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CALIFORNIA INDIAN ETHNOMYCOLOGY AND ASSOCIATED FOREST MANAGEMENT

M. Kat Anderson and Frank K. Lake

Many California Indian tribes utilized mushrooms for food, medicine, and/or technological purposes. This paper summarizes which mushrooms were important to different California Indian tribes in historic and modern times and how they were harvested, prepared, and stored. Oral interviews were conducted and the ethnographic literature reviewed to detail the extent and complexity of indigenous knowledge about fungi harvesting and associated burning to enhance mushroom populations and their habitats. Through two case studies, we review indigenous burning practices of several tribes in the lower montane mixed conifer forests of the central and southern Sierra Nevada, and the mixed evergreen forests of northern California. We explore the potential ecological effects of burning on these forests at different levels of biological organization and conclude by offering suggestions for research, management, and restoration practices needed to perpetuate usable mushrooms.

Key words: *Indigenous knowledge, mushroom harvesting, fire, fungi, mycorrhiza*

Muchas tribus indígenas de California utilizaban setas como alimento, medicina y/o con fines tecnológico. Este artículo resume cuáles eran las setas importantes para varias tribus indígenas de California en los tiempos históricos y modernos y cómo se cosechaban, preparaban y almacenaban. Se realizaron entrevistas orales y se revisó la literatura etnográfica para detallar el alcance y la complejidad del conocimiento indígena sobre la cosecha de setas y sobre la quema que se llevaba a cabo para mejorar las poblaciones de setas y sus hábitats. A través de dos estudios de caso, se han revisado las prácticas indígenas de quema de varias tribus en los bosques mixtos de coníferas del montano bajo de Sierra Nevada central y sur, y los bosques perennes mixtos del norte de California. También se han estudiado los efectos ecológicos potenciales de la quema en estos bosques en diferentes niveles de organización biológica. Como conclusión, ofrecemos sugerencias para la investigación, gestión y las prácticas de restauración necesarias para perpetuar las poblaciones de setas útiles.

Introduction

In parts of California at European contact, different kinds of fungi provided important contributions to native people's existence, serving as food, medicine, tinder, and dyes. Native Americans harvested these useful fungi from a variety of habitats: coastal prairies, chaparral, mixed conifer and hardwood forests, and montane meadows. Tribal harvesters primarily collected the spore-containing fruiting body or sporocarp of some fungi, those commonly referred to as mushrooms. Varieties included chanterelles, morels, boletes, common field, and other soil-growing mushrooms. Other types, such as willow or oyster mushrooms and giant sawtooths, were cut or torn from the trunks or branches of live and dead trees.

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California Indians were intimately familiar with the color, shape, texture, and smell of a diversity of fungal species and knew in which habitats they grew, on what substrates to find them, and which mushrooms have special relationships with different kinds of shrubs and trees. Tribal mushroom harvesters understood how maturation times varied according to elevation, substrate, weather patterns, and microclimatic differences. Today some California Indians still harvest mushrooms, often gathering them in ways that —they assert— ensure plentiful harvests over the long term: acting as dispersal agents, using appropriate gathering tools, being careful to leave some for spore production, and burning areas to encourage mushroom numbers and densities and maintain fungal habitat.

This article begins by reviewing the different kinds of mushrooms, where they are found and their uses in California Indian cultures, and how they were dried, stored, and prepared in historic and modern times. It explores fungi's ecological roles in different ecosystems and how Native Americans may have influenced their abundance, densities, diversity, and habitat quality with harvesting techniques and burning within two forest types— the lower montane forests of the Sierra Nevada and the mixed evergreen forests of northern California. Our findings are analyzed within a broader context of discussions with western mycologists and fire ecologists and the relevant scientific literature to explore the potential effects of indigenous management practices on forest ecosystems. Lastly, we discuss needed research in California and the ways researchers and managers might integrate indigenous harvest and management of useful mushrooms into ecological restoration projects and adaptive management plans. Reintroduction of these techniques may be key for not only the conservation of mushrooms, but also enhancing the health of certain ecosystems today, via the ecological services fungi provide.

Importance of Fungi to Ecosystem Health

Fungi form an important component of different ecosystems, serving as food for a great variety of organisms, enhancing soil structure through mycelia, and having an important role in the breakdown of dead plant and animal remains. Certain fungi maintain natural ecosystems through mutualistic mycorrhizal relationships with plants (Kaul 2002). The vegetative part of the fungus, the part that gets its nourishment and endures from year to year, is hidden underground as a vast network of interwoven threads known as mycelia. This network emanates from the fruiting body in all directions and surrounds and penetrates the roots of individual host trees or shrubs. The fungus's mycelia take up and transport mineral nutrients and water to the plant from the soil in exchange for carbon and simple sugars that move from the plant roots to the fungus (Allen 1991). The nutrient exchange structure, where the fungus grows around and within fine root tips, is called a mycorrhiza. Not only are mycorrhizal mutualisms widespread, but because the mycorrhizal fungal hyphae connect individual plants, the symbiosis acts as an integrator of plant communities (Allen 1991:39–40). Read (1990) would go so far as to conclude that the nutrient dynamics of terrestrial ecosystems can be understood only in terms of the activities of their mycorrhizal fungi.

Many kinds of fungi native people gather have symbiotic relationships with shrubs and trees as mycorrhizal associations. There are two major types of mycorrhizae distinguished by morphological and physiological features: arbuscular mycorrhizae (AM) and ectomycorrhizae (ECM). Arbuscular mycorrhizae are associated with herbaceous species including most agricultural crops. In forested ecosystems AM have relationships with certain herbs, grasses, shrubs, hardwoods, and conifers (see Trappe 1962; Trappe, Molina et al. 2009). Most abundant and commonly collected edible forest fungi fruiting from soil/humus are ectomycorrhizal (David Pilz, Lake unpublished field notes 2010). Forest fungi that form macroscopic fruiting bodies can grow in soil or grow on wood. Only the soil-forming types can have mycorrhizae. Those that fruit above-ground are called epigeous, and those that fruit below-ground are called hypogeous. Examples of epigeous mushrooms include American matsutakes, chanterelles, and boletes (Molina et al. 1993; Molina et al. 2001; Trappe, Molina et al. 2009). Truffles are classified as hypogeous mushrooms (Trappe, Molina et al. 2009). Other fungi that do not form mycorrhizae are called saprotrophic fungi that derive food from decomposing logs, stumps, or other dead organic materials on the forest floor (Arora 1986). They perform vital functions by decomposing organic matter and enriching soils in the process. Without their role as decomposers, dead plant biomass would accumulate.

Methods

Methods employed in this ethnomycological study include a careful review of major published ethnographic descriptions, ethnobotanies, and unpublished university theses on each California Indian tribe, perused for four types of mushroom information: species harvested, harvest strategies, uses, and habitat management. United States Department of Agriculture-Forest Service (USDA-FS), Six Rivers National Forest Heritage Program and Karuk tribal reports were reviewed, and internet search engines were utilized to find tribal newsletters or related publications. These sources enabled us to do a key word search, focusing on the words ''mushroom'' and ''fungus.'' Additionally, the field notes that provide the basis for these published works often contain important information that was never published, and some of these notes, such as those of Frank J. Essene, John W. Hudson, and Frederick S. Hulse, were reviewed for relevant information. Many museums around the country funded expeditions or sponsored individuals to purchase artifacts to enrich their collections including mushrooms and plant parts used for food. Particularly valuable are the associated accession notes (Anderson 2005a). We summarized the mushroom information found in the California Indian collections of two museums, the Phoebe Apperson Hearst Museum of Anthropology at the University of California, Berkeley and the Oakland Museum of California.

Qualitative interviews were conducted with knowledgeable Native Americans from the Amah Mutsun (Ohlone), Big Pine Paiute, Central Sierra Me-Wuk (Miwok), Chukchansi/ Choinumni, Coast Miwok, Hupa, Karuk, Luiseño/ Cupeño, Mono, Salinan, Southern Sierra Miwuk (Miwok), Tuolumne Band of Me-Wuk (Miwok), Washoe, and Yurok tribes between 1986 and 2012[1]. In addition to interviews, some native consultants were taken to mixed conifer and mixed evergreen forests to directly identify mushrooms. Specimens for some mushroom species were gathered and sent to Michael Davis, a mushroom expert in the Department of Plant Pathology at University of California, Davis. In his laboratory, a small amount of tissue was taken from the specimen, frozen in liquid nitrogen, and treated with chemical agents to extract DNA. The laboratory then ran a PCR (polymerase chain reaction) using some DNA building blocks that are specific to mushrooms. Davis (personal communication 2011) explains, ''The PCR simply amplifies a very tiny amount of DNA in the specimen to levels large enough to analyze in a DNA sequencer. Since every organism has a unique DNA fingerprint, we can identify the specimen by matching its sequences with those in a large DNA database.''

Fungus scientific names were updated using the database http://www.indexfungorum.org. Plant scientific names were updated using the PLANTS database http://plants.usda.gov and the new Jepson Manual (Baldwin et al. 2012). Mono name spellings for mushrooms are taken from Bethel et al. 1984.

Mushrooms Harvested: Their Uses, Preparation, and Storage Methods

Mushrooms played an important role in the traditional livelihoods of some California Indian tribes. In the Indian household, mushrooms provided food as well as a range of products (Table 1). In modern Indian households, mushrooms are still consumed, mainly as food.

Documents record California Indian tribes' historic (and in some cases current) use of 26 species of mushrooms. Another 10 species are possible taxa, requiring the acquisition of specimens for verification. Together these 36 species span at least 19 fungal families: Agaricaceae, Amanitaceae, Auriculariaceae, Boletaceae, Cantharellaceae, Fomitopsidaceae, Gomphaceae, Helvellaceae, Hericiaceae, Hydnaceae, Hymenochaetaceae, Lyophyllaceae, Morchellaceae, Pezizaceae, Physalacriaceae, Pleurotaceae, Polyporaceae, Sparassidaceae, and Tricholomataceae. These include mushrooms that are contained in variously shaped fungi fruiting bodies (e.g., *Amanita pantherina* sensu Gonnermann & Rabenhorst, *Aleuria aurantia* (Pers.) Fuckel, and *Hericium coralloides* (Scop.) Pers.) and those that have spores borne inside a spore case or numerous lentil-like capsules —the puffballs (e.g., *Calvatia sculpta* (Harkn.) Lloyd and *Calvatia gigantea* (Batsch) Lloyd) (Burk 1983; McMillin 1956). Additionally, truffles were gathered by at least two tribes, but the species identifications are lacking (Table 1). Tribes in an area greater than two-thirds of the state gathered mushrooms, suggesting that this life form had widespread use (Figure 1).

