These slides are collected and replaced with fresh slides every 24 hours. Soil temperature and relative humidity are recorded for each plot during a sampling visit.

STUDY PERIOD: SEASON OF 1992

Thirty-two monitoring visits were made to 74 2-meter diameter plots between August 29 and January 4 Twelve visits consisted of obtaining data on rainfall from the four weather stations. Twenty monitoring sessions consisted of life-span data observations on three of the four target fungi: *Armillaria ponderosa*, *Leccinum manzanitae*, and *Boletus edulis*. Locations of target fungi within plot, relative humidity, pH, soil temperature and moisture were recorded for these life-span studies.

Among the four target species studied there was a distinct pattern of fruiting only among two of the target fungi. *Boletus edulis* and *Leccinum manzanitae* retained similar fructification patterns as in previous years, while the patterns for *Armillaria ponderosa* and *Cantharellus cibarius* were quite different from previous years. (See Fig. 1 and discussion below.)

SPOROCARP STUDIES: LIFE SPAN AND FRUITING SEASON

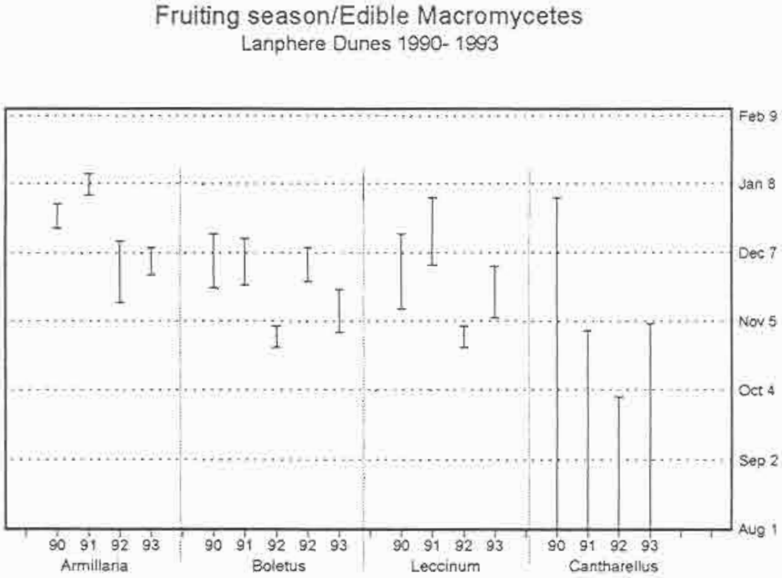


Figure 1

Table 1

year	began	end	season	avg. season
		Armillaria ponderosa		
1990	dec 17	dec 28	11	4
1991	jan 1	jan 11	10	5
1992	nov 12	dec 11	29	14
1993	nov 25	dec 8	13	?
		Boletus edulis		
1990	nov 19	dec 12	15	8
1991	nov 20	dec 14	22	17
1992	oct 22	nov 1	10	5
1992	nov 22	dec 8	26	12.3
1993	oct 29	nov 18	20	
		Leccinum manzanita		
1990	nov 9	dec 14	35	22
1991	nov 30	dec 31	31	15
1992	oct 22	nov 1	10	5
1993	nov 5	nov 29	24	13.8
		Cantharellus cibarius		
1990	?	dec 31	154	
1991	?	oct 30	92	
1992	?	sep 29	61	
1993	?	nov 2	63	

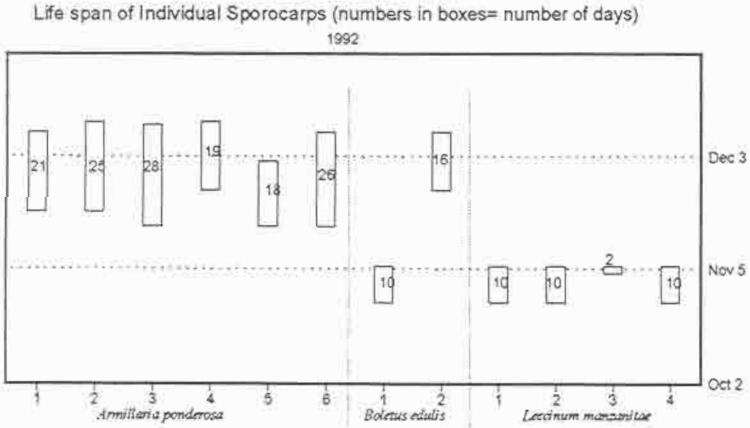


Figure 2

Cantharellus cibarius:

As of 6 June 1992, several sporocarps were detected in plots; however, all were too old for life span or sporulation data. A similar phenomenon was noted on 14 August and 21 September as the few sporocarps encountered had no estimable initiation date as they were too old and dry. From the 21 September until early January, the rest of sampling season, no other sporocarp of was sighted in the study area; thus the fruiting season for this fungus ended nearly 30 days earlier than in 1991 and over 3 months earlier than in 1990 (see Fig. 1 and Table 1). This kind of phenological behavior seems to correlate well with the data from Oregon obtained by Norvell (1992).

Armillaria ponderosa:

In 1992, the fruiting season for *Armillaria ponderosa* was nearly 4 weeks earlier than in 1990 and five weeks earlier than in 1991 (see Fig. 1). A review of the rainfall data indicates that at least 8 cm of rain is required for initiation of fruiting in this species (see Fig. 3). In 1992, the fruiting season lasted 29 days, much longer than either in 1990 and 1991, and terminated, as in the previous years, with the onset of freezing temperatures (Table 1).

Complete life span data was obtained for 6 sporocarps of *Armillaria ponderosa,* with the shortest being 18 days and the longest being 28 days (see Fig. 2). All sporocarps were frozen solid in mid-December and thus these life span periods are not as long as is typical for the species.

Boletus edulis:

Sporocarps of *Boletus edulis* were first observed in mid-October of the 1992 season whereas in 1990 and in 1991 sporocarp initiation was observed in late November (see Fig. 1). The accumulated rainfall in mid-October 1992 was about 5 cm that corresponds nicely with the data obtained in 1991 but is about 1.5 cm more than was observed in 1990. Sporocarp initiation in this species is dictated by a minimum amount of moisture, about 3.5-4.3 cm when the average maximum temperature is below 18 degrees and the average minimum temperature is just above freezing (see Fig. 5). However, with warmer temperatures, more moisture is required for sporocarps to begin to form. An interesting anomaly, previously not observed, occurred this season in that this species had two fruiting periods, one in mid-October and a second in mid-November; the latter period corresponds exactly with onset of fruiting in 1990 and 1991.

Complete life span data was obtained for only two sporocarps of *Boletus edulis*. (See Fig. 2).

Leccinum manzanitae:

In 1992, initiation of fruiting in mid-October by *Leccinum manzanitae* occurred about 1 month earlier than in 1990 and nearly a month and half earlier than in 1991 (see Fig. 1). In each of these seasons, sporocarp initiation began when cumulative rainfall was over 5 cm and just before a very heavy rainfall; thus temperature did not seem to have an effect on sporocarp initiation in this species.

Complete life span data was obtained for 3 sporocarps. The life span varied between 10 and 16 days that corresponds well with data obtained in 1990 and 1991 (see Fig. 2).

INDICATOR SPECIES

The use of *Chroogomphus vinicolor* as the indicator for *Boletus* and *Leccinum* as suggested following the 1990 and 1991 seasons will have to be re-evaluated as this species did not fruit this season until several weeks after the boletes started to fruit; however, *C. vinicolor* was the indicator species for the second flush of *Boletus edulis* sporocarps. Another candidate for an indicator species is *Hygrophoropsis aurantiacus* which fruited about one week prior to sporocarp production by the boletes.

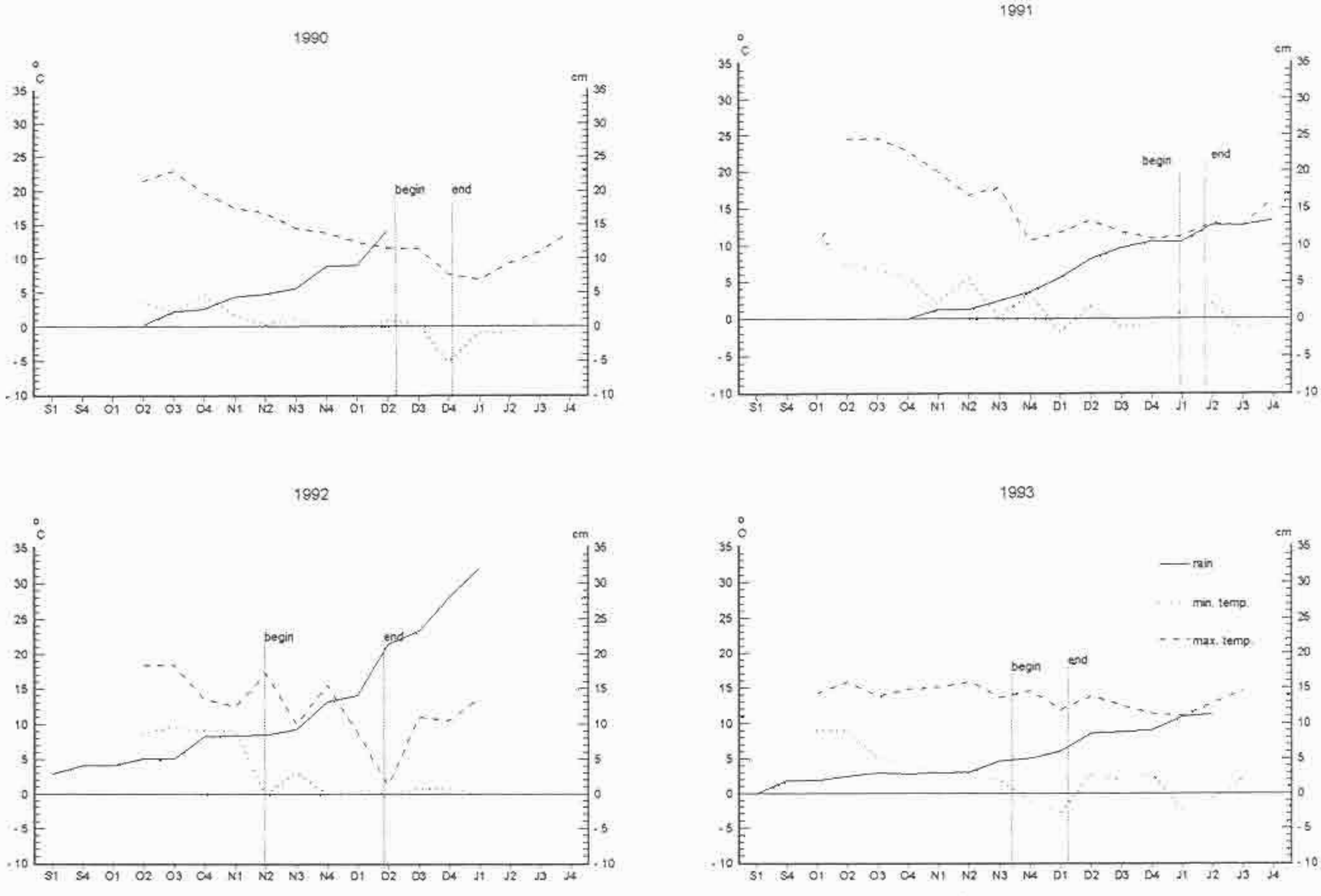
SOIL MOISTURE, pH, SOIL TEMPERATURE AND RELATIVE HUMIDITY STUDIES

Soil moisture, pH, soil temperature and relative humidity were recorded for each plot that had sporocarps of the target species. No trend could be determined for the sporulation studies. However sporocarp formation in *Boletus* and *Leccinum* favored areas with a pH of between 6.3 and 6.6 as well as a soil moisture level of between 20% and 25%. In *Armillaria ponderosa*, sporocarps favored sites with a pH near or more typically above 6.6 and with soil moisture content that begins at 28% and quickly drops to between 10 and 20%.

