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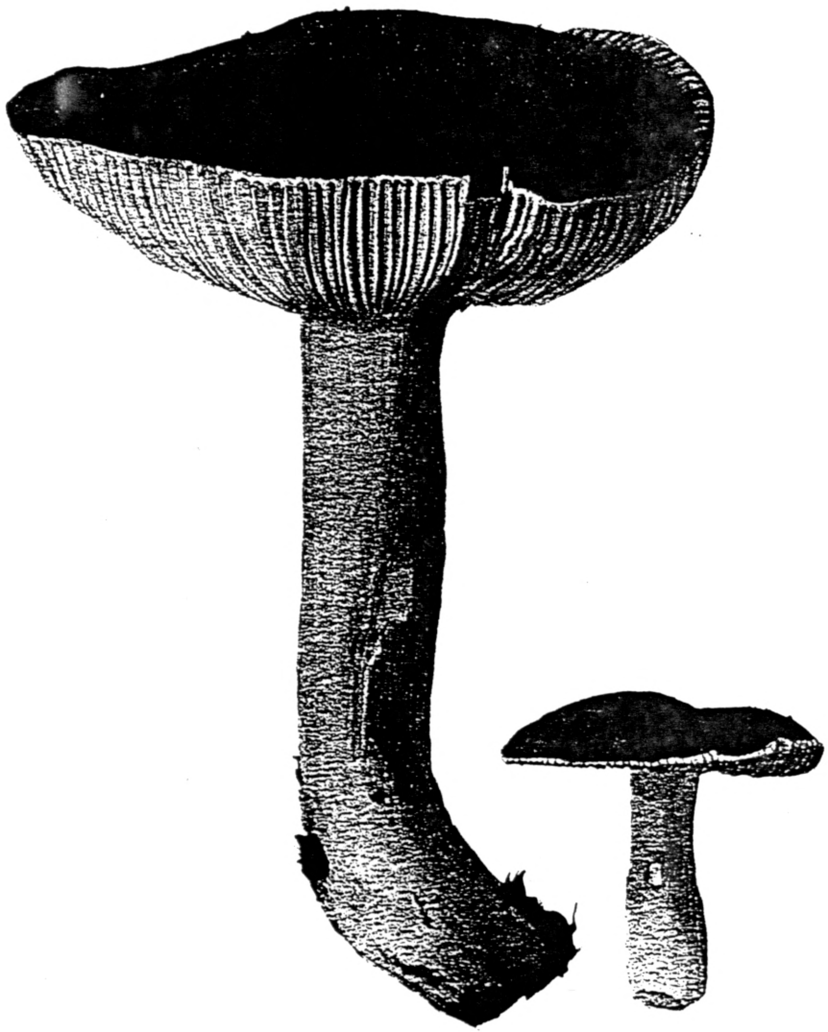

Espenscheid July 1970

with as many as 2,000 species (Trappe, 1977). The ability for plants to form mycorrhizae with numerous fungus species benefits the host by increasing access to nutrients and water, and by protecting against fine-root pathogens.

Mycorrhizal fungal filaments (hyphae) greatly extend the nutrient-absorbing surface area of the roots and are more effective in nutrient and water absorption than roots themselves. Soil nutrients essential to plant growth, such as phosphorus and nitrogen, are absorbed by the mycorrhizal fungus and transported back to the root for use by the plant. In return, the plant provides sugars produced in photosynthesis to the mycorrhizal fungus; these sugars are used by the fungus to fuel its activities and form fruiting bodies (truffles and mushrooms). The hyphae of mycorrhizal fungi can link plants, of the same or different species, forming a belowground network that allows nutrients to pass among them (Read *et al.*, 1985).

Truffles and mushrooms are important wildlife food and are consumed by numerous forest animals including deer, elk, bear, small mammals, slugs, and insects (Fogel and Trappe, 1978; Maser *et al.*, 1978; Carey, 1991). The fruiting bodies appear to provide animals with an essential source of minerals, amino acids, and vitamins. Some rodents such as the California red-backed vole (*Clethrionomys californicus*) and northern flying squirrel (*Glaucomys sabrinus*) rely on truffles and mushrooms for over 90% of their food supply (Hayes *et al.*, 1986; Maser *et al.*, 1978, 1985). In turn, these small mammals are primary prey for species such as the northern spotted owl (*Strix occidentalis caurina*).

Truffles, because of their belowground habit, depend on mycophagous (fungus-eating) animals for spore dispersal. As truffles mature, they produce odors that attract forest mammals, especially small mammals like squirrels, chipmunks, voles, and mice, that excavate and consume the truffles; spores pass through the digestive tract unharmed and are excreted in the animal's feces (Maser *et al.*, 1978; Maser and Maser, 1988). Spores from the fecal pellets are washed into the soil where they contact roots of mycorrhizal hosts. Spores may be dispersed over long distances by predatory birds such as owls, hawks, and eagles that feed on truffle-eating rodents (Trappe, 1988).

Edible truffles in the Pacific Northwest

Truffle consumption by people falls outside the interconnected web described above because a potentially critical connection is broken: spores are not returned to the forest floor. Many mycologists believe that harvesting fungal fruiting bodies is as harmless as picking fruit off a tree. This analogy assumes that the fungi are harvested with little disturbance to the forest floor and that some fruiting bodies remain for spore dispersal.

Long-term monitoring is needed to determine if harvest methods and reduced spore production are damaging to the forest fungus populations. In the Pacific Northwest, truffles are harvested by raking the forest floor, resulting in considerable disturbance to the soil and fine roots of host trees. In contrast, in Europe, the pungent, mature truffles are sniffed-out by trained dogs or pigs, then carefully removed by the accompanying person. Studies are in progress to determine the effects of raking on fungal production (Pilz *et al.*, in press).