Figure 1 likely underrepresents the number of California tribes that used mushrooms because when anthropologists asked about the plants Indians ate or used, few questions were directed towards the mushrooms they harvested. Mushrooms are poorly represented or absent from the majority of ethnographic descriptions of early California Indians, and when mentioned, mushrooms are infrequently identified to genus or species (see Table 1). For example, anthropologist Samuel Barrett (1952:93) jotted in his field notebook that the Pomo ate mushrooms, noting that there were ''many'' and that they were

Table 1. Uses of fungi by California tribal groups. Descriptions come from the associated reference.

Tribe	Tribal, common name (Description)	Scientific name or possible taxon	Associated plants or plant community	Use[1]	References[2]
Atsugewi	(Fungus)	Unknown		T-face and body paint	Voegelin 1942:83
Atsugewi	***Kramcai*** (Mushroom)	Unknown		F	Garth 1953:139
Cahto/Kato	***Tŭnsik*** (White mushroom), ***Aatcwt*** (Large flat mushroom)	Unknown		F	Essene 1942:86
Cahuilla	***Saqapish***	Possibly *Pleurotus cornucopiae*	Dead limbs of cottonwoods, sycamores, and willows	F	Bean and Saubel 1972
Cahuilla	***Ttivilyem***	Unknown	Under mesquite	F	Lando and Modesto 1977
Cahuilla	***Yulal***	Unknown	Oaks		Bean and Saubel 1972
Cahuilla	Unknown	Unknown		F	Bean 1978:576
Chilula	(Red fungus)	Unknown		T-face and body paint	Driver 1939:333
Chilula	Unknown	Unknown		F	Kroeber 1976:269
Chumash	(Shelf fungus)	Unknown		F	Timbrook 1990 in Richards 1997
Chumash (Ineseño)	***Ch'eweleqey*** (Mushroom-like growth)	Unknown	On rotten wood and elsewhere	F	M. Solares, Harrington Notes, Timbrook, pers. com 2012
Chumash (Ventureño)	***Chtop 'I shaqshanuch***, *Hombligo de difunto*, *Hongo*	Unknown		F [started in the 20th century]	S. Pico, Harrington Notes, Timbrook, pers. com 2012
Cupeño	Oyster or willow mushroom	*Pleurotus cornucopiae*	Dead and live alders, oak, cottonwoods and willows	F	W. Pink, AFN 2010
Hupa	(Red fungus)	Unknown		T-face and body paint	Driver 1939:333
Hupa	Coral fungus	*Ramaria* sp.		F	Richards 1997
Hupa	American matsutake or tanoak mushroom	*Tricholoma magnivelare*		F	C. Hostler, LFN 2010; W. Colegrove and M. Nixon, LFN 2005; I. McCovey and E. Masten, Paulides 2008
Hupa	Unknown	Unknown		F	USDA-FS 1981 Interview 290

Table 1. Continued.

Tribe	Tribal, common name (Description)	Scientific name or possible taxon	Associated plants or plant community	Use[1]	References[2]
Karuk	***Tuxuwai ixbahakaiwish***, Red-belted conk	*Fomes hemitephrus*	On conifer logs	T-buckskin polish	Schenck and Gifford 1952
Karuk	Turkey tail	*Fomitopsis cajanderi*		T-buckskin polish	Schenck and Gifford 1952
Karuk	(Tree shelf fungus)	Possibly *Fomes hemitephrus*		T-hides	Gifford 1939-1940
Karuk	(Red fungus)	Unknown		T-face and body paint	Driver 1939:333
Karuk	Black trumpet	*Craterellus cornucopioides*	Tanoaks, mixed hardwoods	F	L. Glaze, LFN 2010
Karuk	Lion's mane	*Hericium erinaceus*	Tanoaks, injured tissue	F	L. Glaze, LFN 2010
Karuk	American matsutake or tanoak mushroom	*Tricholoma magnivelare*	Tanoaks, mixed hardwoods	F	L. Glaze, AFN 2005; J. Peters 2005 in Lake 2007; Richards 1997
Karuk	Chanterelle-golden	*Cantharellus cibarius*	Douglas-fir/mixed conifer forests	F	L. Glaze, LFN 2010
Karuk	Coral fungus	*Ramaria* sp.	Douglas-fir/mixed conifer forests	F	Richards 1997
Karuk	Hedgehog	*Hydnum repandum*		F	Lake 2007
Karuk	Oyster or willow mushroom	*Pleurotus cornucopiae*	Hardwoods, alders and oaks	F	L. Glaze, LFN 2010; J. Peters 2005 in Lake 2007
Karuk	Morel	*Morchella* sp.		F	J. Peters 2005 in Lake 2007
Karuk	(Mushroom)	Unknown		F	Informant ''KS005'' in Karuk Tribe and Cultural Solutions 1999; USDA FS-1981 Interviews 298, 299 & 306; 1983 Interview 353
Kawaiisu	(Fungus)	Unknown	From pith of oaks	T-tinder	PAHMA, T.D. McCown collector (1929), Cat # 1-28028
Kumeyaay-Ipai (Northern Diegueño)	(Larger mushroom)	Unknown	Fields	F	Hedges and Beresford 1986:46

Table 1. Continued.

Tribe	Tribal, common name (Description)	Scientific name or possible taxon	Associated plants or plant community	Use[1]	References[2]
Kumeyaay-Ipai (Northern Diegueño)	(Small mushroom)	Unknown	On dead cottonwoods or black oaks	F	Hedges and Beresford 1986:46
Kumeyaay-Ipai (Northern Diegueño)	Unknown	Unknown	Stumps	F	J. Farmer, LFN 2010
Lassik	***Sakatne'lŭc***, Puffball	*Lycoperdon* sp.		M-to stop bleeding	Essene 1942:92
Lassik	***Kŭlkots***; ***Klotci***; and ***Tŭnla*** (3 Yellow mushrooms); ***Tŭntcai*** (White mushroom); ***Klantŭs*** (Large, flat mushroom)	Unknown		F	Essene 1942: 86
Luiseño	(Fungus)	Unknown	Decayed wood of Engelmann oaks	T-fire punk	Sparkman 1908
Luiseño	***Sakopis***, Oyster or willow mushroom	Possibly *Pleurotus cornucopiae*	Dead and live cottonwoods and willows	F	W. Pink, AFN 2010
Luiseño	(Tree fungus)	Unknown		F	Bean and Shipek 1978:552
Maidu	***Yoh'me'n wam***	Unknown		F	PAHMA, R.B. Dixon n.d., Cat. # 1-7421
Maidu	(Fungus)	Unknown		Unknown	PAHMA, R.B. Dixon n.d., Cat # 1-7435
Maidu	Unknown	Possibly *Polyporus* or related genus		F	Anderson 2005a, Cat. #16.1554, M. Wood and C. Thayer ocular ID 2005
Maidu (Dogwood Rancheria)	Unknown	Possibly Tricholomatacae		F	Anderson 2005a, Cat. # 16.1644, M. Wood and C. Thayer ocular ID 2005
Maidu	Unknown	Unknown- Russulaceae or Tricholomataceae		F	Anderson 2005a, Cat. # 16.2222 collected from L. Jack, M. Wood and C. Thayer ocular ID 2005

Table 1. Continued.

Tribe	Tribal, common name (Description)	Scientific name or possible taxon	Associated plants or plant community	Use[1]	References[2]
Maidu	Unknown	Possibly a Gasteromycetes		F	Anderson 2005a, Cat # 16.2365. M. Wood and C. Thayer ocular ID 2005
Maidu (Concow)	Puffball	Unknown		M-to stop bleeding	Duncan III 1964:24
Maidu (Concow)	***Jo'menwa***	*Amanita* sp.		F	Duncan III 1964
Maidu (Concow)	***Pulkowa*; *Pu·dony*; *Typi***	Unknown		F	Duncan III 1964
Maidu (Concow)	Unknown	*Polyporus* sp.	On the base of alder trees and logs	F	Chesnut 1974:300-301
Maidu (Concow)	Unknown	Unknown		F	Voegelin 1942:61
Maidu (Foothill)	Unknown	Unknown		F	Voegelin 1942:61
Maidu (Mountain)	(Fungus)	Unknown	On spruce	T-face and body paint	Voegelin 1942:83, 197
Maidu (Mountain)	(Red fungus)	Unknown	On firs	T-face and body paint	Dixon 1905:167
Maidu (Mountain)	Unknown	Unknown		F	Voegelin 1942:61
Maidu (Mountain)	***Wa-da-te*** (Bracket fungus)	Polyporaceae		F	McMillin 1956:111
Maidu (Mountain)	***Wam***	Basidomycetes		F	McMillin 1956:119
Maidu (Mountain)	Sierra puffball	*Calvatia sculpta*		F	McMillin 1956:120
Maidu (Mountain)	***Jo'menwa***	*Amanita* sp.		F	Duncan III 1964
Maidu (Mountain)	***Ba-chec-chec-eh*; *In-ca-sa-tee*; *Ko-la-wa*; *Kum-lay*; *Moon-too*; *Pol-ko*; *Pul-ka-tee*; *Tee-pee*; *We-le-le-wam***; and ***Yoh-men-wa***	Unknown		F	McMillin 1956:119
Maidu (Mountain)	***Be cek'ceke*; *Inkasaty*; *Kolewa*; *K'umle*; *Po-lko*; *Typi*; *Wa'date*; *Wylylywam***	Unknown		F	Duncan III 1964
Maidu (Mountain)	***Wawuku*** (Shelf fungus)	Unknown	White firs and black oaks	F	Duncan III 1964:25

Table 1. Continued.