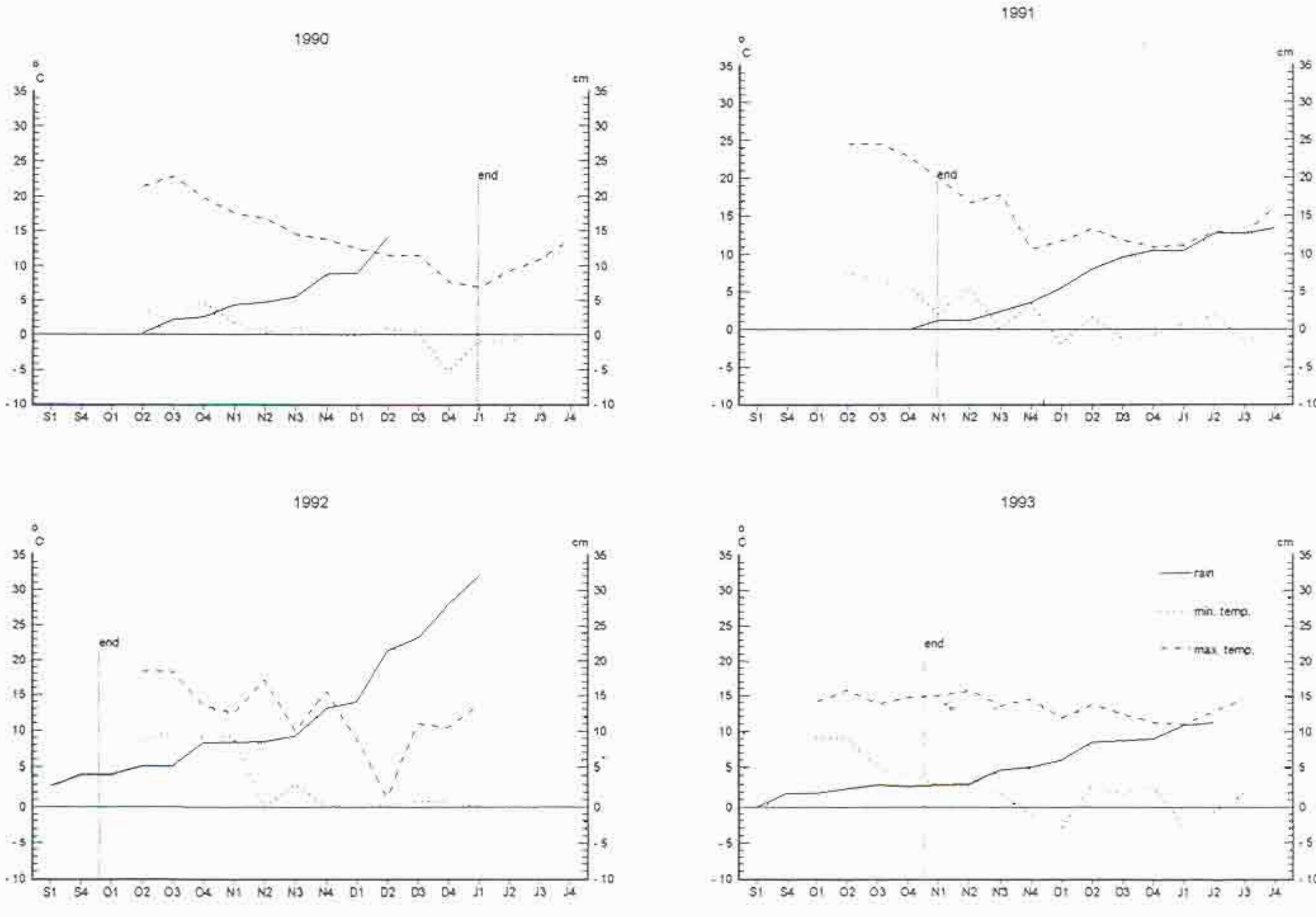
SPOROCARP NUMBERS

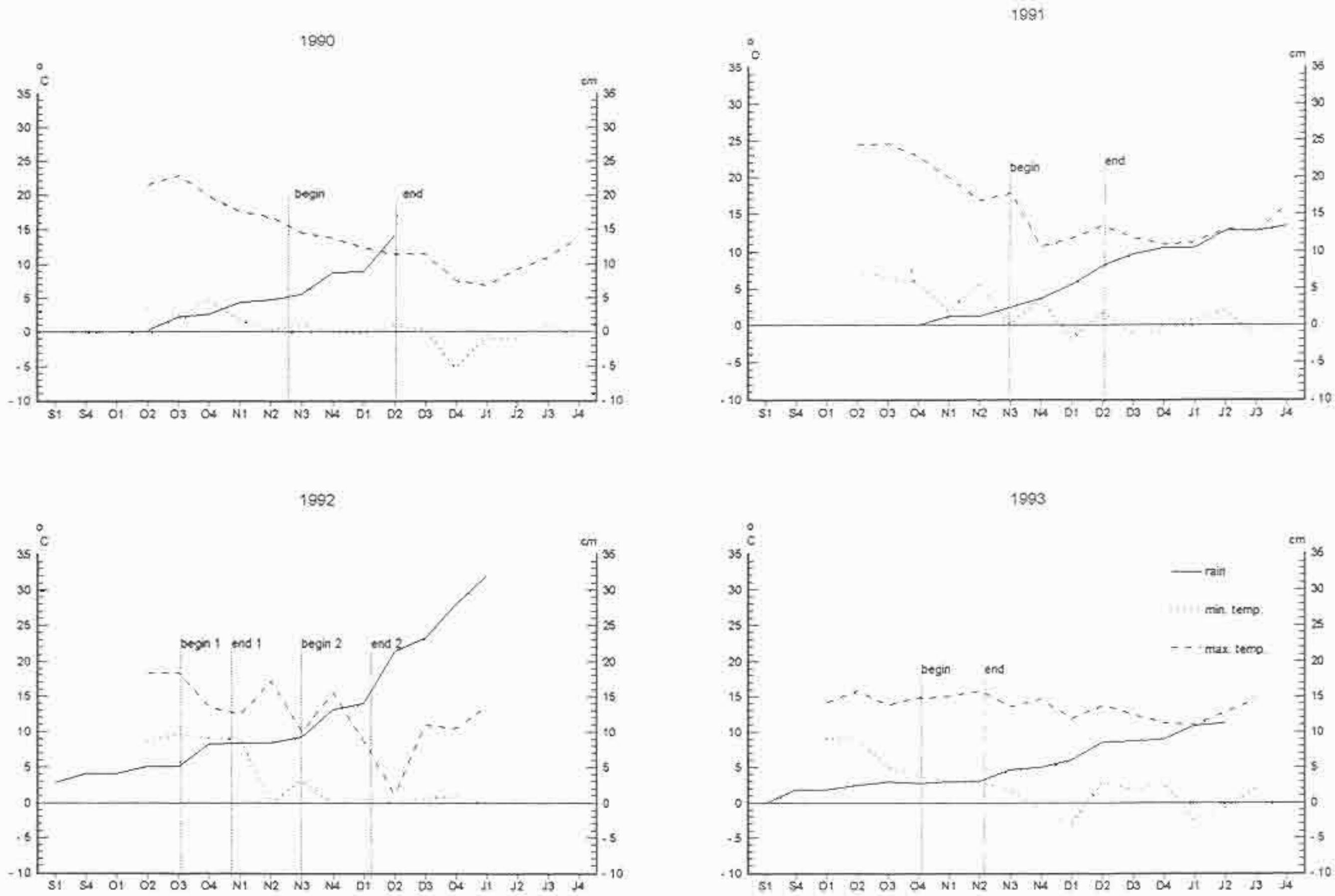
Because of poor data collection, valid sporocarp numbers for Lanphere Dunes were not obtained for the 1992 mushroom season.

Armillaria ponderosa ↓ (Figure 3)

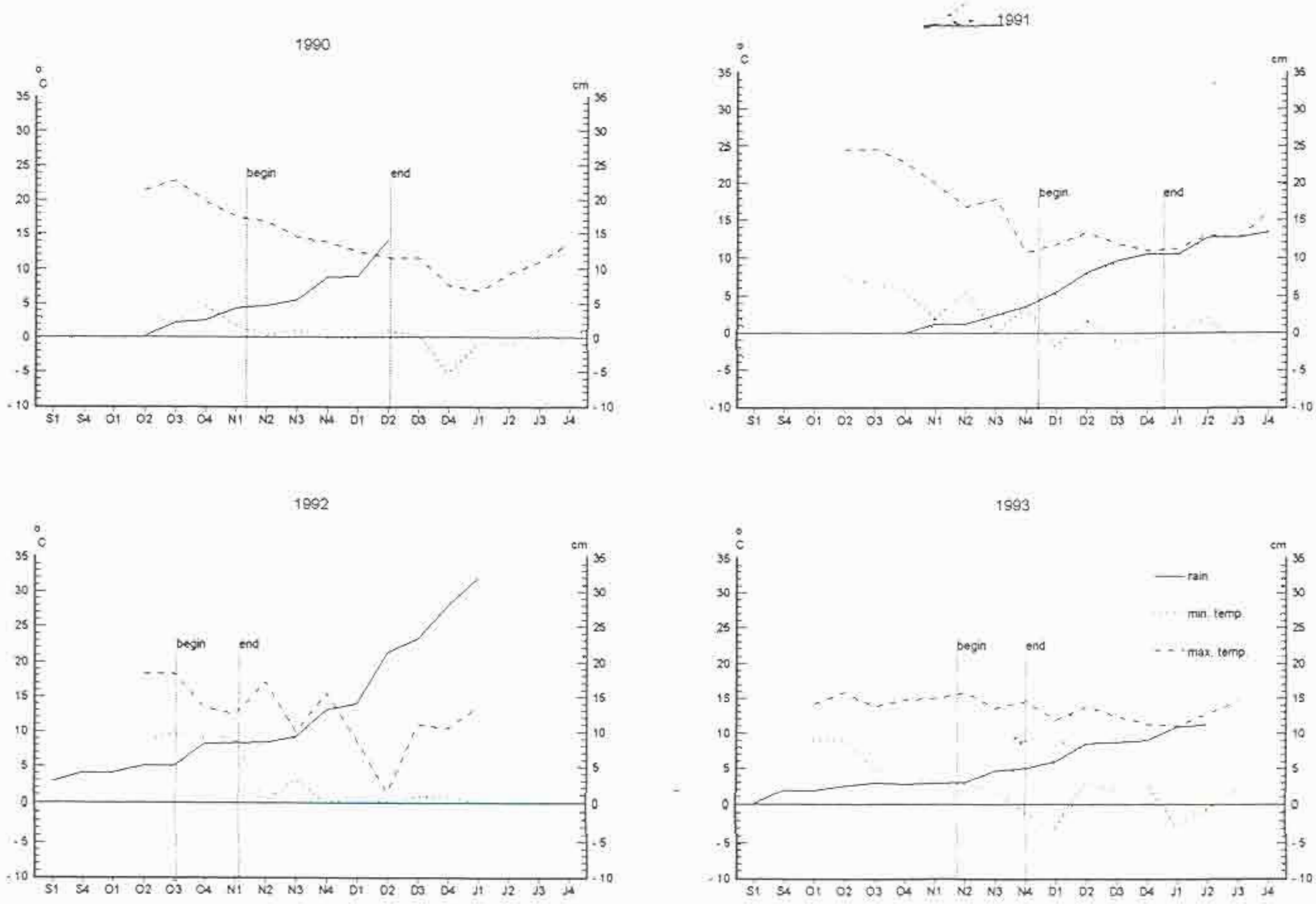


Cantharellus cibarius ↓ (Figure 4)





Leccinum manzanitae ⬇ (Figure 6)



SPORULATION STUDIES

Complete sporulation data for the entire life span was obtained for six *Armillaria ponderosa* sporocarps and one *Boletus edulis* sporocarp. No studies were conducted on *Cantharellus cibarius* nor was complete life span sporulation data obtained for *Leccinum manzanitae*.