Observational data at one site suggest that raking an area for two consecutive years virtually eliminated truffle production in the third year (Trappe, 1990).

Two edible truffle species are widely collected in Douglas-fir forests in the Pacific Northwest. Several thousand pounds each of the Oregon white truffle (*Tuber gibbosum*) and the black picoa (*Picoa carthusiana*) are collected annually, mostly for international markets (Schlosser and Blatner, 1995; Amaranthus and Pilz, in press). The Oregon white truffle reminds some of the Italian white truffle, and the black picoa produces pleasant aromas reminiscent of pineapple (North American Truffling Society, 1987). Price per pound to pickers in 1992 in Oregon averaged $75 for the black picoa and $30 for the Oregon white truffle (Schlosser and Blatner, 1995).

Truffle diversity in Pacific Northwest forests

Truffle fungi, like their aboveground relatives, depend on particular plant species and habitat conditions (such as tree composition, tree age, and soil qualities) for survival (Molina *et al.*, 1993). Some truffle species are more abundant in certain age-classes of forests. Changes in plant species composition from forest succession or large-scale disturbances, such as wildfires or logging, affect truffle species composition. Accurate mycological data in human-disturbed (harvested) forests and undisturbed (old-growth) forests are needed to understand truffle community dynamics. Several studies now in progress in the Pacific Northwest are designed to clarify the intricate relation between truffle fungi and habitat conditions (Colgan *et al.*, in press; Luoma *et al.*, in press; Smith *et al.*, in press).

Preliminary data from the study by Smith *et al.* (in press) comparing truffle species diversity among young (20-30 years), rotation-age (45-60 years), and old (over 400 years) Douglas-fir stands are presented below. From 1991 to 1994, truffles were collected from three replicate stands of each age-class of Douglas-fir in and near the H.J. Andrews Experimental Forest in the western Cascade Range of Oregon. Stands were sampled once each in the spring and fall, and sampling was timed to coincide with the seasonal peak fruiting period. Truffles were collected from a total area of 100 m^2 per stand in 25 uniformly sized plots. Of the 25 total genera, 32% were unique to an age-class; 24% occurred only in the young stands compared to 4% in each of the rotation-age and old stands **(Table 1)**. Several species were also unique to an age-class. Of the 49 identified species, 20% were unique to the young stands compared to 10% and 22% in the rotation-age and old stands. Our results suggested that all age-classes of forests are critical for maintaining biological diversity of truffle fungi.

Conclusion

Recent interest in conserving biological diversity has highlighted the need to inventory all forest organisms, including truffle fungi, in the Pacific Northwest. This region contains ancient (old-growth) forests that have experienced little or no human disturbance for centuries, resulting in a late-successional or climax stage in forest development (Norse, 1990). Much controversy has surrounded the management and harvest of late-successional forests in the Pacific Northwest during the last decade. Legal challenges to forest management plans emphasized that many species, including the northern spotted owl, depend on this diminishing habitat. Controversy and legal action have contributed to developing a holistic approach to land management. This new approach, termed ecosystem management, emphasizes understanding and maintaining all components, interactions, and processes of ecological systems.

Reasons for maintaining biological diversity include the anthropocentric concern about loss of fungi and other species potentially useful to the treatment of viruses and cancers, or of high commercial value, because of habitat destruction or mismanagement. Other reasons to preserve viable populations of diverse species include recognizing that all organisms have intrinsic value (Cobb, 1988), and that conserving diversity is essential to sustaining ecosystem productivity and a healthy environment. People are an integral part of ecosystems and their successful management. We cannot discount the importance of poorly understood organisms to ecosystem function. The importance of the diverse fungal community of Pacific Northwest forests to tree growth and interactions with forest organisms has just recently been recognized. Belowground fungi may be hidden, but given their critical ecosystem functions, they must never be forgotten.

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TABLE 1. DISTRIBUTION OF TRUFFLE GENERA IN YOUNG (20-TO-30-YR-OLD), ROTATION-AGE (45-TO-60-YR-OLD) AND OLD (MORE THAN 400-YR-OLD) DOUGLAS-FIR STANDS IN THE H.J. ANDREWS EXPERIMENTAL FOREST, 1991-94

Family	Genus	Season	Young	Rotation-age	Old
Astraceae	*Pyrenogaster*	S	X	X	
	Radiigera	S,F	X	X	X
Boletaceae	*Alpova*	S	X		
	Rhizopogon	S,F	X	X	X
	Truncocolumella	F	X	X	X
Cortinariaceae	*Cortinomyces*	S			X
	Hymenogaster	S	X		
Elaphomycetaceae	*Elaphomyces*	S,F		X	X
Endogonaceae	*Endogone*	S	X	X	X
Geneaceae	*Genabea*	S	X	X	
	Genea	S		X	
Helvellaceae	*Balsamia*	S	X		
	Barssia	S	X		
	Hydnotrya	S	X		X
Hysterangiaceae	*Hysterangium*	S,F	X	X	X
Leucogastraceae	*Leucogaster*	S,F	X	X	X
	Leucophleps	S		X	X
Melanogastraceae	*Melanogaster*	S	X		
Pezizaceae	*Peziza*	S	X		
Pyronemataceae	*Geopora*	F	X		
Russulaceae	*Martellia*	S,F		X	X
	Zelleromyces	F	X	X	
Sclerodermataceae	*Scleroderma*	F	X	X	
Strobilomycetaceae	*Gautieria*	S,F	X	X	X
Tuberaceae	*Tuber*	S,F	X	X	X