Tribe	Tribal, common name (Description)	Scientific name or possible taxon	Associated plants or plant community	Use[1]	References[2]
Maidu (Neeshenams)	***Pūl'-kut*** (A little round ball from the size of a marble to a black walnut)	Unknown	Chaparral and pine thickets underground	F	Powers 1976
Maidu (Neeshenams)	***Wa'-chuh***	Unknown		F	Powers 1976
Maidu (Nisenan)	***Jo'menwa***	*Amanita* sp.		F	Duncan III 1964
Maidu (Nisenan)	***Bobol***; ***Tca·ngwá*** ; ***Wa'*** or ***Yú · wa***	Unknown		F	Beals 1933:353
Maidu (Nisenan)	***Bu·cukcuk***; ***Pulket***	Unknown		F	Duncan III 1964
Maidu (Nisenan)	***Ca·pakpak***	Unknown	Under manzanita bushes	F	Duncan III 1964
Maidu (Nisenan)	***Ca·nwa***	Unknown	On oaks or other trees	F	Duncan III 1964
Maidu (Nisenan)	***Wadat***	Unknown	On pine stumps	F	Duncan III 1964
Maidu (Nisenan)	***K'umle***; ***Po-lko***; ***Typi***	Unknown		F	Duncan III 1964
Maidu (Foothill Nisenan)	Unknown	Unknown		F	Voegelin 1942:61
Maidu (Mountain Nisenan)	(Fungus)	Unknown		T-face and body paint	Voegelin 1942:83
Maidu (Valley)	Unknown	Unknown		F-cooked with fish	Voegelin 1942:61, 512
Miwok	Unknown	Unknown		F	Godfrey 1941
Miwok (Me-Wuk)	Unknown	Unknown		F	Aginsky 1943
Miwok (Plains)	(Mushroom and tree fungus)	Unknown		F	Aginsky 1943:401
Miwok (Sierra)	***Elmayu*** (Red-edged yellow tree fungus)	Possibly *Laetiporus sulphureus*	On trunks of black oaks and water oaks (*Quercus lobata*)	M-cathartic and cure for rheumatism	Barrett and Gifford 1933:164
Miwok (Sierra)	(Conk?)	Unknown	Oaks	T-fire punk	Haslam 1911
Miwok (Sierra)	Sierran puffball	*Calvatia sculpta*		F	Russell 1924
Miwok (Sierra)	***Potokele*** and ***Patapsi***, Sierran puffballs	*Calvatia sculpta*		F	Barrett and Gifford 1933:163-64
Miwok (Sierra)	Two kinds unnamed	Unknown		F	Barrett and Gifford 1933:164

Table 1. Continued.

Tribe	Tribal, common name (Description)	Scientific name or possible taxon	Associated plants or plant community	Use[1]	References[2]
Miwok (Sierra)	***Atita*** (One foot in diameter with bulging stem); ***Awakayu*** (Puffball white inside); ***Helli*** (Large white with straight cylindrical stem); ***Kippisü*** (Small and tastes like an onion); ***Wunesati*** (Puffball yellow inside)	Unknown		F	Barrett and Gifford 1933:164
Miwok (Sierra)	***Sun-a-lk-a-loo*** or ***Sunokulu*** (Black mushroom)	Unknown	Under manzanita bushes	F	Barrett and Gifford 1933:164; Maniery 1983:192
Miwok (Sierra)	***Elmaiu*** (Fungus)	Unknown	Oaks	Unknown	PAHMA, S.A. Barrett collector (1906), Cat. # 1-9953
Miwok (Sierra)	Unknown	Unknown		Unknown-shredded and dried	PAHMA, S.A. Barrett collector (1906), Cat. # 1-10205
Miwok (Sierra)	Unknown	Unknown		Unknown	PAHMA, S.A. Barrett collector (1906), Cat # 1-10258
Miwok (Sierra)	Unknown	Unknown		Unknown-shredded and dried	PAHMA, S.A. Barrett collector (1906), Cat # 1-10290
Miwok (Sierra)	(Mushroom and tree fungus)	Unknown		F	Aginsky 1943:401
Miwok (Tuolumne Band of Me-Wuk)[3]	***Helli***	*Amanita calyptroderma*	Under ponderosa and sugar pines and California black oaks	F	T. Carsoner and P. Montgomery, AFN 2010
Miwok (Tuolumne Band of Me-Wuk)[3]	Coral mushroom	*Ramaria violaceibrunnea*	Under ponderosa pines and white firs	F	P. Montgomery, AFN 2010
Miwok (Tuolumne Band of Me-Wuk)[3]	Oyster or willow mushroom	Possibly *Pleurotus cornucopiae*	Dead and live alders, oaks and willows	F	P. Montgomery, AFN 2010

Table 1. Continued.

Tribe	Tribal, common name (Description)	Scientific name or possible taxon	Associated plants or plant community	Use[1]	References[2]
Miwok (Tuolumne Band of Me-Wuk)[3]	Sierran puffball	Possibly *Calvatia gigantea*		F	P. Montgomery, AFN 2010
Miwok (Tuolumne Band of Me-Wuk)[3]	White morel	Possibly *Morchella deliciosa* Fr.	In roads and after burns	F	P. Montgomery, AFN 2010
Miwok (Tuolumne Band of Me-Wuk)[3]	Shaggymane	Possibly *Coprinus comatus* (O.F. Müll.) Pers.		F	P. Montgomery, AFN 2010
Miwok (Tuolumne Band of Me-Wuk)[3]	Buckskin	Possibly *Boletus* sp.		F	P. Montgomery, AFN 2010
Miwok (Tuolumne Band of Me-Wuk)[3]	Truffle	Unknown	In the roots of California black oaks	F	P. Montgomery, AFN 2010
Miwok (Tuolumne Band of Me-wuk)[3]	Black morel	Possibly *Morchella elata*		Unknown	P. Montgomery, AFN 2010
Miwok (Tuolumne Band of Me-Wuk)[3]	Yellow morel	Possibly *Morchella esculenta* (L.) Pers.		Unknown	P. Montgomery, AFN 2010
Miwok (Southern Miwuk)	Bolete	*Boletus* sp.		F	Neely 1971
Miwok (Southern Miwuk)	Truffle	Unknown		F	Brubaker 1926

Table 1. Continued.

Tribe	Tribal, common name (Description)	Scientific name or possible taxon	Associated plants or plant community	Use[1]	References[2]
Miwok (Southern Miwuk)	***Paki*** (Mushroom has pink ribs and cream color on top)	Unknown	Open grasslands	F	Anderson 1988
Miwok (Southern Miwuk)	***Hahiya*** (Pine mushroom)	*Amanita calyptroderma*	Under ponderosa pines up through pine needles	F	N. Brocchini, L. James, J. Johnson, L. Kramer, and B. Tucker, AFN 1986-1987
Miwok (Southern Miwuk)	Oyster or willow mushroom	*Pleurotus cornucopiae*	On alders and willows	F	M. Spears, AFN 1987
Miwok (Southern Miwuk)	(Burnt-ground mushroom)	Unknown	Spring-In burned areas	F	M. Spears, AFN 1989
Miwok (Southern Miwuk)	Unknown	*Agaricus* spp.		F	Neely 1971
Miwok (Southern Miwuk)	Unknown	Unknown		F	L. Cramer, AFN 1986
Miwok (Southern Miwuk)	Unknown	Unknown	Under pines	F	M. Spears, AFN 1989
Miwok (Southern Miwuk)	(Cry baby mushroom)	Unknown	Under chaparral and manzanita bushes after a fire	F	K. Apling, AFN 1989
Miwok (Southern Miwuk)	(Bright orange mushroom)	Unknown	On black oaks	F	K. Apling, AFN 1989
Mono	(Red spruce fungus)	Unknown		T-paint	Aginsky 1943:415
Mono	Oyster or willow mushroom	Possibly *Pleurotus cornucopiae*		F	L. Bill, AFN 2006
Mono	***ToopO***, Coccora	*Amanita calyptroderma*	Under California black oaks, conifers, and pine needles and in burned areas	F	M. Beecher, H. Hutchins, and N. Turner Behill, AFN 1992

Table 1. Continued.

Tribe	Tribal, common name (Description)	Scientific name or possible taxon	Associated plants or plant community	Use[1]	References[2]
Mono	***Seexayu'***, Fried chicken mushroom	*Lyophyllum decastes*	Under white oaks, buckeyes, chaparral and scrub oaks	F	H. Hutchins and N. Turner Behill, AFN 1992; M. Coho, T. Lewis, AFN 2006
Mono	***Sorog***	*Neolentinus ponderosus*	On stumps	F	M. Beecher, AFN 1992
Mono	Sulfur shelf	*Laetiporus sulphureus*	On pine or black oak stumps	F	M. Beecher and H. Hutchins, AFN 1992
Mono (North Fork)	Brown field mushroom	Possibly *Agaricus cupreobrunneus* (Jul. Schäff. & Steer) ***Pilát***		F	Goode 1992
Mono (North Fork)	Cauliflower	Possibly *Sparassis crispa* (Wulfen) Fr.		F	Goode 1992
Mono (North Fork)	***No'ē***	Unknown	On black oak stumps and dead trees	F	R. Pomona: AFN 2006
Mono (North Fork)	***Pagu'***	Possibly *Agaricus bisporus*		F	Goode 1992
Mono (North Fork)	Giant puffball	Possibly *Calvatia gigantea*		F	Goode 1992
Mono (North Fork)	***Cuyu'***	*Morchella elata*	Burned areas	F	M. Jackson, A. Lewis, D. McSwain, A. Punkin and N. Williams, AFN 1991; Goode 1992
Mono (North Fork)	***Naqa'***, Boring brown cup fungus	Possibly *Peziza sylvestris*		F	Goode 1992
Mono (North Fork)	***ToopO***	*Amanita calyptroderma*		F	Goode 1992
Mono (North Fork)	Oyster	Possibly *Pleurotus cornucopiae*		F	Goode 1992
Mono (North Fork)	***Cayaakē'***	Possibly *Ramaria* sp.		F	Goode 1992
Mono (North Fork)	(Orange mushroom)	Unknown	On black oaks; come out after lightning and picked right away so it's not so rubbery	F	R. Bethel, AFN 1989

Table 1. Continued.

Tribe	Tribal, common name (Description)	Scientific name or possible taxon	Associated plants or plant community	Use[1]	References[2]
Mono (North Fork)	Unknown	Unknown		Unknown	P. and L. Conners, AFN 1991
Mono (Tuhukwadj)	***Napana*** (Fungus)	Unknown	Willow	Unknown	PAHMA, F.A. Riddell and F. Fenega collectors (1948), cat. # 1-102159. Collected from I. Dick
Mono (Wobonuch)	Morel	Possibly *Morchella elata*	Burned areas under pines and California black oaks	F	B. and E. Bowman, AFN 1991
Nomlaki	***Mi-mude*** and ***Kitmude*** (Big white mushroom and another kind)	Unknown		F	Goldschmidt 1951:408, 410
Nomlaki	Unknown	*Polyporus* sp.	On base of alder trees and logs	F	Chesnut 1974:300-301
Nongatl	(Red fungus)	Unknown		T-face and body paint	Driver 1939:333
Ohlone (Costanoan)	***Ah-sah-kwah*** (Mushroom)	Unknown		F	Heizer 1967b:383
Ohlone (Amah Mutsun Tribal Band)	(Tree mushroom; other mushroom)	Unknown		F	Anonymous Mutsun consultants, AFN 2011
Ohlone (Costanoan)	(Hongo)	Unknown		F	Bocek 1984
Ohlone (Costanoan)		Unknown		F	Mason 1912:121
Paiute (Mono Lake/ Sierra Miwok)	(Red fungus)	Unknown	On red firs in upper elevations of the Sierra Nevada	T-red pigment	PAHMA, C.D. Bates collector (no date), Cat # 1-236793
Paiute (Owens Valley)	Unknown	Unknown	Under cottonwood trees	F	R. Stone documented by B. Helmer, AFN 2011
Paiute (Owens Valley)	***Taw-Po***	Unknown	Tree trunks-pine trees and under sagebrush	F	J. Newlan in F. Essene 1936
Pit River (Achumawi)	(Fungus)	Unknown		T-face and body paint	Voegelin 1942:83

Table 1. Continued.