Spores were gathered by placing a spore trap under the hymenium of a viable sporocarp, and leaving it in place for a 24 hour period. Once a sporocarp collapsed it was considered dead and spore collection ceased. The sporulation pattern (Figs. 7,8) for *Armillaria* was different when compared to past studies. Four of six sporocarps studied produced most of their spores during a single period during their life span; 1 (B) of these produced spores at the beginning of the life span, as was previous observed in 1990 and 1991, and the remaining 3 (A, D, E) produced spores near the end. Each of the remaining sporocarps produced spores during two periods during their life span, C at the beginning as well as the end and F at the beginning and the middle. No correlation with any environmental factor could be determined.

In every instance observed during this season as well as in the last two seasons, sporocarps of *Armillaria ponderosa* did not produce spores over their entire life span. Moreover, a majority of the sporocarps produces an abundance of their spores immediately after expanding from a button. Thus the spore load of this species could be dramatically affected by harvesting sporocarps in the button stage.

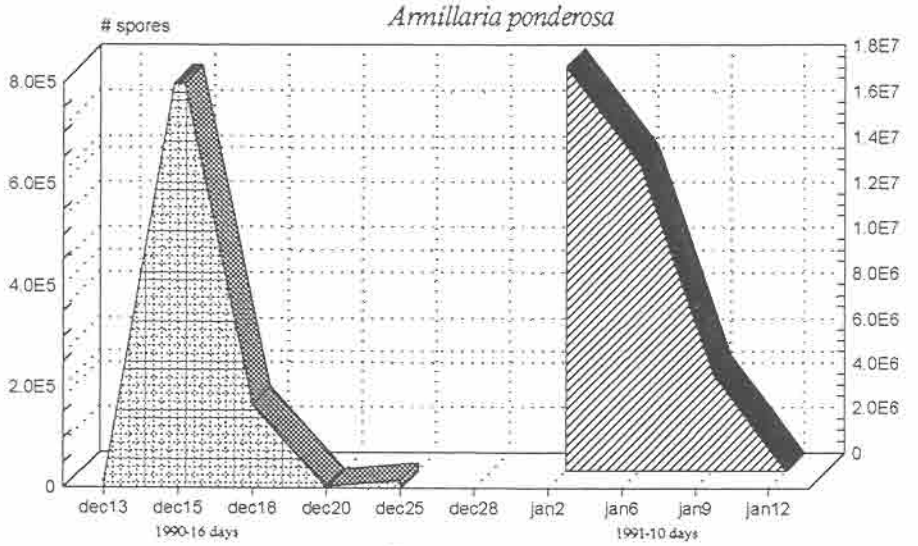


Figure 7

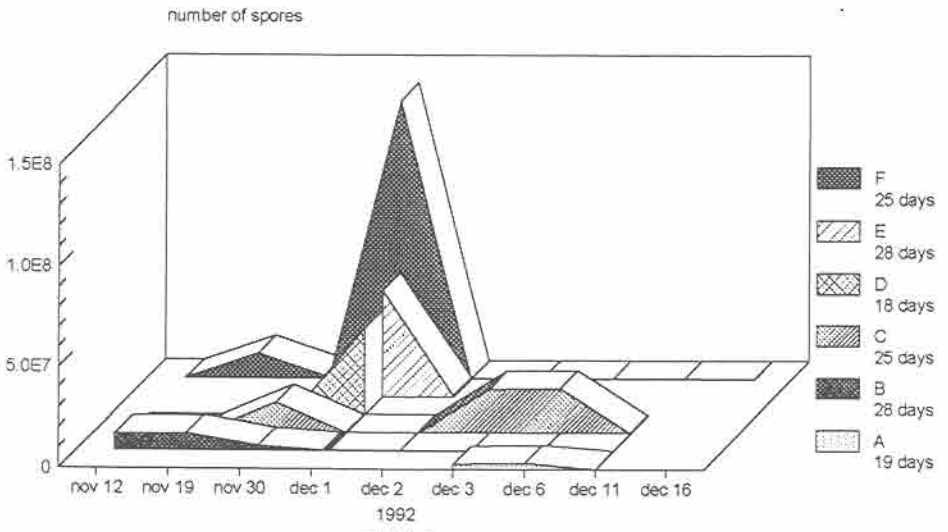


Figure 8

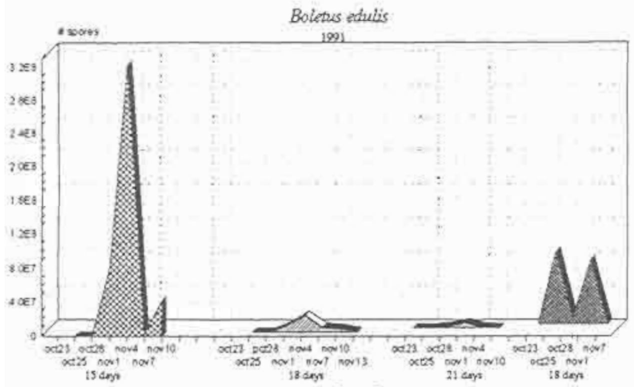


Figure 9

In *Boletus edulis* sporulation occurred steadily as the fungus developed (see Figs. 9, 10). Eventually sporulation decreased and even ceased as the sporocarp aged. As in previous seasons, sporocarps of this species produced large numbers of spores over their entire life span with the majority of spore being produced in the middle of the life span. Although, no sporulation studies were completed for *Leccinum manzanitae*, previous studies indicate the pattern is similar to that of *Boletus edulis* (see Fig. 11).

Boletus edulis

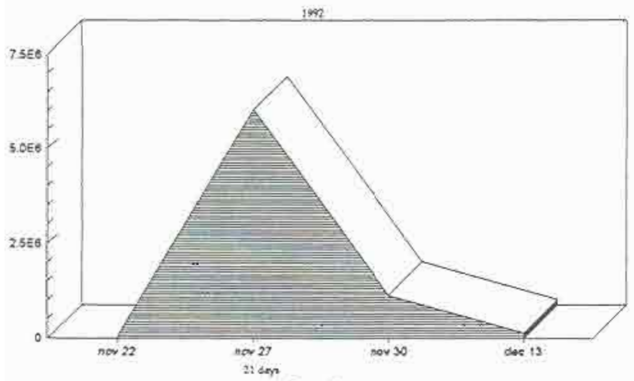


Figure 10

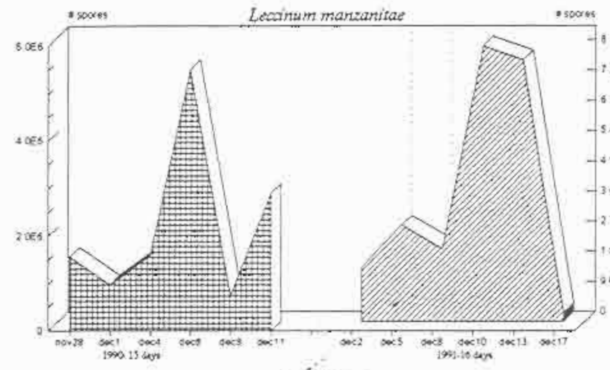


Figure 11

STUDY PERIOD: SEASON OF 1993

The mushroom research at Lanphere Dunes Preserve was performed on a semiweekly basis from September 10, 1993 to January 9, 1994. Seventy-nine 2-meter diameter plots were monitored on Tuesday and Friday of each week for appearance of any of the four target species: *Leccinum manzanitae, Cantharellus cibarius, Armillaria ponderosa (Tricholoma magnivelare), and Boletus edulis.* When a sporocarp was detected in a plot, it was monitored twice weekly throughout its entire lifespan.

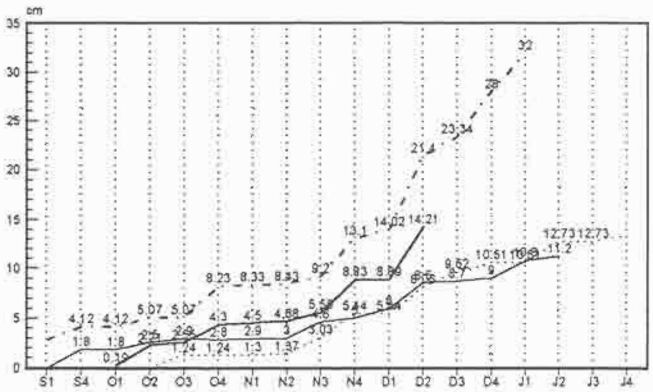
Monitoring consisted of measuring and recording: soil pH and moisture content using a Kelway soil tester, soil temperature at a depth of 7 to 9 cm using an Ertco soil thermometer, and relative humidity and air temperature using a VWR digital humidity and temperature meter. Each semiweekly visit included monitoring four weather stations in different locations in the Preserve. Each station was equipped with a rain gauge and a Taylor maximum/minimum thermometer.

WEATHER (see Figures 12-17)

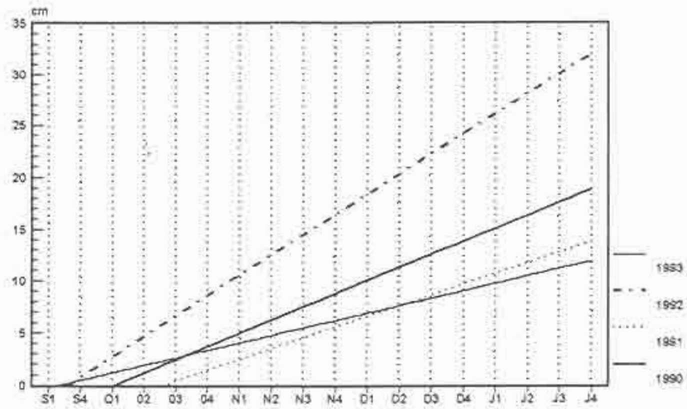
In 1993, rainfall during the monitoring period totaled 12.73 cm which makes it the second driest season since this study began in 1990. The 1993 season was dry and warm with the total accumulated rainfall pattern and the maximum temperature pattern being similar to those of the 1991 season. The average minimum temperature pattern, on the other hand, was unique.

The 1990 season was cold and wet, the 1992 season was wet and warm, and the 1991 and 1993 seasons were dry and warm.

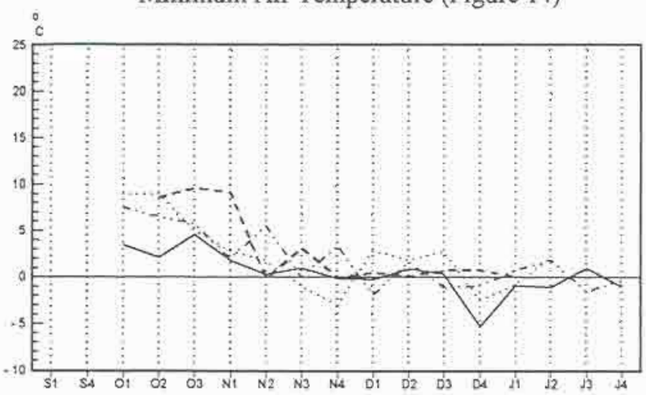
Cumulative Rainfall (Figure 12)



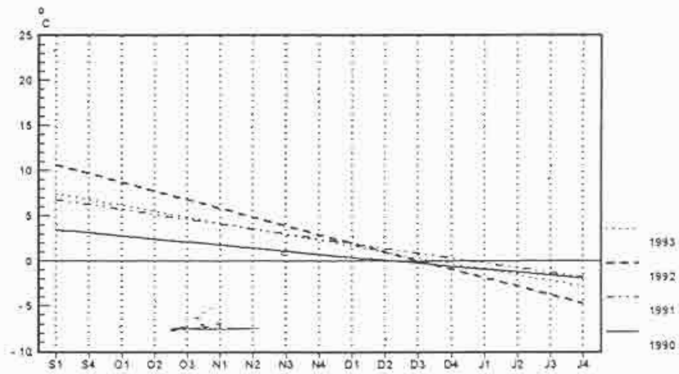
⇦ Trend (Figure 13)