Tribe	Tribal, common name (Description)	Scientific name or possible taxon	Associated plants or plant community	Use[1]	References[2]
Pit River (Achumawi)	Morel	*Morchella* sp.		F	F. Buckskin 1986
Pit River (Ajumawi)	(Yellow mushroom)	*Amanita pantherina*		M (religious)	J.P. Harrington 1984 in Buckskin and Benson 2005:91
Pit River (Ajumawi)	***P'holk'oy*** (Mushroom)	Unknown		F	J.P. Harrington 1984 in Buckskin and Benson 2005
Pit River (Ajumawi)	***Mak mah ka 'ulah*** (Big red mushroom)	Possibly *Russula* sp.		F M	J.P. Harrington 1984 in Buckskin and Benson 2005
Pomo	Unknown	Unknown	Black oaks	T-bowls	Grace Hudson Museum Archives n.d.a
Pomo	***Pi-ko'tci***, Morel	*Morchella crassipes*		F	Grace Hudson Museum Archives n.d.b
Pomo	Unknown (Many kinds)	Unknown		F	Barrett 1952:93
Pomo (Calpella)	***Kä-lā' chā'-ā***	*Polyporus* sp.	On base of alders trees and logs	F	Chesnut 1974:300-301
Pomo (Calpella)	Unknown	*Boletus* sp.		F	Chesnut 1974:301
Pomo (Kalekau)	Unknown	Unknown		F	Essene 1942:7
Pomo (Kashaya)	Chanterelle	*Cantharellus cibarius*	Under pines	F	Goodrich et al. 1980
Pomo (Kashaya)	Cup fungus	*Aleuria aurantia*	Bare gravels, paths, lawns, and bare soil in woods	F	Goodrich et al. 1980
Pomo (Kashaya)	Hedgehog	*Hydnum repandum*	In rich soil and leaf mulch of pine and deciduous forests	F	Goodrich et al. 1980
Pomo (Kashaya)	King bolete	*Boletus edulis*	Rich leaf mulch in conifer and deciduous woods, especially under beech family trees	F	Goodrich et al. 1980
Pomo (Kashaya)	Meadow mushroom	*Agaricus bisporus*	Pastures and meadows	F	Goodrich et al. 1980
Pomo (Kashaya)	Oyster or willow mushroom	*Pleurotus cornucopiae*	On dead wood from leaf-bearing trees, especially of the beech family	F	Goodrich et al. 1980

Table 1. Continued.

Tribe	Tribal, common name (Description)	Scientific name or possible taxon	Associated plants or plant community	Use[1]	References[2]
Pomo (Kashaya)	Woodland agaricus	*Agaricus silvicolae-similis*	On the ground in the woods	F	Goodrich et al. 1980
Pomo (Kashaya)	Unknown	*Hericium coralloides* (Scop.) Pers.	Dead trunks of firs and beech family trees	F	Goodrich et al. 1980
Pomo (Little Lake)	Unknown	*Polyporus* sp.	On base of alders trees and logs	F	Chesnut 1974:300-301
Pomo (Northern)	***Kom tce é***	*Leucoagaricus americanus* (Peck) Vellinga	Under evergreen trees	F	Grace Hudson Museum Archives n.d.c
Pomo (Northern)	***Ka-li' tce é*** (Small reddish mushroom)	*Armillaria novae-zelandiae* (G. Stev.) Boesew.	On logs	F	Grace Hudson Museum Archives n.d.c
Pomo (Northern)	***Ta tce é*** (Common mushroom); ***Tea la' tce é*** (Pure white mushroom); ***Tsi-tăl' tci-é*** (Big edible mushroom—nine varieties eaten)	Unknown		F	Grace Hudson Museum Archives n.d.c
Quechan (Yuma)	***Ku cówc*** (Grayish, umbrella-shaped mushroom)	Unknown		F	Castetter and Bell 1951:201, 203
Quechan (Yuma)	***I dút*** (Fungus)	Unknown	On mesa in spring	F	Forde 1930-31
Salinan	Unknown	Unknown	On white oaks and cottonwoods	F	J. Campos, AFN 2002
Serrano	Unknown	Unknown	On cottonwoods	F	M. Lerch interviews with Martha Manuel Chacon (1979-1981) AFN 2012
Shasta	***Koo'-pah-mah*** (Mushroom)	Unknown- Varnish Conk?	On old firs	T-red dye	Heizer 1967a: 214, 216
Shasta	(Fungus)	Unknown	On knot or burl of white fir	T-face and body paint	Voegelin 1942:83, 197
Tolowa	Unknown	Unknown		F	USDA-FS 1981 Interview-310
Wailaki	American matsutake or tanoak mushroom	*Tricholoma magnivelare*		F	USDA-FS 1983 Interview-359

Table 1. Continued.

Tribe	Tribal, common name (Description)	Scientific name or possible taxon	Associated plants or plant community	Use[1]	References[2]
Wailaki	Unknown	*Polyporus* sp.	On base of alders and logs	F	Chesnut 1974:300-301
Wailaki	Unknown	Unknown		F	K. Heffner, Lake 2007
Wappo	***Hol-tsêma***, Wood ear	Unknown		F	Driver 1936:187
Washoe (Hungalelei)	Morel and Puffball (Young)	Unknown		F	D. Cruz, AFN 2012
Wintu	(Fungus)	Unknown	On bark of white fir	T-face and body paint	Voegelin 1942:83, 197
Wintu	Unknown	*Agaricaceae*		F	Knudtson 1992
Yana	***Yah'poon-nah***, Puffball	*Calbovista subsculpta* Morse ex M.T. Seidl		F	Elsasser 1981:72
Yokuts	Unknown	Unknown		F	Gayton 1948:37,40
Yokuts (Foothill-Chuckchansi)	***Ha-hi***	Unknown	Burned areas	F	R. Cordero and C. Jones, AFN 1991
Yokuts (Foothill-Chuckchansi)	(Mushroom yellow on top and black underneath)	Unknown	Burned areas	F	R. Cordero, AFN 1991
Yokuts (Foothill-Chuckchansi)	***Colosu*** (Yellow and orange mushroom)	Unknown	Burned areas	F	C. Jones, AFN 1989
Yokuts (Foothill-Chukchansi)	(Mushroom and tree fungus)	Unknown		F	Aginsky 1943:401
Yokuts (Foothill-Chukchansi)	***Peti*** (Fungus)	Unknown	From trees	Unknown	PAHMA, A.L. Kroeber collector (1904), Cat # 1-4045
Yokuts (Valley)	(Red spruce fungus)	Unknown		T-paint	Aginsky 1943:415
Yokuts (Valley)	(Mushroom and tree fungus)	Unknown		F	Aginsky 1943:401
Yokuts (Yelahmani)	(Willow tree mushroom)	Unknown		F	F. Nieto, AFN 1992
Yokuts (Yelahmani)	(Live oak mushroom)	Unknown	On live oaks	F	F. Nieto, AFN 1992
Yokuts (Yelahmani)	(Pine mushroom)	Unknown	On old log	Unknown	F. Nieto, AFN 1992
Yokuts	Unknown	Unknown		F	Mason 1912:121
Yuki	Puffball	*Lycoperdon* sp.		M	Chesnut 1974
Yuki	Unknown	*Polyporus* sp.	On alders	F	Chesnut 1974:300-301
Yuki	***Kä'-ē***	Unknown	Forests of oaks and madrones	F	Chesnut 1974:302

Table 1. Continued.

Tribe	Tribal, common name (Description)	Scientific name or possible taxon	Associated plants or plant community	Use[1]	References[2]
Yuki	Unknown	Unknown		F	Essene 1942:7
Yurok	***Wagins*** (Fungus)	Unknown	Red fir	Unknown	PAHMA, S.A. Barrett collector (1907) Cat # 1-12720
Yurok	(Red fungus)	Unknown		T-face and body paint	Driver 1939:333
Yurok	Black trumpet	*Craterellus cornucopioides*	Tanoaks, mixed hardwoods	F	C. Peters, Lake field notes 2010
Yurok	Chanterelle	*Cantharellus cibarius*	Fir and spruce forests	F	C. Peters, LFN 2010; Yurok Tribe Newsletter Nov. 2010
Yurok	Hedgehog	*Hydnum repandum*	Fir and spruce forests	F	C. Peters, LFN 2010; Yurok Tribe Newsletter Nov. 2010
Yurok	King bolete	*Boletus edulis*	Conifer forests	F	C. Peters: LFN 2010; Yurok Tribe Newsletter Nov. 2010
Yurok	Meadow mushroom	*Agaricus bisporus*		F	C. Peters, LFN 2010
Yurok	Oyster or willow mushroom	*Pleurotus cornucopiae*	Riparian-dead alders	F	C. Peters, LFN 2010
Yurok	American matsutake or tanoak mushroom	*Tricholoma magnivelare*	Mixed hardwoods, conifers, rhododendrons	F	C. Peters, LFN 2010; Yurok Tribe Newsletter Nov. 2010
Yurok	Unknown	Unknown	Mixed hardwoods, conifers	F	USDA-FS 1981 Interview-293
Yurok	Unknown	Unknown		F	O. Foseide, Lake 2007; USDA FS 1981 Interviews 301, 303

[1]Use: F = Food, T = Technology, M = Medicine.
[2]Reference abbreviations: AFN = Anderson Field Notes, LFN = Lake Field Notes, PAHMA = Phoebe Apperson Hearst Museum of Anthropology.
[3]Tuolumne Band of Me-wuk is one of the Central Sierra Miwok tribes.

Figure 1. Map showing the widespread use of mushrooms among California Indian tribes.

''excellent foods.'' But he failed to record any species, saying, ''no opportunity to identify these 'right kinds' presented itself.'' There are probably a number of reasons for these slights or omissions. First, the science of mycology at the University of California, Berkeley (UCB), where most of the major anthropological studies of California Indian tribes were conducted, was not well developed during the most productive period of these investigations, between 1903 and 1975 (Heizer 1978). In 1939, Lee Bonar, a pioneer in California mycology, compared our knowledge of the state's mycota with that of its flora, emphasizing the overwhelming need for the systematic collection and study of fungi, and according to mycologist Peter Werner (2007), this is just as true today. An accessible (not technical) mushroom identification text for California was lacking until 1985 (Tom Bruns personal communication 2011). Second, mushrooms are highly seasonal and variable, dependent on certain kinds of ecological conditions, and unlike plants in a plant press, they spoil quickly when harvested. In historic times, it would have taken extra effort to collect specimens and identify them taxonomically before spoiling, given no rapid transportation or mailing services across many areas of the state. Third, there is a negative mystique around mushroom use, as the fear of being poisoned has kept many westerners from learning about their virtues. Fourth, there is also the popular, but mistaken notion, that mushrooms are empty calories offering little or no nutrition. Finally, mushrooms may not have been an important component in the diet, medicine chest, or technologies of some California Indian tribes.

Today native people of different tribes remember their families gathering mushrooms, but the specific scientific identifications are lacking. Given the sparse ethnographic research on the topic of mushrooms and lack of mushroom identifications in the literature, it is conceivable that many more species were gathered and utilized in various ways than what we describe and tally here. Hints of the significance of mushrooms in the traditional diet, for instance, are found embedded in cultural values and societal organization of certain tribes. For example, Sierra Miwok rituals were performed before the eating of the first crop of particular mushrooms (Barrett and Gifford 1933:164). The mention of edible mushrooms in tribal myths, such as among the Chilula, may also refer to their importance and possibly the antiquity of their use (Kroeber 1976:269).

Medicines

Certain mushrooms that California Indians used and continue to use are an important source of biological active compounds of medicinal value, having antioxidant, antimicrobial, antitumor, and antimutagenic benefits (Barros et al. 2008; Grüter et al. 1990; Ko et al. 2005). They can boost the immune system, lower high blood pressure, and increase defenses against viral infections and cancer (Cheung 2008; Yang 2011), and particular mushrooms may have topical, in addition to internal, benefits. It is no wonder then, that some California Indians valued mushrooms for their healing properties. For example, cooked mushrooms and their broth were fed to the sick and elderly among the Mono as recalled by Norma Turner Behill, Mono/Dumna:

> Up at Tamarack Flats there is a mushroom [possibly wood ear *Auricularia auricula-judae* (Bull.) Quél.] that grows on dead pines and firs. This mushroom is used for healing —boil it and drink the broth. One time I had blood poisoning. I soaked my leg in it and drank the broth. ***Naqa'*** is 'ear' in Mono. It can be used as a poultice on burns (Anderson unpublished field notes 2006).

The Yuki applied the spores of puffballs (*Lycoperdon* sp.) to dry up running sores (Chesnut 1974). In the 1940s, Lucy Young, Lassik, described how her tribe used puffballs medicinally when a woman was shot in the mouth with an arrow: ''An uncle of the woman pulled out the arrow…. ***Sakatne'lŭc*** (puffballs, a fungus) were gathered, ground up into a powder, and rubbed into the wound. This stopped the bleeding'' (Essene 1942:92). The Sierra Miwok made a decoction of the red-edged yellow tree mushroom, called ***elmayu*** (possibly *Laetiporus sulphureus* (Bull.) Murrill) and drank it as a cathartic and a cure for rheumatism. The mushroom was also used as a poultice (Barrett and Gifford 1933:164).

Technological Uses

Mushrooms supplied the raw material for some native technologies. They played a role as tinder, especially the polypores which when ground up and added to a friction-fire generated coal, can extend its life (Storm 2004). For example, Sparkman (1908:233) recorded the Luiseño starting a fire with a fungus growing on the decayed wood of Engelmann oak (*Quercus engelmanni* Greene). Mushrooms also served as a medium for carrying fire. When moving, the Central Sierra Me-Wuk carried fire in a kind of punk, a mushroom procured from the dead stumps or exposed roots of oak trees. According to Mrs. L. Haslam (1911:11), ''A small coal of fire inserted in this punk would keep for days if kept dry.''

The Karuk found the red-belted conk (*Fomes hemitephrus* (Berk.) Cooke) on conifer logs. The white underside of this fungus was peeled off and rubbed on buckskin to polish or smooth the skin. *Fomitopsis cajanderi* (P. Karst.) Kotl. & Pouzar was used in the same way (Schenck and Gifford 1952:377). A fungus on the California black oak (*Quercus kelloggii* Newberry) caused a gnarl which the Pomo cut off, hollowed with fire, and used for cups, bowls, and other housewares (Grace Hudson Museum Archives n.d. a). Many tribes used a mushroom (species unidentified) to make a brilliant red pigment mixed with water or grease for painting the face and body for dances and other events (Dixon 1905:167; Driver 1939:333; Heizer 1967a:214, 216). An Indian shaman encountered by V.K. Chesnut in 1902 in Mendocino County, used the leathery outer covering of a puffball (*Lycoperdon* sp.) to encase small pieces of stone, securely fastening them to a stick to make a rattling sound.

Foods

Mushrooms were likely an important part of the traditional cuisine of certain California tribes, yet they are probably the least known of all the terrestrial foods recorded by anthropologists (Table 1). Mushrooms were a dietary supplement in some tribes, but in others, such as among the Mono, they were much more substantial, having all the attributes of a staple food: they have important nutritional value; they can be gathered in large quantities; they dry and store well; and in many cases they occur in the same areas repeatedly, providing a predictable harvest. N. Turner Behill remembered as a child that her family gathered a lot of ***seexayu'*** (*Lyophyllum decastes* (Fr.) Singer): ''After drying them we usually had two 25 pound flour sacks that would be filled.'' Her family harvested the same amount of willow mushrooms each year (Anderson unpublished field notes 2006). Ron Goode, North Fork Mono, said: ''Dad and Mom would gather three or four grocery bags half full of one kind of mushroom. They'd check the same crop several times and they might get several harvests in the same season. A season might last a month and a half. They gathered nine or ten different kinds of mushrooms'' (Anderson unpublished field notes 2012). Mushrooms were often gathered while collecting other seasonally available foods. Mildred Nixon, Hupa, recalled: ''…we were taught how to go out in the mountains to find food, different kinds of food and picked up acorns. … And then we always found mushrooms. And whatever we found out in the woods we brought it home and ate'' (Lake 2007:570). Among the Karuk: ''People used to gather huckleberries, mushrooms, and especially tanoak acorns [during the same outing]…'' (USDA-FS 1983 Interview-353).

Harvesting, preparation and consumption of mushrooms by various California tribes ranged from yearly to seasonal to daily practices. For example, the daily diet of the Central Sierra Me-Wuk during the early historic period included manzanita berries, black mushrooms, quail, salmon, bulbs, and leafy greens (Maniery 1983:194). In southern California among the Luiseño, mushrooms provided an important food supplement (Bean and Shipek 1978:552).

Having such a hearty flavor, mushrooms are likened to meat. Born in 1871, Jennie Newlan, Owens Valley Paiute, told anthropologist Frank Essene (1936), ''This edible plant [***taw-po***, a mushroom] grows anywhere, on tree trunks, and also [on the] ground, the older people gather these on pine tree trunks or under sage brush. It is gathered cleaned and boiled and salted and eaten. They say it has the flavor of the meat.'' Today Central Sierra Me-Wuk elder Phyllis Montgomery says, ''the willow [oyster] mushrooms [possibly *Pleurotus cornucopiae* (Paulet) Rolland formerly *P. ostreatus*] are like a steak —they're chewy'' (Anderson unpublished field notes 2010). Generally, protein concentrations in mushrooms range from 1 to 4% of fresh weight, or about 10–45% of dry weight, a significant amount (Hobbs 1995:54–55). For the amount of crude protein they provide, mushrooms rank below animal meats but well above most other foods, including milk (Chang 2008). Additionally, mushroom protein contains all of the nine essential amino acids required by the body (Cheung 2008). They are high in fats, phosphorus, copper, iron, various trace elements, and such vitamins as B, D, K, thiamine, riboflavin, ascorbic acid, ergosterol, and niacin (Arora 1986; Barros et al. 2008; Cheung 2008).

Throughout the year, mushrooms provided an important accompaniment to acorn, venison, elk, fish, nuts, and other foods. For example, the Valley Maidu cooked mushrooms with fish (Voegelin 1942:180). The Central Sierra Me-Wuk ''used a bowl mortar and pestle to pulverize deer meat to combine with the mushrooms. This meal was quite popular…'' (Maniery 1983:192). The Central Sierra Me-Wuk and North Fork Mono mixed hazelnuts or pine nuts with mushrooms of various kinds (Aginsky 1943:455). The Nisenan Maidu dried ground mushrooms and tree fungi to flavor acorn soup in the winter (Beals 1933:351).

Traditionally, mushrooms were kept whole, sliced, or shredded and were cooked in various ways: baked on hot stones, roasted or broiled on live coals, or made into a mush by boiling (Barrett 1952; Castetter and Bell 1951; Foster 1944;

Goodrich et al. 1980). Some mushrooms were also eaten raw. For example, the Pomo harvested the yellow morel called ***pi-ko'tci*** (*Morchella crassipes* Schwein. & Cooke) and ate it fresh as a confection, and it was reputed to be sweet (Grace Hudson Museum Archives n.d. b) —although, due to toxic compounds, the consumption of fresh, uncooked morels is not recommended as it may cause intestinal discomfort (Pilz et al. 2007:62). Certain mushrooms were poisonous if eaten uncooked, and special methods were employed to remove their toxicity. According to the Sierra Miwok, the red-edged yellow tree fungus (possibly *Laetiporus sulphureus* (Bull.) Murrill) was eaten only after boiling, squeezing, and salting because if eaten raw, could cause vomiting (Barrett and Gifford 1933:164).