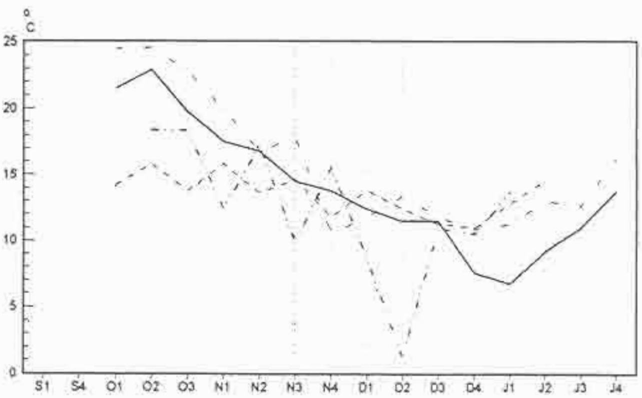
Minimum Air Temperature (Figure 14)



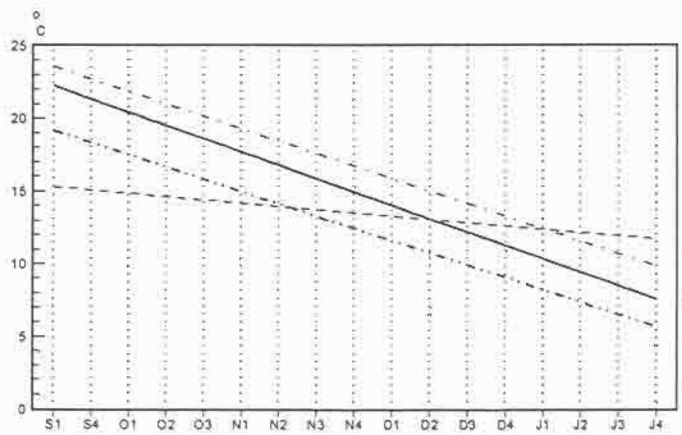
⇦ Trend (Figure 15)



Maximum Air Temperature (Figure 16)



⇦ Trend (Figure 17)



LIFE SPAN AND FRUITING SEASON.

Among the four target species studied, there was a distinct pattern of fruiting among all four of the target species.

Cantharellus cibarius (Figures 1, 4; Table 1)

Cantharellus cibarius began fruiting before our study started and continued fruiting until day 63 of the study. Fifteen sporocarps from seven different plots were recorded. The average lifespan for a *Cantharellus cibarius* fruiting body was 14.25 days.

The fruiting season of sporocarps was 63 days, the longest of all the target species, and began during the summer when the rainfall was below a centimeter, similar to the season found in Patrick's Point State Park. The season ended when rainfall began to increase, a pattern similar to that in Patrick's Point State Park. The 1993 season was similar in length and in pattern to that of 1991

The four environmental factors recorded at initial sporocarp observation averaged as follows:

Average soil temperature ....14.9°C
Average soil pH 6.98
Average soil moisture 9.46%
Average relative humidity 72.8%

At *Cantharellus cibarius* fruiting body death, the averages of the environmental factors recorded were:

Average soil temperature ....12.4 °C
Average soil pH 6.97
Average soil moisture 5.1%
Average relative humidity 67.2%

Armillaria ponderosa. (Figures 1, 3; Table 1).

Armillaria ponderosa (= Tricholoma magnivelare) was observed in two plots with a total of two sporocarps recorded. Fruiting season for this species was the shortest of those studied, beginning on November 25th and ending on December 8th.

The life span was 13 days and, as in previous years, the fruiting season was abruptly terminated by freezing temperatures. Fruiting was initiated when the average maximum temperature dropped below 15 °C and the average minimum temperature was near freezing. A distinct correlation exists between the beginning of the fruiting season and the difference between average maximum temperature and average minimum temperature; fruiting seems to begin when the temperature difference is at least 15 °C, a pattern which appears each season over the last 4 years.

At the beginning of button stage for this species the environmental factors averaged:

Average soil temperature ....9.4 °C
Average soil pH 6.15
Average soil moisture 10%
Average relative humidity 81.45%

At fruiting body death, the observed averages for environmental factors were:

Average soil temperature ....10.8 °C
Average soil pH 6.1
Average soil moisture 42.5%
Average relative humidity 89.55%

Boletus edulis (Figures 1, 5; Table 1)

Boletus edulis was not observed in any of the designated plots but was found at different locations in the Preserve. Sporocarp-related data was not recorded for *Boletus edulis* since it did not appear in marked plots; however, beginning and end of fruiting season was noted. The fruiting season for this species went from October 29 to November 18.

Sporocarps of *Boletus edulis* had a fruiting season of 20 days, similar to in length to that found during the 1991 and 1992 seasons and similar in length to that of *Leccinum manzanitae*.

A pattern has developed over the past 4 years with the fruiting season beginning when the rainfall reaches at least 2.75 cm, in dry years, 1991 and 1993, and when the rainfall reaches 5 cm in wet years, 1990 and 1992.

Fruiting ended when rainfall abruptly increased and the average minimum temperature dropped. This pattern was similar to that found in previous years and suggests that the combination of increased soil moisture and soil temperature cause the termination of fruiting and the minimum temperature dropped near or below freezing.

Leccinum manzanitae (Figures 1, 6; Table 1)

Leccinum manzanitae was observed in four plots and seven sporocarps were recorded. Fruiting season began on November 5th and continued until November 29th. The average lifespan of a *Leccinum* sporocarp was 13.8 days.

The fruiting season lasted 24 days, similar to that of *Boletus edulis*.

Fruiting is initiated in dry years when the rainfall nears 3-5 cm and in wet years when the rainfall nears 5 cm. As in *Boletus edulis*, fruiting is terminated when the rainfall increases and the average minimum temperature drops to near 0 °C.

The average environmental factors calculated for when fruiting began for *Leccinum manzanitae* were:

Average soil temperature ....6.4 °C
Average soil pH 6.43
Average soil moisture 15%
Average relative humidity 82.5%

When *Leccinum manzanitae* fruiting body death occurred, the observed averages were:

Average soil temperature ....9.0 °C
Average soil pH 6.46
Average soil moisture 25.2%
Average relative humidity 76.1%

Location: Patrick's Point State Park, near Trinidad, California

BACKGROUND

Patrick's Point State Park is located about 20 miles north of Humboldt State University on the Pacific coast near Trinidad, California. The study area is dominated by Pacific Hemlock (*Tsuga heteropylla*) and Sitka Spruce (*Picea sitchensis*). This site was added to the project in the 1992 season through the cooperation of the North Coast Redwoods District of the California Parks and Recreation Department. This is a popular and easily accessible park and a favorite site for mushroom pickers. Picking mushrooms is prohibited in the park but proximity to good roads and uncontrolled accesses through unfenced boundaries make it easy for pickers to get in and out quickly.

STUDY PERIOD: SEASON OF 1992

During the summer of 1992, a permanent plot of 1024 square meters was established in Patrick's Point State Park. This plot was divided into 256 subplots of four square meters each. The location of all trees and vegetation within each subplot was surveyed and noted accurately on individual maps. (See Figure 7 for a sketch map of the entire plot.) Monitoring of the subplots began on August 24, 1992; however, sporocarps of *Cantharellus cibarius* were observed in mid-June before the permanent plot was established. Each monitoring visit involved the following: once it was established a target species was fruiting in a subplot, the sporocarp was assigned an identification number, the date and developmental stage were noted (i.e., button or mature), and the subplot number recorded. In addition, relative humidity, soil temperature, soil pH, and soil moisture content were recorded for each subplot in which sporocarps were observed. Furthermore, sporocarps of other epigeous fungi were noted which will provide information on indicator species.

Sampling occurred from late August 1992 through March 1993. Ten individuals from the Humboldt Bay Mycological Society (HBMS) volunteered their time for the entire sampling period with their supervision conducted by David Sime from the Humboldt State University mycology laboratory. Two individuals were used during each of the twice weekly sampling periods that lasted from 4-6 hours; therefore this project involved approximately 450 volunteer hours of assistance.

In addition, life span and sporulation data were obtained twice weekly for *Cantharellus cibarius* by placing microscope slides under the hymenium of the sporocarps in the morning and leaving in place for 24 hours. Volunteers were not used for this aspect of the study.

Sampling methods for *Boletus edulis* were different from methods for *Cantharellus cibarius*. Thirty 2x2 meter plots were established in Abalone campground during nine sampling dates during November and December. Each plot was located around a group of sporocarps deemed fruiting from the same mycelium. Relative humidity, soil temperature, soil pH, and soil moisture content were recorded for each of the plots. Life span and sporulation data were also obtained. Volunteers were not used for the studies on *Boletus edulis*.

Vandalism by recreational and commercial mushroom pickers was reduced in the permanent plot by posting easily visible, iridescent signs and painting the sporocarps to indicate their potential uselessness for harvesting purposes. However, all of the sporocarps located outside the permanent plot were either harvested by recreational or commercial mushroom pickers or were eaten by various mammals.

Overall observations for 364 sporocarps of *Cantharellus cibarius* were recorded with a majority of the sporocarps located in the southeastern quarter of the permanent plot (see Fig. 18). Because of mammal predation and commercial or recreational mushroom harvesting, 232 sporocarps were lost; thus complete life span and environmental data were obtained for 132 sporocarps. Furthermore, 163 microscope slides for spore collections were placed and collected from 12 different sporocarps of *Cantharellus cibarius* over their complete life span.

Observations on 30 different *Boletus edulis* sporocarps yielded only two complete life cycles; however all *Boletus edulis* sporocarps were lost from intense commercial or recreational mushroom harvesting.

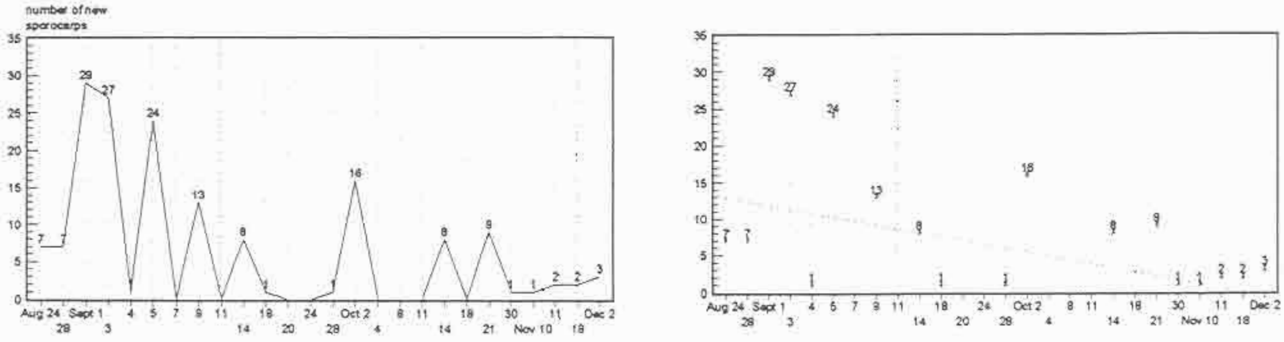
Weather data from May until the project's inception on 24 August was provided by Virginia Waters (HBMS); after August 24, weather data was recorded in the permanent plot on a continuing basis.

SPOROCARP STUDIES: LIFE SPANS, SEASON AND SPOROCARP LONGEVITY

Cantharellus cibarius:

As early as June 7, a few scattered sporocarps were observed in Patrick's Point State Park; however, all of these were outside the permanent plot. Initiation of a large number of new sporocarps began in the plot on August 24; most probably the result of accumulation of moisture from fog drip that was retained in the woody debris and correlated with gentle drop in the air temperature. From the August 24 until October 21, new sporocarps were produced in a series of flushes, a phenomenon similar to that found in the Oregon studies. (Norvell, 1992) The stimulus for each flush seems to be a rise in both the average maximum and average minimum air temperatures. The largest numbers of new sporocarps were produced during the month of September when only 0.25 cm of rain occurred and the average maximum temperature was above 15 degrees and the average minimum temperature did not drop below 10 degrees (Fig. 19, 21). As the minimum temperature dropped below 15 degrees there was an abrupt reduction of sporocarp initiation, particularly in the months of November and December (Fig. 20, 21).

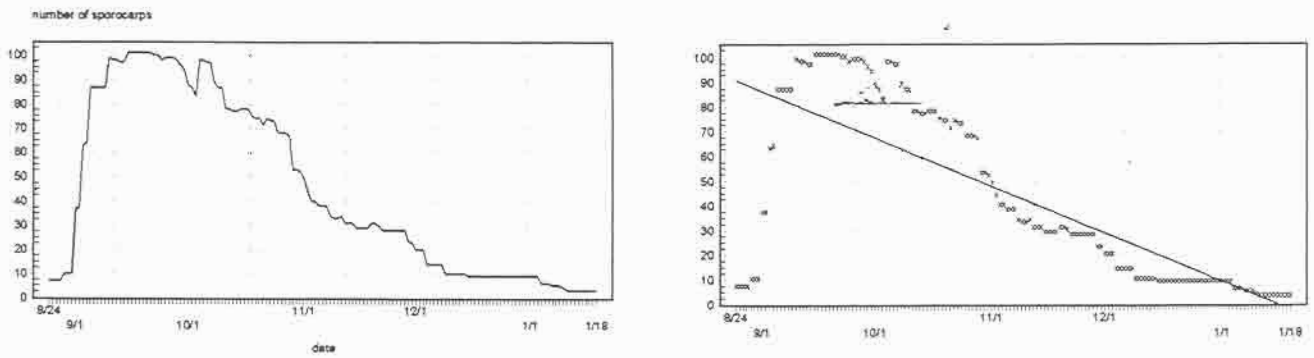
As a general trend, the number of new sporocarps produced as well as the total number of sporocarps decreased steadily as the accumulated rainfall rose and both the maximum and minimum temperatures dropped (see Fig. 19, 20, 21).



Number of New Sporocarps

Trend

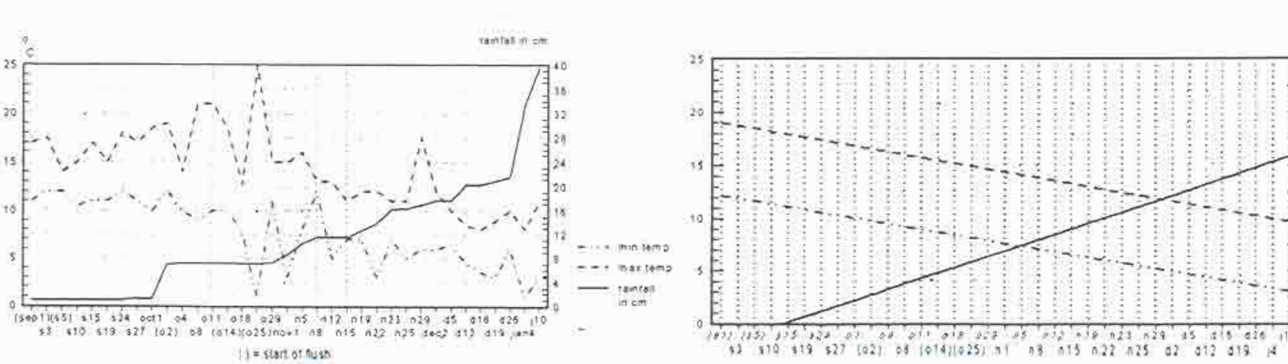
Figure 19 (*Cantharellus cibarius*)



Total Number of New Sporocarps

Trend

Figure 20 (*Cantharellus cibarius*)



Rainfall, Maximum. and Minimum Temperatures

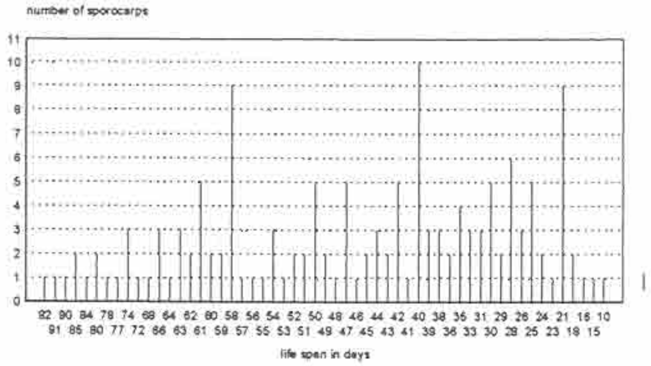
Trend

Figure 21 (*Cantharellus cibarius*)

The mid-point for the fruiting season was around October 1 with the maximum number of sporocarps being found from the first week of September through the second week of October (see Fig. 20). The total number of sporocarps reached zero in January when minimum temperatures dropped below 3.3 degrees. Thus the fruiting season for *Cantharellus* dominated stands in Patrick's Point State Park lasted 152 days within the permanent plot (see Fig. 24) and approximately 227 days within the entire park. When rainfall reached nearly 20 cm in December, new sporocarp production ceased (Fig. 19, 21).

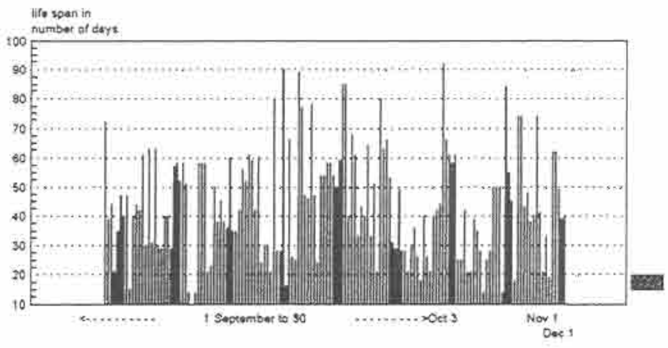
Complete life span data was obtained for 132 sporocarps of *Cantharellus cibarius* with the shortest being 10 days, the longest 92 days; the average life span was 44 days. The largest number of sporocarps had a life span of 58 or 40 or 21 days (see Fig. 22).

On the average, sporocarp longevity per number of sporocarps produced for *Cantharellus cibarius* increased each month beginning in September and ending in December (Fig. 23). However, September had the longest lived sporocarps, with seven sporocarps living up to or past 80 days. Analysis of the data on rainfall and air temperature did not readily provide an explanation and thus this characteristic could possibly be genetically controlled or related to host intervention.



Number of Sporocarps and their life span

Figure 22



Life Span of Individual Sporocarps related to the beginning of furiting

Figure 23

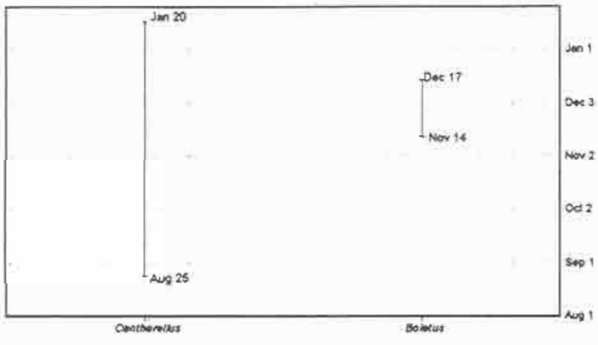
PH, SOIL MOISTURE, SOIL TEMPERATURE, RELATIVE HUMIDITY

Cantharellus cibarius:

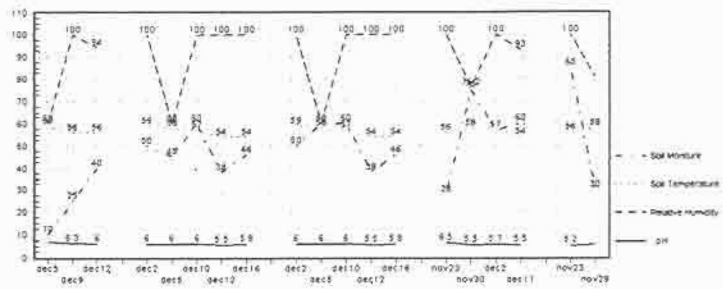
In *Cantharellus cibarius*, sporocarp initiation within most of the subplots is related to a decided rise in soil moisture after a period of relative dryness and in most instances with an accompanying rise in soil temperature; in almost all instances the relative humidity is less than 100%. The death of the sporocarp seems to be correlated with a distinct drop in soil moisture after a prolonged period of rather wet soil. The pH of the soil seems to have no bearing on sporocarp initiation or cessation. Generally sporocarps of *Cantharellus* seem to be found in econiches that have pH above 6.5

Boletus edulis:

Initiation of *Boletus edulis* sporocarps began the third week in November and lasted about three weeks (Fig. 24). Apparently an accumulation of at least 10 cm of rain was necessary for sporocarps to begin to form. Sporocarps of *Boletus* also seem to prefer sites with a pH of between 6.0 and 6.5 (Fig. 25).



Fruiting Season 1992
Figure 24

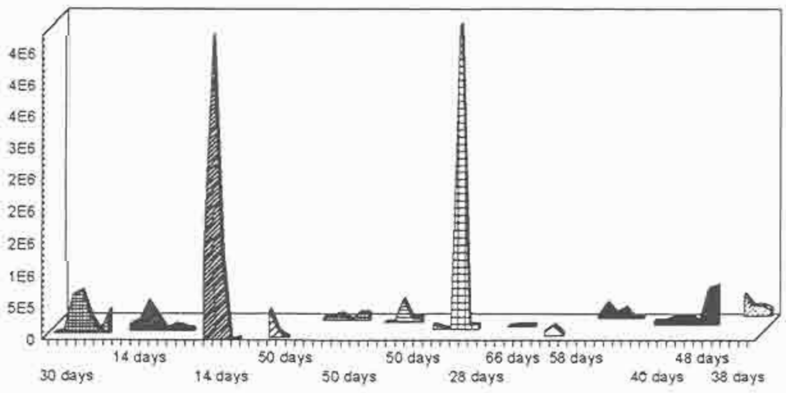


pH, Relative Humbidity, Soil Temperature, Soil Moisture
4 plots, partical life span for *Boletus edulis*
Figure 25

SPORULATION STUDIES

During the four months when sporocarps were observed, data was gathered on the duration and time of sporulation for each of the two target species. Spores were obtained by placing microscope slides in metal holders (spore traps) under the hymenium of a viable fruiting body. Once Deuteromycetes overtook the sporocarp or the hymenophore collapsed, the fruiting body was considered dead. Spore traps were left out for a period of 24 hours and were collected twice a week. Spores were counted on thirty 1 micron grids for 163 micro slides for a total of 4,890 spore measurements.

Micro slides were collected, twice weekly, over the entire life span of 12 different sporocarps of *Cantharellus cibarius*. Distinctly different patterns of sporulation were observed (see Fig. 26). In general, sporocarps of *Cantharellus cibarius* produce far less spores per day than any other of the edible mushrooms studied with 10 of 12 sporocarps having less than 1,000,000 spores per square centimeter of hymenophore produced per 24-hour period. Maximum spore production during the life span of a sporocarp of *Cantharellus* is dependent on a rise in soil moisture accompanied by a distinct rise to near or at 100% relative humidity and these conditions must be preceded by a period in which the soil moisture and the relative humidity had dropped.



Spore production for 12 different sporocarps of *Cantharellus cibarius*
Figure 26

BIOMASS STUDIES OF *CANTHARELLUS CIBARIUS*

Pileus diameters and diameters of the stipe apex were recorded for 81 sporocarps of *Cantharellus cibarius* over a ten-week period. Thirty-one of the sporocarps were located within the permanent plots and 50 were located outside the plot. All of the sporocarps outside the plot were harvested in the same manner and fresh and dry weight recorded for each. Age classifications were established for all 81 sporocarps.

Preliminary Results:

Of the 31 sporocarps studied within the plots, 20 were lost due to some type of vandalism. Complete data was recorded for the remaining 11 sporocarps over their entire life span. Thus correlation of biomass with life span and with environmental data should be possible.

Results indicate that biomass increases in direct proportion to the pileus diameter as well as to the stipe diameter. It would appear that it may be possible to determine biomass from measuring sporocarp diameter. However the data has to be analyzed.