Many tribes dried mushrooms for future use, placing them on rooftops in baskets in the sun, or by a campfire, strung on a string, or skewered on sticks (Anderson 2009; Beals 1933:351; Lake 2007; Maniery 1983:192). When dry, mushrooms were stored indoors in porous baskets or outdoors in structures similar to granaries (Duncan III 1964:21). Dried mushrooms were then pounded in bedrock mortars and added to soups or boiled in baskets with hot rocks (Duncan III 1964:21). For example, when the Southern Miwuk wanted to eat their dried shredded mushrooms they boiled and ate them with mineral salt or ground and cooked them as a soup (Godfrey 1941). In 1983, a Wailaki elder shared how she gathered American matsutake, also known as tanoak mushrooms (*Tricholoma magnivelare* (Peck) Redhead), each fall and either dried or canned them (USDA-FS 1983 Interview-359). These preservation techniques are still used by other northern California Indian tribes (Lake 2007; Richards 1997).

The staying power of mushrooms in Native American diets is remarkable. Mono families still gather, for example, fluted black elfin saddles (*Helvella lacunosa* Afzelius) and ***seexayu'***, also known as fried chicken mushrooms (Figure 2) (Anderson unpublished field notes 2008). The Karuk continue to gather golden chanterelles (*Cantharellus cibarius* Fr.), black trumpets (*Craterellus cornucopioides* Persoon), lion's mane (*Hericium erinaceus* (Bull.) Pers.), hedgehogs (*Hydnum repandum* L: Fr.), and oyster mushrooms (Lake 2007, unpublished field notes 2010, 2012), and the Yurok still gather golden chanterelles, hedgehogs, king boletes (*Boletus edulis* Bull.), and meadow mushrooms (*Agaricus bisporus* (J. E. Lange) Imbach) (Lake unpublished field notes 2010; Yurok Tribe Newsletter 2010). The Tuolumne Band of Me-Wuk still gather the coral mushroom (*Ramaria violaceibrunnea* (Marr & D. E. Stuntz) R. H. Petersen) under ponderosa pines (*Pinus ponderosa* Lawson & C. Lawson) and white firs (*Abies concolor* (Gordan & Glend.) Hildebr.) in the central Sierra Nevada mountains (Figure 3) (Phyllis Montgomery, Anderson unpublished field notes 2010).

Particularly important among the northwestern California tribes are the American matsutake, harvested predominately under tanoaks (*Notholithocarpus densiflorus* (Hook. & Arn.) Manos et al.); the coccora (*Amanita calyptroderma* G.F. Atk. & V.G. Ballen) among the Mono and Southern Sierra Miwuk found in association with ponderosa pines, sugar pines (*Pinus lambertiana* Douglas), and California black oaks; and the willow or oyster mushroom, growing from dead hardwoods, which is still gathered by many tribes.

Today, mushrooms are boiled or fried with garlic and onions and eaten with tortillas or they flavor soups, meats, and pastas. They are sautéed with butter and

Figure 2. Melba Beecher, Mono, holding fried chicken mushrooms (*Lyophyllum decastes*) in Sierra National Forest, 2006. Photograph by M. Kat Anderson.

flour to make gravy over rice, or stir-fried with vegetables. They are still eaten with acorns. Melba Beecher, Mono, describes another modern way to eat them as a healthy snack food: ''In the wintertime when you run out of nuts or raisins, you pull out the dried mushrooms and boil them and put salt on them or dip them in salsa and eat them while you watch T.V.'' (Anderson unpublished field notes 2006).

Some contemporary mushroom harvesters have adopted uses of taxa not recorded as historically used by their tribal groups. Similar to non-tribal novice mycologists/collectors, tribal people today use field guides, attend mushroom fairs and workshops, and then try new types of mushrooms and culinary preparations (Lillian Rentz and Janet Morehead (sisters), Karuk, Lake unpublished field notes 2012). In these ways, the (neo-) traditional mycological knowledge of tribal communities is adaptive and responsive to the available mycological science, forest management, and recreational, subsistence, or commercial experiences of the general public.

Strategies of Mushroom Harvest

Many kinds of mushrooms, such as ***sorog*** (*Neolentinus ponderosus* (O.K. Mill.) Redhead & Ginns), appear in the same places year after year, arising from the surfaces of rotting wood, dead stumps, snags, or downed logs during the long process of decomposition. Other mushrooms arise from the ground and have long-

Figure 3. Phyllis Montgomery, Central Sierra Me-Wuk, with a coral mushroom (*Ramaria violaceibrunnea*) in Stanislaus National Forest, 2010. Photograph by M. Kat Anderson.

term associations with trees, shrubs, and grasses (Douhan et al. 2005; Hynes et al. 2010; Plamboeck et al. 2007). Thus, many California Indians have special areas that they repeatedly visit (Anderson 2009; Richards and Creasy 1996). ''These sites are hundreds of years old,'' said N. Turner Behill, regarding mushroom gathering areas (Anderson unpublished field notes 2006). Tom Carsoner, Central Sierra Me-Wuk, described his mushroom gathering sites as ''a garden'' because ''you always know where to go'' (Anderson unpublished field notes 2010). Because some edible mushrooms resemble and can be confused with toxic varieties, the Pit River tribe (Ajumawi band) of northeastern California had family plots to which they regularly returned to harvest certain types (Buckskin and Benson 2005:91).

There are several indigenous harvesting strategies that were and still are practiced in California. These include: 1) use of specific harvest technologies; 2) moderating intensity of harvest by leaving some mushrooms (e.g., young buttons and old, rotten ones) and leaving the stems behind and covering them with soil, litter or duff, while being careful to leave ''threads'' (mycelium) under the ground undisturbed; and 3) dispersing some of the mushroom spores around the site and new locations.

Appropriate Harvest Technologies

Several tools were traditionally used for mushroom harvesting. The human hand was used for breaking off or twisting the mushroom out, while employing a stick to poke and uncover those mushrooms lightly draped with litter, was a precaution to ensure they were mushrooms and not snakes (Anderson 1993). Stone knives were used for cutting the stem of the mushroom. Scrapers were used for retrieving mushrooms growing on trees or downed wood, as Pauline Conner, North Fork Mono, described: ''On the black oak tree there was this unusual yellow mushroom. You take a scraper and knock it off. Lily [Conner's mother] gathered it in the spring. It looked puffy and it was stuck on the tree. They could get long, one and one-half feet, and it was slick to the touch'' (Anderson unpublished field notes 1991).

Contemporary tribal mushroom harvesters use knives, scissors, trowels, sticks, or hands to gather mushrooms. They recognize that shovels and rakes can be destructive and purposefully do not use them on particular mushrooms (Anderson 2009; Richards 1997). For example, the deep raking of humus, moss, and soil in search for buried mushroom buttons and immature fruit bodies (e.g., American matsutake) was and is generally discouraged. These unopened buttons have not yet formed spores and raking can damage the mycelium in the upper layers of the soil, affecting future harvests.

Intensity of Harvest

Certain practices based on tribal beliefs are adhered to when picking mushrooms. Individuals interviewed take primarily only the bigger mushrooms, allowing younger mushrooms to grow larger. N. Turner Behill instructed the gatherer in harvesting ***naqa'***: ''Cut off the stem and only take the bigger ones'' (Anderson unpublished field notes 2006). Marie Coho, Mono, said: ''The willow mushrooms down here below North Fork are harvested now. You only pick the biggest one —usually the lowest layer and leave the other ones to grow bigger'' (Anderson unpublished field notes 2006).

Indigenous gatherers also are instructed to spare some mushrooms for tomorrow and leave some for the other animals. Tillie Lewis Mono/Chukchansi said: ''Don't take all the mushrooms —if you do you're not going to have any more'' (Anderson unpublished field notes 2006). This strategy preserves the genetic diversity of the mushrooms by leaving some for spore activity. Each fruiting body produces millions of tiny spores that are spread by the wind, water, and animals. Spore dispersal is the major way for mushrooms to outcross, leading to high levels of genotypic diversity. Furthermore, this native practice is considerate of wildlife that also feed on the mushrooms. Over-mature mushrooms growing from the ground that are too woody, decaying, or full of insects or mollusks are left alone. They still provide spores that will germinate and thrive when the environmental conditions are suitable.

For mushrooms that are ready to pick, the cap and part of the stalk is removed and the remaining stem is re-covered with soil and duff or leaf litter so

Figure 4. LaVerne Glaze, Karuk/Yurok, with American matsutake mushrooms (*Tricholoma magnivelare*). Photograph by Frank K. Lake.

that ''no one can see that you have been there'' (Richards and Creasy 1996:368). Southern Sierra Miwuk mushroom gatherers are aware of the mycelium under the ground that their grandmothers said were important not to disturb (Anderson 1988). California Indians knew to protect the underground portion of the mushrooms, which in turn produces the aboveground edible fruiting body. All of these rules are remembered by indigenous mushroom harvesters and are still practiced by the Karuk, Mono, Southern Sierra Miwuk, Tuolumne Band of Me-Wuk, Washoe, Yokuts, and Yurok. LaVerne Glaze, Karuk/Yurok, said, ''We were taught by my folks to cut them [American matsutake] off with a knife at the ground level and cover them up with the duff. They said to leave the ones that had flowered out —they were better left alone. Once they have really opened up they get buggy'' (see Figure 4) (Anderson unpublished field notes 2005). M. Beecher, said that in harvesting ***cuyu'*** (*Morchella elata* Fr.), ''[if] you leave the stem, next year it will probably be in the same place'' (Anderson unpublished field notes 1992). T. Carsoner learned how to gather mushrooms from his Aunt Etta Fuller (Northern Sierra Me-Wuk) who was born in 1900: ''If you don't take care of the mushrooms, they won't take care of you'' (Anderson unpublished field notes 2010). Darrel Cruz, Hungalelei Washoe, was instructed by his elders to ''snip them [mushrooms] at the base in order to leave the roots there'' (Anderson unpublished field notes 2012). Mushrooms, such as the willow or oyster mushrooms, that grow on dead downed wood or snags must also be gathered with care. Lawrence Bill, Mono/Yokuts, learned how to judiciously gather willow or oyster mushrooms from his mother: ''I watched my mother leave the stump of the mushroom behind'' (Anderson unpublished field notes 2006).

According to N. Turner Behill: ''The places where the mushrooms are thickest, are the places where we gather them. Gathering doesn't hurt them and I leave a little offering and say a little prayer'' (Anderson unpublished field notes 2006). Studies confirm that the harvest of fungal fruiting bodies, without raking, does not negatively affect future harvests in the short-term and may even have a slight stimulating effect (Arora 1995; Egli et al. 2006; Norvell 1992). However, technique and tool used are extremely important. A study that compared different harvesting techniques of American matsutakes demonstrated that careful picking, with gentle rocking and pulling and minimal disturbance to the litter layer, was not detrimental to mushroom production during the initial ten years of mushroom harvest activity. On the other hand, one-time treatments in which the forest-floor litter layers were removed by heavy, deep raking and not replaced, appeared to be strongly detrimental, with the effects persisting for nine years (Luoma et al. 2006). However, no statistically-based monitoring information exists about the cumulative impacts of intensive and widespread commercial harvesting over longer periods (Pilz and Molina 2002).