INDICATOR SPECIES

Observations of the fungal flora indicate that *Chroogomphus tomentosus* may be the indicator species for sporocarp initiation of *Cantharellus cibarius* in late-October and *Tricholoma inamoenum* may be the indicator species for initiation of fruiting of *Boletus edulis*.

COMPARISON BETWEEN LANPHERE DUNES AND PATRICK'S POINT STATE PARK

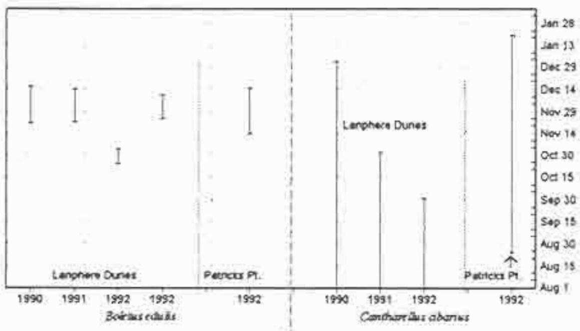
Lanphere Dunes is located approximately 20 miles south of Patrick's Point State Park and is a sand-dune ecosystem. All of the plots are located in a Lodgepole-pine dominated ecosystem with Huckleberry and Dwarf Manzanita being the dominant understory shrubs. The Preserve is dominated by various completely open areas in which sandy soils are densely covered with mosses and lichens that retain moisture and thus prevent desiccation.

The permanent plots established in Patrick's Point State Park are dominated by large conifers in a closed canopy stand with the dominant conifer being Sitka Spruce. Very little understory exists in the plot and the deep, needle dominated humus is filled with woody debris that functions to keep the soil moisture high; the closed canopy prevents desiccation.

Cantharellus cibarius and *Boletus edulis* occur in both areas (see Fig. 27 for comparison of fruiting seasons). For *Cantharellus cibarius* the length of the fruiting season is not as long in Lanphere Dunes as it is in Patrick's Point State Park. In 1992, *Cantharellus cibarius* dominated the fungal flora in the Park but was conspicuously reduced and almost absent in the Dunes; in both areas the environmental conditions were the same.

Boletus edulis began to fruit approximately 1 month later in Patrick's Point State Park than in Lanphere Dunes. In each case, the lengths of life span of sporocarps were similar and the number of spores produced by each sporocarp was equally large.

Leccinum manzanitae and *Armillaria ponderosa* occur in Lanphere Dunes; the former species is rather rare in the Park while the latter species apparently does not occur at all.



Comparinson of Fruiting Season of Target Species
Patrick's Point State Park and Lanphere Dunes
Figure 27

FRUITING SEASON OF 1993

During the summer of 1993, two new permanent plots, 2 and 3, were established in Patrick's Point State Park with the intent of studying sporocarps of *Boletus edulis*. Plot 2 is located southwest of Plot 1 which was established in 1992. It is 1024 m^2, and is divided into 256 subplots; each subplot is 4 m^2. Plot 3 is located approximately 50 yards north of Plot 1 and is composed of 324 m^2;plot 3 is divided in 81 subplots, each subplot is 4 m^2. The location of all trees and vegetation within each subplot has been surveyed and noted accurately on individual maps. The subplots, associated vegetation, and mushroom sporocarps have been entered into a computer and maps are presently being analyzed and printed during the summer of 1994. Although fruiting of *Cantharellus cibarius* was noted in mid-May, monitoring did not begin until July 25th when the first flush of a nine sporocarps were observed in Plot 1. Monitoring continued until November 7th when nearly all sporocarps were deemed absent from the plots. The monitoring protocol was identical to that established during the 1992 season.

Sampling occurred from July 25th through November 7th on a weekly basis. Eleven individuals from the local, community oriented, Humboldt Bay Mycological Society volunteered their time once a week during the entire sampling period with their supervision conducted by David Sime from the Humboldt State University mycology laboratory. Two individuals from the Mycological Society would sample 4 hours per week and these individuals sampled for 16 weeks. In addition, two senior students from the Humboldt State University Department of Biological Sciences completed their senior thesis by sampling Plot 1; each of these students sampled 1/2 of the plot, two times a week for 20 weeks. Each sampling period lasted 4 hours. Therefore, this project involved approximately 260 volunteer hours of assistance.

In addition, the maximum and minimum air temperature and the amount of rainfall was sampled once a week for 52 weeks. Finally, sporulation studies on *Cantharellus cibarius* were conducted twice weekly from July 25th until October 24th and prepared slides, on which spores were deposited, were obtained during the entire life span of 56 sporocarps. A total of 3477 slides were obtained during this period and the data is still being analyzed.

SPOROCARP STUDIES: LIFE SPANS, FRUITING SEASON, AND SPOROCARP LONGEVITY

Cantharellus cibarius

Observations were obtained on 529 individual sporocarps of *Cantharellus cibarius*. In plot 1, observations were made over the entire life span of 335 sporocarps; mammal predation accounted for a loss of 73 sporocarps while vandalism claimed 60. In Plot 2, data was obtained over the entire life span of 47 sporocarps; only 9 were lost to mammals and 5 to vandals. No sporocarps were observed in Plot 3.

Fruiting Season:

The fruiting season of *C. cibarius* began on 24 May 1993 and lasted until 1 Dec. 1993. Fruiting was not abundant, however, until the 27 of June 1993. Of the micrometeorological factors which may affect the beginning of the fruiting season, the average minimum air temperature and the amount of rainfall are most important.

As the mean minimum air temperature at the soil surface (hereafter indicated by T min) in Plots 1 and 2 increased from 5.5 in April to 9 °C in June, sporocarp production began and thus the fruiting season was initiated. The fruiting season continued until the mean minimum air temperature dropped below 9 °C (see Fig. 28). Initially the T min. climbed in May 1993 from 9 °C to 10.2-11 °C in August. At this time (29 July-11 August) only 55 new sporocarps were initiated. As the T min. dropped to 9.3 C, 214 new sporocarps were observed during the month of September. Once the T min. began to rise again in mid-September to above 10 °C, there was a decrease in new *C. cibarius* primordia to only 53 produced. As such, it appears that the mean T min. must rise for sporocarp initiation to occur and must reach a critical level of 10 °C for the mycelium to activate large numbers of primordia

The cumulative rainfall for the three months preceding the initiation of the fruiting season was a minimum of 23 cm and a substantial amount of rain occurred in the month preceding the initiation of fruiting (Fig. 29). Rainfall during peak production was less than a centimeter (see Fig. 28, 31). The fruiting season is initiated during the driest part of the year and sporocarp production occurs when it is not raining heavily. An analysis of the data soil moisture (SM), soil temperature (ST),and soil pH did not readily provide an explanation as to any influence on the phenology of *C. cibarius*. However, at Relative Humidity of 60% for sporocarps to form and if the Relative Humidity rises to above 90%, sporocarp production decreases and eventually ceases. (Fig. 32).

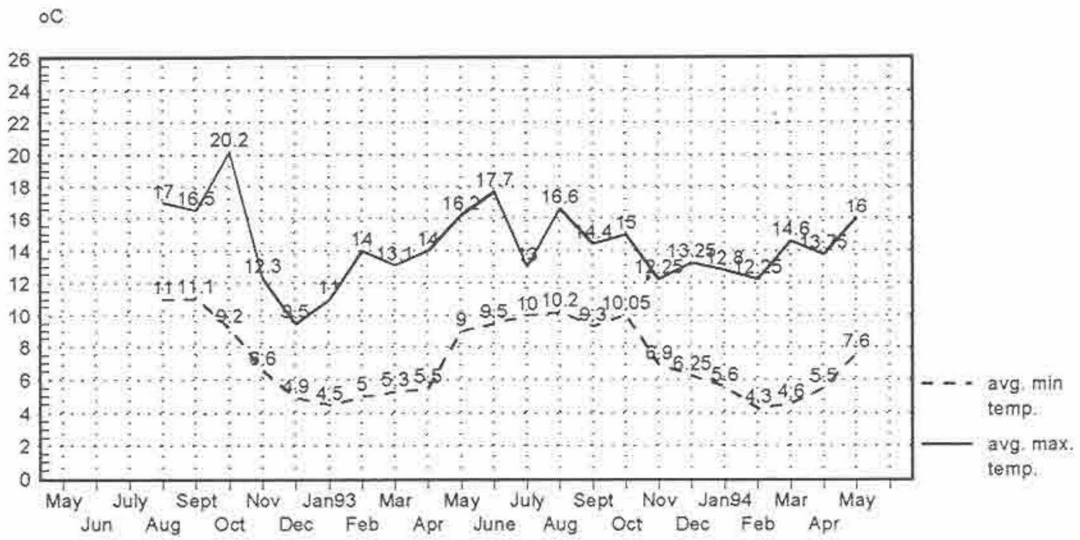


Figure 28

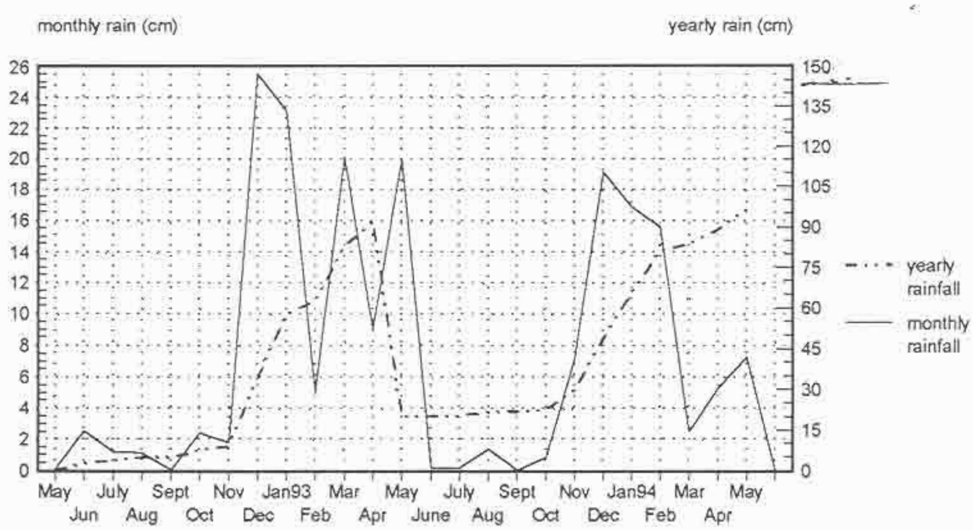


Figure 29

(Figure 28/29 *Cantharellus cibarius*)

Total Population

As in the 1992, the total number of sporocarps found during the entire fruiting season rose dramatically during the first two months of the season and in 1993 the highest number of sporocarps present at one time reached a peak of 270 sporocarps from October 4th through the 7th. (Fig. 30). Rain, in the amount of 1.6 cm., which occurred on July 23rd appears to be the stimulus to increase the population from 9 sporocarps on July 23rd to 70 sporocarps on August 16th. Another 1.5 cm of rain, which occurred on Aug. 16th is the stimulus to increase the number of sporocarps to 270 on October 4th. As in 1992, the majority of sporocarps of *Cantharellus cibarius* are produced by only 3 cm of rain. As the rainfall increased 50 mm (5.0 cm), the total number of sporocarps began to decline. Therefore, as in 1992, an increase of rain after a dry period is the stimulus to start a decline in the total number of sporocarps (Figure 31).

In 1993, the total number of sporocarps in Plots 1 and 2 dropped by 97% abruptly after the average maximum air temperature rose to nearly 20 °C and remained at this temperature for over one week. Between 23-26 October the Relative Humidity dropped more than 50%, the % Soil Moisture fell over 40% while the average maximum air temperature rose to +19 °C in the study Plots. (Fig. 31, 32). Once average minimum air temperatures were below 7 °C, sporocarp formation ceased.