Humans as Dispersal Agents

Many kinds of mammals are vectors of mushroom spores (Grove 2002; Maser et al. 1978; Schigel 2009). Humans incidentally disperse spores by carrying mushrooms to different harvesting areas or returning home with their harvest. The Concow Maidu, for example, dried mushrooms on milkweed fiber strings which they passed through the mushrooms and hung between bushes. The Nisenan Maidu skewered mushrooms on twigs on shrubs (Beals 1933). Anthropologist John Whitfield Duncan III (1964:21) described a typical camp as ''surrounded by bushes heavily weighted down with drying fungi.'' At least one tribe, the Karuk, deliberately spread the spores of various mushrooms as well. They scattered the rotten caps of American matsutake mushrooms downhill to lengthen the fruiting line (Richards 1997).

Complexity of Indigenous Knowledge about Mushroom Harvesting

Indigenous knowledge of mushroom gathering was an intricate system that took into account weather patterns, elevation, environmental site criteria, habitats, substrates, soil types, plant associations, wildlife, and ecological relationships. Tribal peoples likely learned which mushrooms were edible by observing wildlife consuming mushrooms. For instance, the Karuk tell of how they learned to eat particular mushrooms by watching deer forage (Richards 1997).

The ability to distinguish between edible and poisonous mushrooms by shape, color, smell, texture, and size was keen, as demonstrated by the indigenous use of *Amanita calyptroderma* and *Agaricus silvicolae-similis* Bohus & Locsmándi, both of which could be confused with the more deadly *Amanitas* that are similar in appearance. Mushroom color was sometimes an indicator of age as Ruby Pomona, North Fork Mono, points out: ''***No'ē*** is a mushroom that is yellow when it's young and orange when it's too old. You find it on black oak stumps or dead trees. The mushroom is in layers'' (Anderson unpublished field notes 2006).

Tribal people describe different criteria and various methods for evaluating the suitability of habitats for where, when, and under what conditions different mushrooms are likely to be found. For example, physical clues are used, such as time since last precipitation, temperature, humidity, soil, slope, or aspect of terrain. They also utilize biological clues such as forest stand density, canopy cover, tree age or size, abundance and distribution of woody material, and duff/litter quality of the forest floor. Additionally, clues regarding ecological relationships were employed, such as the presence of particular wildlife, associations with certain plants, or severity or type of disturbance history at the site, such as time since last fire. One pattern that emerges regarding tribal peoples is that intergenerational knowledge about mushroom harvesting and use comes from collective site-specific geographic experiences.

Seasonality

Edible mushrooms were gathered year round, demonstrating native people's sophisticated knowledge of how meteorological and seasonal patterns (e.g., weather patterns and day length) are connected with different ripening times. The optimal season for many varieties was following fall and winter rains. Following fall precipitation, ground fruiting American matsutakes, white and golden chanterelles, coccoras, and boletes were harvested. Wood-fruiting sawtooths were harvested generally in the fall to early winter. The potential time of harvesting for most mushrooms may have extended throughout mild winters into the spring. For example, black trumpets and hedgehogs fruit from late winter to spring. Other mushrooms, such as black morels, fruit in the spring or early summer. However, the extent and relative abundance of morel patches are correlated with disturbances such as fires or soil pH (L. Glaze, Lake unpublished field notes 2010). Oyster mushrooms fruiting from decomposing wood are likely dependent on humidity and temperature regimes (Richards 1997), and could be harvested in the fall, spring, or summer. T. Lewis explains, ''They [oyster or willow mushrooms] are harvested when the fog sets in —in October or November'' (Anderson unpublished field notes 2006).

Similar to gathering plant foods, mushroom harvesting spurred Indians to pay attention to environmental cues, often gaining hints to mushroom ripening. According to Lorraine Cramer, Southern Sierra Miwuk/Mono Lake Paiute, a sure sign that the mushrooms are out is when the ferns start coming up (Anderson unpublished field notes 1986). Mary Spears, Southern Sierra Miwuk/Yokuts, learned from her grandmother that the mushrooms under the pines are ready when the black oaks are leafing out (Anderson unpublished field notes 1989). M. Beecher would agree: ''It is time to go looking for ***toopO*** [*Amanita calyptroderma*] because the black oaks are leafing out'' (Anderson unpublished field notes 2006). According to the Pit River tribe (Ajumawi band): ''When the red bells, Johnny-jump-ups, and dogwood start to bloom, the mushroom hunts can begin'' (Buckskin and Benson 2005:89). Among the Karuk, coral mushrooms (*Ramaria* sp.), called ''grandmas,'' generally precede the fruiting of American matsutake and are used as an indicator to gauge optimal time for harvesting (Richards 1997). According to T. Carsoner, ''Mothers [inedible mushrooms identified as *Collybia butyrea*] are harbingers of the mushrooms to come —the most important of which are the ***helli*** [*Amanita calyptroderma*]'' (Anderson unpublished field notes 2010).

Habitats and Substrates

California Indians gathered mushrooms from sea level to mountaintops, across diverse vegetation types: valley grasslands, montane meadows, chaparral, forests, and along streams. Within these habitats, useful mushrooms were found on a variety of soil types and live or dead plant tissues. Sometimes the same kinds of mushrooms were and continue to be harvested from different soil or wood substrates (Richards 1997). For example, American matsutake mushrooms are harvested both on shale soils and decomposed metamorphic-red clay soils in a similar geographic area, although those on shale soil are generally harvested earlier in the fall. A Karuk elder said: ''You look for places where they [American matsutakes] are buried in red dirt [clay] or shale. Someplace where it is not real damp but where it doesn't dry out. They come in after it rains where the soil holds the moisture'' (Richards 1997:7). Other factors correlated with mushroom abundance and harvest were stand composition and surface litter/duff (fuel load) which potentially affect soil pH. For example, according to T. Carsoner, his relatives ''would gather ***helli*** in the spring. In the fall they would rake the acorns into a pile with a branch, then scratch for the acorns in the duff, pulling them out and leaving the duff behind. Where the rows of duff were —the mushrooms would be thick'' (Anderson unpublished field notes 2010).

Other mushrooms are found only on dead trees, on the ground, or only in burned areas. According to N. Turner Behill: ''***Cuyu'*** is scattered —not together. Twenty-five or thirty are scattered in one area. They grow in meadows and under the sugar pines and cedars from 3000 to 7000 ft. by Huntington Lake. They come up good after a burn. After a burn we knew there were going to be a lot'' (Anderson unpublished field notes 2006).

Because some kinds of mushrooms (saprotrophic) appeared on the same dead wood year after year, snags, downed logs, and rotting wood of oaks and conifers were left in place to provide a continuous food supply. For example, willow or oyster mushrooms will repeatedly fruit from rotting alder (*Alnus* sp.), tanoak or willow snags and logs until the decay is too advanced. According to T. Lewis: ''The willow mushrooms are on old trees and logs. You leave the downed willows because that's where they grow'' (Anderson unpublished field notes 2006). Lion's mane can be found growing from injured tissues (bark/wood interface) year after year at the same wound spot on the same hardwood tree (such as a tanoak), provided the local habitat conditions of the individual tree are maintained (Lake personal observation/harvesting with L. Glaze). Recent research on American matsutakes indicates that different factors affect mushroom abundance at spatial and temporal scales, ranging from the site to the forest stand and across the landscape, even regionally (Amaranthus et al. 2000). Tree and shrub composition, diameter, and height, as well as forest structure and canopy cover, are important indicators of where particular mushrooms will be located, and when (Lake 2007).

Ecological relationships

Indigenous people observed and monitored particular environmental or meteorological conditions such as precipitation and temperature (Lake 2007; Richards 1997). California Indians correlate the fall rains, coupled with dry/cold and warm/moist weather patterns with stimulation of mushroom fruiting (Paulides 2008; Richards 1997). Scientific studies substantiate these broad-level weather phenomena that directly affect soil or wood moisture and temperature properties, thus stimulating or suppressing fungal fruiting potential (Pilz and Molina 2002; Pinna et al. 2010). Tribal harvesters have accumulated intergenerational knowledge about particular locations, disturbances or growth conditions that foster or provide suitable habitat for various mushrooms (Buckskin and Benson 2005).

Indigenous people recognize that certain mushrooms are found only in association with specific kinds of trees, shrubs, or herbaceous plants (Table 2). For example, the Mono, recognizing that certain species of mushrooms occur in a relationship with specific species of trees, use the trees as an aid in the search for mushroom types. According to N. Turner Behill, ''***Cayaakē'*** [possibly *Ramaria rasilispora* Marr & D. E. Stuntz] grows under the pines. They are found under the pine needles; they make mounds. They are gathered in June and July between 4,000 and 7,000 ft.'' while ***seexayu'*** ''grows under buckeyes, white oaks, black oaks, and live oaks –not water oaks. It has a different little odor. They are gray on top and tannish underneath. Sometimes you find one or two and sometimes you find up to twelve under one oak'' (Anderson unpublished field notes 2006).

Other mushrooms have fidelity to plant community seral stages or micro-site conditions. Tribal peoples sought particular seral stages or age classes of forest stands and shrub patches. A 74 year-old Karuk elder recalled that in the western Klamath Mountains: ''Where the tanoak [trees] grow about 15 inches in diameter and it's damp and moist with decayed leaves, is where the tanoak mushrooms grow'' (USDA-FS 1981, Interview-281). Additionally, other features of certain habitats are used to aid the search for mushrooms or fungi. For example, some mushroom species are used as indicators of the relative likelihood of finding target species.

Decline of Useful Mushroom Abundance and Habitat

Many California tribal mushroom harvesters report that edible and medicinal mushrooms are dwindling, in part because of the change in conditions of gathering sites with new land uses. M. Beecher recalls many areas in the central Sierra Nevada where she and her family used to gather ***toopO***: ''We used to look for mushrooms all through Meadow Lakes, Pine Ridge, and Bretz Mill Road. Now you bump into homes.'' Other reasons for the decline of useful mushrooms can include: environmental pollution, fire suppression/exclusion, climate change, application of dung and artificial fertilizers, industrial timber management, native and exotic

Table 2. Tribally used fungi, their host plants, and association.