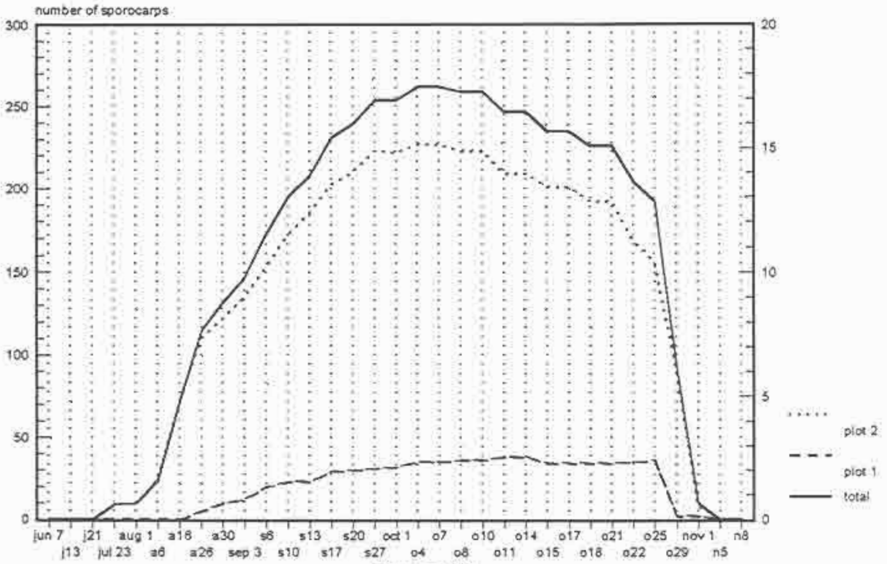


Figure 30

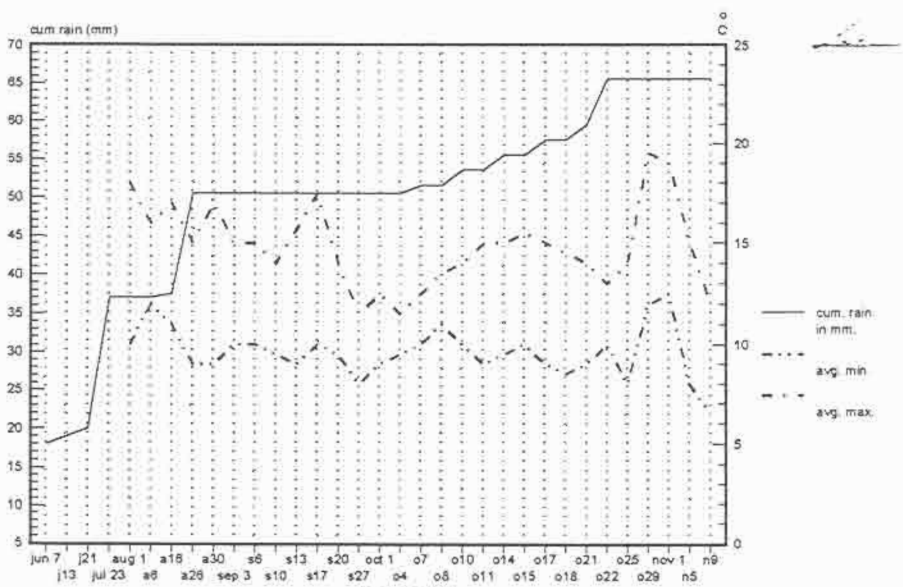


Figure 31

New Sporocarp Production

Throughout the fruiting season, new sporocarps are produced in flushes or peaks. (Figs. 32, 33). Relative Humidity seems to affect the number of sporocarps produced during each peak; the largest number of new sporocarps produced per flush occur when the relative humidity is between 60 and 80%. Once the relative humidity rises to 90%, the number of sporocarps per flush decreases and eventually the number of flushes cease when the relative humidity reaches 100%.

A distinct correlation exists between the production of new flushes and soil moisture and soil temperature. New flushes seem to be initiated when the soil moisture rise to or above 30% and the soil temperature rises to near or above 12 °C. Each new flush seems to terminate when the soil moisture drops below 30% and the soil temperature drops below 12 °C. (Fig. 33).

Flushes seen to occur in clusters and each cluster is influenced by the amount of daily rainfall (Fig. 33). Rainfall on July 23 influenced the clusters produced up to September 2nd. Rainfall on August 26 influenced the clusters produced during the entire month of September.

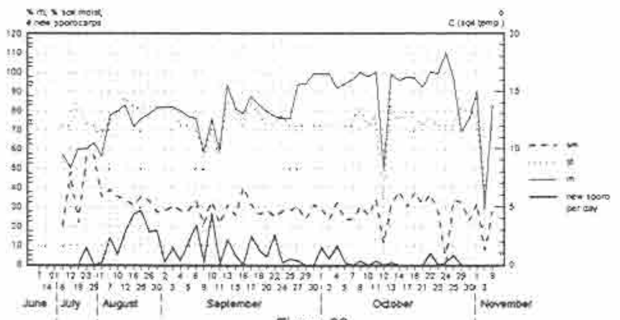


Figure 32

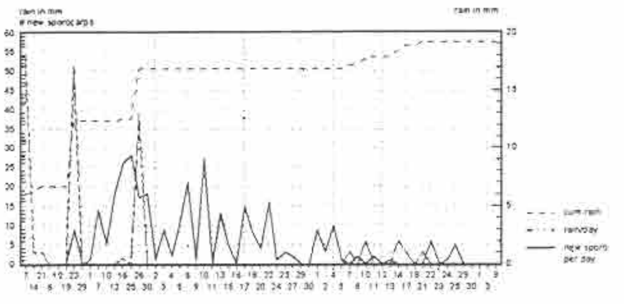


Figure 33

Life Span

Life span data has to be interpreted carefully since the entire fruiting season ended with the dramatic rise in maximum air temperature during the last week of October. During this period, the longest life span was 84 days produced by a sporocarp formed in early August and The shortest life span was 11 days produced by a sporocarp formed in mid-October.; the average life span was 46.5 days.

Of the micrometeorological factors affecting length of individual lifespans it was found that as Relative Humidity decreased and Soil Moisture decreased, longevity also decreased. Contrary to 1992, longest life spans were produced by sporocarps formed early in the fruiting seasons and as the fruiting season progressed, the average life span decreased. (Fig. 34,35).

However, each month produced long and short life spans. July sporocarps lived an average of 52.5 days, August 61.2 days, and September 41 days. The data on soil pH, T soil did not appear to influence longevity.

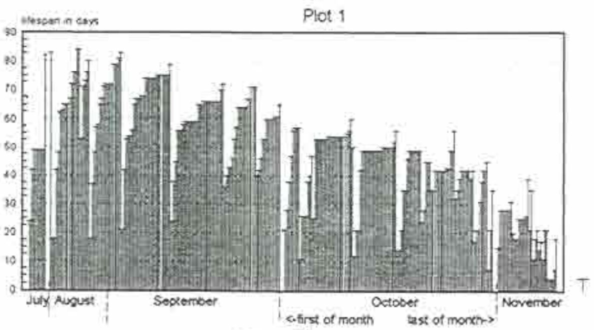


Figure 34

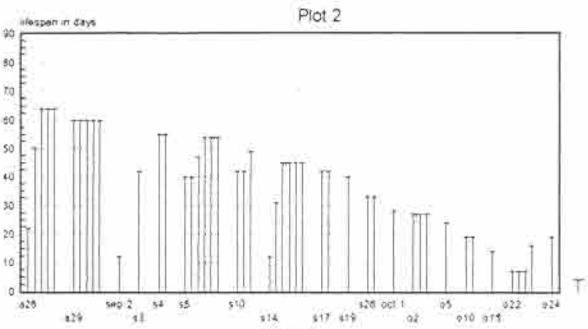


Figure 35

Boletus edulis

Observations on 6 sporocarps were made, 5 formed in Plot 2 and 1 formed in Plot 3. The fruiting season began on September 2nd, about one month earlier than in 1992. However, all of the sporocarps were vandalized by commercial or private mushroom pickers. Therefore, data on the end of fruiting season, life span of individual sporocarps, and sporulation studies were not available. Information on rainfall, average maximum air temperature, and average minimum air temperature at the time of sporocarp formation is found in Figure 36. Information on Relative Humidity, Soil Temperature, Soil Moisture, and pH for each of the 6 sporocarps observed is found in Table 4..

Table 4

date	plot	mushroom ID	Relative Humidity	Soil Temperatur	Soil Moisture	p
sep 1	2	62	83	14	32	6.
sep 15	2	55	78	14	30	6.
sep 13	2	81	62	14	30	6.
sep 25	2	49	75	12	37	6.
oct 28	2	81	60	13	5	7.
oct 29	3	55	81	14	30	6.

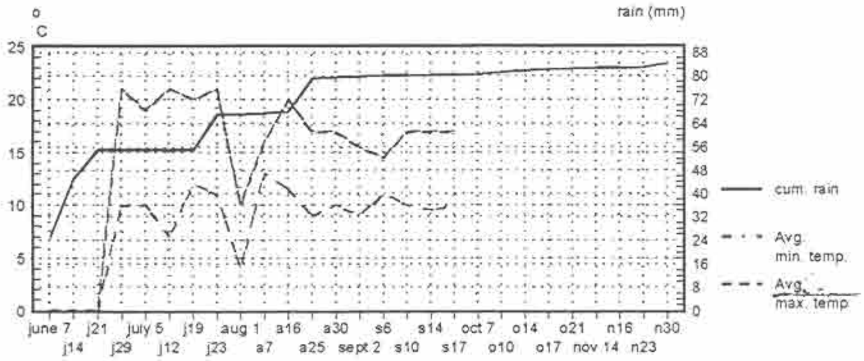


Figure 36

SPORULATION STUDIES

During the four months when sporocarps were found in Plots 1 and 2, data was gathered once a week on the duration and quantity of basidiospores discharged in a 24 hour period; slides were placed under sporocarps in the morning of one day and gathered at the same time the next day. Sporulation data was gathered from a total of 62 sporocarps of *Cantharellus cibarius*. Of these, data was obtained for the entire life cycle of 42 sporocarps from Plot 1 and 5 from Plot 2. The remaining 20 sporocarps were consumed by mammals at some point in their development. Therefore a total of nearly 700 slides were obtained during this study.

Out of 42 life cycles the mean life span was 56 days, with sporulation first observed on a mean day of 44. The fungi that received spore measurements started sporulating with a mean Rh of 94.3%, T soil of 13.6 C, and a SM of 30.94%. All fungi had a maximum spore discharge per square centimeter of hymenophore (>100,000,000) at mean Rh of 78.8%, T soil of 14.4 C, and SM of 32%. A higher spore load and warmer soil temperatures appear to be correlated.

For all 42 sporocarps studied, at least 6 different patterns existed during which spores were produced as follows:

number of sporocarps	when majority of spores are produced during the life span
20	near the end
2	from the middle to the end
5	at the beginning
7	in the middle
2	from the beginning to the middle
5	over entire life cycle

Sporulation for each mushroom will be found in the unfinished graphs located in Appendix A.

Some fruiting bodies produced their spores in two to three flushes, some all at once, while others did not produce more than 500,000 spores per square cm. In a mycorrhizal fungus such as *C. cibarius* basidiospore production may be genetically controlled.

Sporulation data is still being analyzed as of this date. During the next few months, an attempt will be made to determine if sporocarp clustering has an effect on sporulation. However, the maps on which all sporocarp and vegetation will be located have to be completed.

Comparison between 1992 and 1993 Fruiting Seasons.

Comparisons of the data collected in 1992 with that of 1993 indicate distinct differences between the two years. The fruiting seasons in each year began roughly at the same time; however 1992 was a bit later than 1993.

Cantharellus cibarius

The fruiting season in 1992 lasted nearly two months longer than in 1993. In 1992, freezing temperature terminated the life span near January 20th whereas in 1993 the season was terminated on November 12th due to the week long period of warm weather. The initiation of the fruiting season were similar with the season observed to begin on June 7th in 1992 and the season observed to begin near June first in 1993 (see Figure 37). In each year, the fruiting season began during a period of dry weather which was preceded by wet weather. In each year, new sporocarps were formed as long as the cumulative rainfall was kept below 5 cm. and the largest number of sporocarps were produced during a time when no to very little rain occurred. The termination of the fruiting season began when the relative humidity increased and new rain occurred. Therefore, it appears that sporocarp formation in *Cantharellus cibarius* responses to very little rain. The stimulus for the initiation of the fruiting season seems to be a low relative humidity near 60 %, average minimum air temperatures rising from 5 to 9 °C. In each year, sporocarp formation was more restricted to the southeastern quadrant of plot 1 which has a large amount of buried wood. Therefore, sporocarp formation seems to respond to moisture found in this woody debris, a phenomenon which correlates with the studies of Norvell.

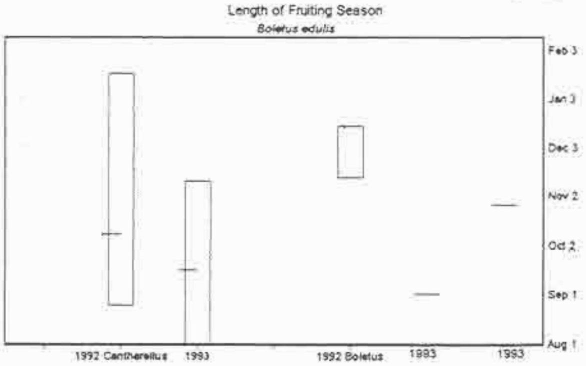


Figure 37

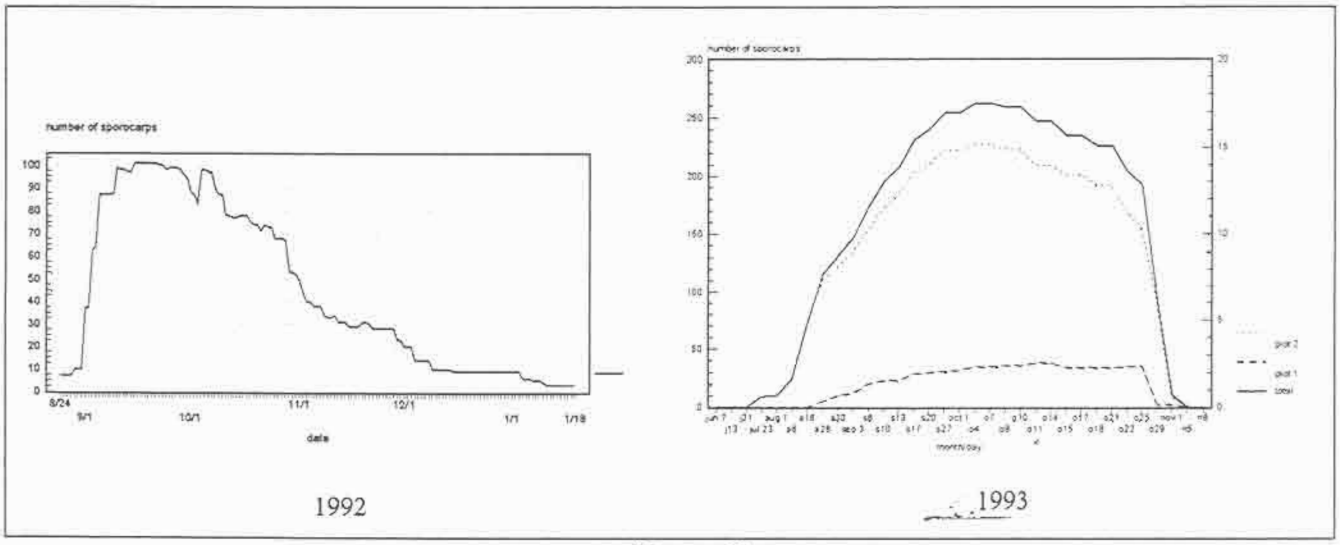
The highest number of sporocarps found in plot 1 in 1992 was about 105 whereas in 1993 the highest number was 267. The patterns of the highest number of sporocarps present at any one time were similar in 1992 as in 1993; however the abrupt disappearance of sporocarps in 1993 was caused by the warm weather. (see Figure 38). The temperatures in 1993 were warmer and the rainfall less than in 1992. Therefore, an increase in sporocarp numbers during drier weather seems to correlate well with information provided by Norvell (1992). (See Figure 41).

New sporocarps were produced in flushes in both 1992 and 1993. However, the number of flushes were about 3 times more in 1993 than in 1992. Interesting, the highest number of new sporocarps produced per flush were equal in 1992 as in 1993 (see Figure 39).

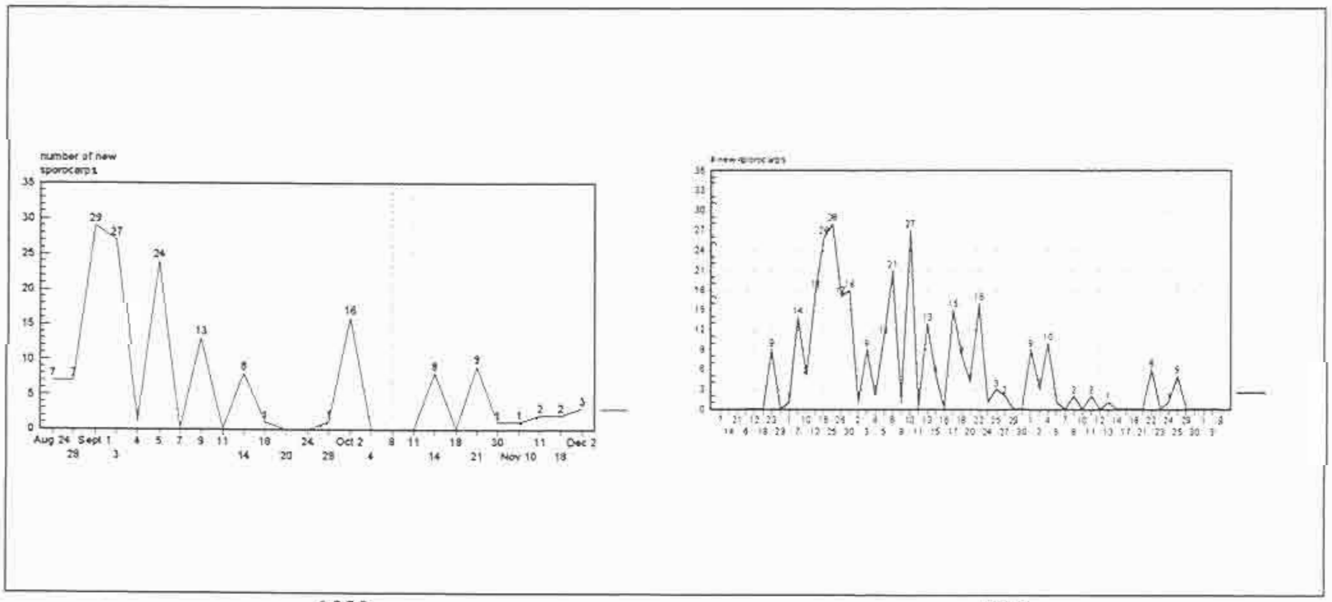
The pattern of life spans were very different in 1992 than in 1993. (See Fig 40). In 1992, the longest life spans were produced towards the middle and the end of the fruiting season; however all parts of the fruiting season produced sporocarps with different lengths of life span. In 1993, the longest life spans were produced in the beginning of the fruiting season, and the average life span length was reduced as the fruiting season progressed. However, the longest life span, shortest life span, and average life spans were nearly identical in 1992 as in 1993. (see Table 5)

	life span of individual sporocarps			total number of sporocarps observed in plot 1	highest number of sporocarps at any one time in plot 1
	longest	shortest	average		
1992	92	10	44	364	105
1993	84	11	46.5	454	267

Sporulation patterns for the two years did correlate with maximum spore output for Relative Humidity, Soil Moisture, and Soil Temperature. In 1992 the Relative Humidity was 90%, the Soil Moisture was 31.6% and the Soil Temperature was 14.3 C. In 1993 the Relative Humidity was 87.8%, the Soil Moisture was 32% and the Soil Temperature was 14.4 C. Sporocarps growing only in bryophytes and those growing in woody debris need to be compared for sporulation patterns.

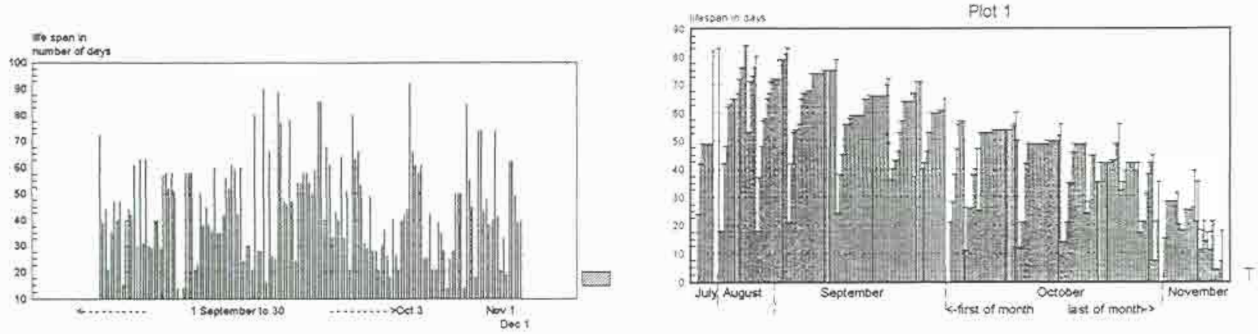


Firgure 38



1992 1993

Figure 39

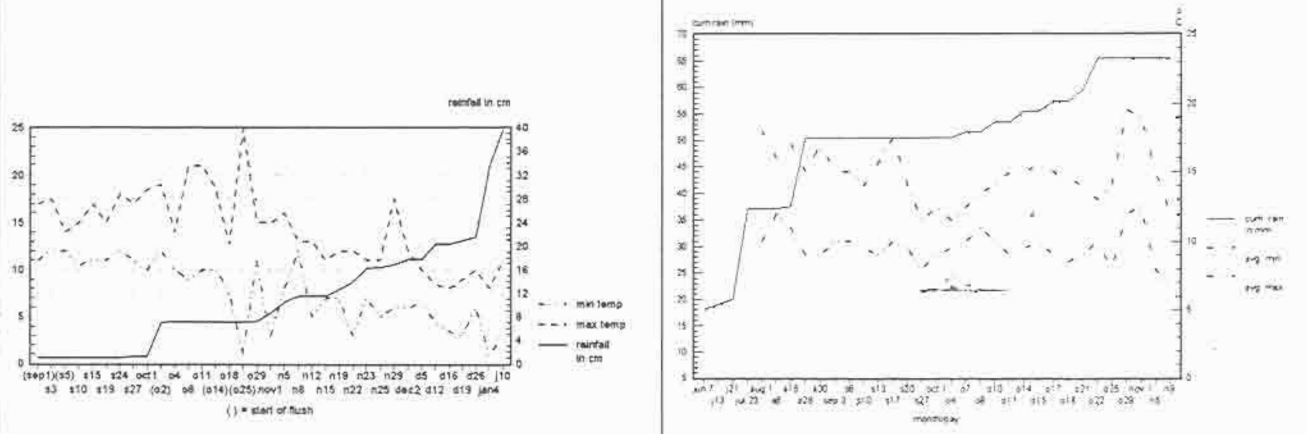


1992

1993

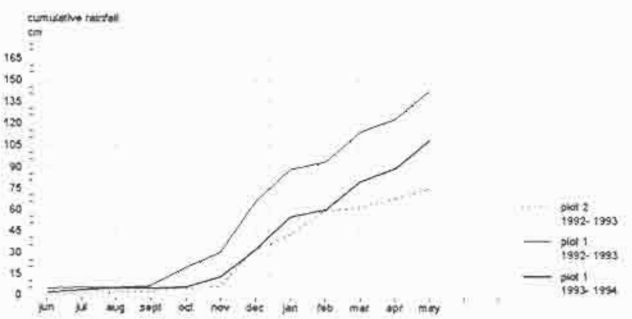
▲Figure 40

▼Figure 41



1992

1993



Comparison of rain fall plot 1 and plot 2

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