Mushroom-fungus	Host plant species name	Association	Reference
Agaricales	*Notholithocarpus densiflorus*	ECM	Kennedy et al. 2003
	Pseudotsuga menziesii	ECM	Kennedy et al. 2003
	Quercus wislizenii	ECM	Hynes et al. 2010
Agaricus campestris		Saprotrophic	Kuo 2001
Agaricus sp.		ECM	Lakhanpal 2000
Amanita calyptrata	*Arbutus menziesii*	ECM	Kuo 2006
Amanita sp.	*N. densiflorus*	ECM	Bergemann and Garbelotto 2006
Boletales	*Pinus sabiniana*	ECM	Hynes et al. 2010
	Quercus douglasii	ECM	Hynes et al. 2010
	Q. wislizenii	ECM	Hynes et al. 2010
Boletus edulis	*Abies grandis*	ECM	Trappe 1962
	Abies sp.	ECM	Molina and Trappe 1982
	Picea sitchensis	ECM	Molina and Trappe 1982
	Pinus contorta	ECM	Molina and Trappe 1982
	Pinus ponderosa	ECM	Molina and Trappe 1982
	Pinus sylvestris		Trappe 1962
	Pseudotsuga menziesii	ECM	Molina and Trappe 1982
	Quercus sp.	ECM	Molina and Trappe 1982
	Tsuga sp.	ECM	Molina and Trappe 1982
Boletus sp.	*N. densiflorus*	ECM	Bergemann and Garbelotto 2006
	Quercus garryana	ECM	Valentine et al. 2002
	Tsuga sp.	ECM	O'Dell et al. 1999
Calvatia gigantea		Saprotrophic	Rinaldi et al. 2008
Calvatia sculpta		Saprotrophic	Rinaldi et al. 2008
Cantharellus cibarius	*Abies alba*	ECM	Trappe 1962
	Picea sitchensis	ECM	Trappe 1962
	Pseudotsuga menziesii	ECM	Trappe 1962
	Quercus sp.	ECM	Trappe 1962
	Tsuga heterophylla	ECM	Trappe 1962
Cantharellus sp.	*N. densiflorus*	ECM	Arora and Dunham 2008
	Pinus muricata	ECM	Arora and Dunham 2008
	Pseudotsuga menziesii	ECM	Arora and Dunham 2008
	Quercus pacifica	ECM	Arora and Dunham 2008
	Sequoia sempervirens	ECM	Arora and Dunham 2008
	Tsuga sp.	ECM	O'Dell et al. 1999
	Arbutus menziesii	ECM	Arora and Dunham 2008
	Quercus agrifolia	ECM	Arora and Dunham 2008
	Quercus chrysolepis	ECM	Arora and Dunham 2008
	Quercus parvula var. *shrevei*	ECM	Arora and Dunham 2008
	Q. wislizenii	ECM	Arora and Dunham 2008
Cantharellus sp. (rare)	*Quercus kelloggii*	ECM	Arora and Dunham 2008
	Arctostaphylos sp.	ECM	Arora and Dunham 2008
Calbovista subsculpta		Saprotrophic	Boddy et al. 2008
Craterellus cornucopioides	*Picea* sp.	ECM	Trappe 1962
	Quercus sp.	ECM	Trappe 1962
Fomitopsis penicola	*Abies* sp.	Saprotrophic	Boddy et al. 2008
Fomitopsis cajanderi	*Abies* sp.	Saprotrophic	Boddy et al. 2008
Helvella sp.	*Q. douglasii*	ECM	He et al. 2007
	Q. wislizenii	ECM	He et al. 2007
Helvellaceae	*Q. douglasii*	ECM	Morris et al. 2008
	Q. wislizenii	ECM	Morris et al. 2008
Hericium erinaceus	*N. densiflorus*	Saprotrophic	Boddy et al. 2008
Hydnum (*Dentinum*) *repandum*	*Corylus* sp.	ECM	Trappe 1962
	Picea sp.	ECM	Trappe 1962
	Pseudotsuga menziesii	ECM	Trappe 1962
Laetiporus sulphureus		Saprotrophic	Boddy et al. 2008

Table 2. Continued.

Mushroom-fungus	Host plant species name	Association	Reference
Lycoperdon sculptum		Saprotrophic	Boddy et al. 2008
Lycoperdon sp. (see *Calvatia*)		Saprotrophic	Boddy et al. 2008
Lyophyllum decastes	*Pinus* sp.	ECM	Trappe 1962
Lyophyllum sp.	*N. densiflorus*		Bergemann and Garbelotto 2006
Morchella elata	*Picea* sp.	ECM	Buscot 1994
Morchella sp.	*Pinus contorta*	ECM	Dahlstrom et al. 2000
	P. ponderosa	ECM	Dahlstrom et al. 2000
	Pseudotsuga menziesii	ECM	Dahlstrom et al. 2000
Peziza sp.	*Q. garryana*	ECM	Valentine et al. 2002
	Q. garryana	ECM	Southworth et al. 2009
Pezizaceae	*Q. douglasii*	ECM	Morris et al. 2008
	Q. wislizenii	ECM	Morris et al. 2008
Pezizales/*Peziza* sp.	*Pinus sabiniana*	ECM	Hynes et al. 2010
	Q. wislizenii	ECM	Hynes et al. 2010
Pleutrotus ostreatus	*Alnus* sp., *Quercus* sp., *Notholithocarpus* sp., *Salix* sp.	Saprotrophic	Boddy et al. 2008
Polyporus sp.		Saprotrophic	Boddy et al. 2008
Ramaria sp.	*N. densiflorus*	ECM	Bergemann and Garbelotto 2006
	Tsuga sp.	ECM	O'Dell et al. 1999
Sarcoscypha coccinea		Saprotrophic	Rinaldi et al. 2008
Sparassis crispa		Saprotrophic	Boddy et al. 2008
Tricholoma magnivelare	*Abies magnifica* var. *shastensis*	ECM	Amaranthus et al. 2000
Tricholoma sp.	*N. densiflorus*	ECM	Bergemann and Garbelotto 2006
	Pseudotsuga menziesii	ECM	Kennedy et al. 2003

diseases and pests, road building, and compacted soils from trampling (Arnolds 1991; Egli et al. 2006; Pilz and Molina 2002). N. Turner Behill says that ***cayaakē'*** are less plentiful now because ''people walk all over and stomp on the mushrooms'' (Anderson unpublished field notes 1991). Several Southern Sierra Miwuk consultants mentioned that the pine mushroom (*Amanita calyptroderma*) is not as plentiful on the Yosemite Valley floor as it used to be years ago (Anderson 1988).

Perceived declines in abundance might also be due, in part, to increased competition in harvesting. Today, commercial and non-tribal harvesters cover the same areas as California Indian subsistence harvesters in search of morels, American matsutakes, chanterelles, and other highly prized edibles. They market the mushrooms locally, nationally, and internationally, or consume them for personal use. The mushrooms command a high price in grocery stores and are forming an important part of the new California fusion cuisine being used more and more frequently in gourmet restaurant recipes (Young and Viverito 1998). Tribal people consider some harvesting methods of these commercial harvesters inappropriate when raking, shoveling or other extensive disturbance to the duff/ soil interface is employed (Richards 1997). L. Glaze discusses the recent fate of the American matsutakes:

> All I know is that they were plentiful while [I was] growing up. There were sackfuls that we could can or dry. In recent times, there were so

> many commercial mushroom pickers from other places and you could see the decline after that. They were overharvesting. I've been to areas where some commercial pickers have been and they never put the duff back and they rake the area. The buttons are what they are looking for. They are found under tanoak leaves and rotted sticks (Anderson unpublished field notes 2005).

While mushroom decline can be linked with certain human practices such as raking, it is possible that other kinds of activities, such as indigenous burning or purposeful scattering of rotten caps, can enhance or foster edible mushrooms.

Indigenous Burning of Mushroom Habitat and Its Potential Ecological Effects

Fire affects the abundance and spatial and temporal availability of mushrooms. Those that fruit abundantly in burn sites are called pyrophilous, meaning ''fire-loving'' (Cooke 1958:363; Pilz et al. 2007), and include the morels (*Morchella* spp.), cup fungi (*Peziza* spp.), fried chicken mushrooms (*Lyophyllum* spp.), and elfin saddles (*Helvella* spp.) (Arora 1986; Greene et al. 2010). *Amanita* spp. and *Boletus* spp. have been found on charred soil (Baar et al. 1999; Trappe, Molina et al. 2009; Watling 1988). Many explanations have been offered for this affiliation, such as elimination of competition from higher plants, fire stimulation of pre-established mycelium in the forest floor, ash deposition, increased soil temperatures, and abiotic and biotic factors associated with the surface and subsurface soil layers, including nutrient and soil chemistry changes (Duchesne and Weber 1993; Pilz et al. 2007; Wicklow 1975:852; Zak and Wicklow 1980:1915). Fire may alter the habitat by reducing thick litter and duff (i.e., humus) layers, thus affecting mushroom fruiting emergence (Pilz et al. 2004). Additionally, moderate severity fires can result in opening up canopies and thinning forests which may reduce stress to host trees with mycorrhizal associations (Egli et al. 2010).

The abundance and spatial and seasonal availability of particular mushrooms are increased indirectly when fire kills or injures trees or shrubs, creating new sources of woody material (Olsson and Jonsson 2010). Fire-scorched bark, in which the cambium tissue was killed, provides pathways for saprotrophic mushroom spore colonization, potentially via insect inoculators. For example, hardwoods killed by fires become new substrate for oyster mushrooms under suitable microclimates and meteorological conditions. Additionally, microbes or insects which feed on colonized dead, woody material can facilitate the establishment of some mushrooms (Grove 2002; Schigel 2009).

Some California Indians observed the relationship between fire and mushroom abundance and visited areas that had been recently struck by lightning to harvest mushrooms that grew in the recently burned areas. Katie Apling, Southern Sierra Miwuk/Paiute, recalled: ''Cry-baby mushrooms [taxonomic identification lacking] that are brown and shaped like teardrops come up after fires under bushes in the chaparral and manzanita'' (Anderson unpublished field notes 1989). M. Spears remembered, ''They picked mushrooms in burned areas. They were called 'burnt ground mushrooms' [taxonomic identification lacking]. They were very black when picked. They were the size of a pink bottom [taxonomic identification lacking] and gathered in the spring. Mom would fry them. They kind of tasted like charcoal'' (Anderson unpublished field notes 1989). ''You find white morels [*Morchella deliciosa* Fr.] in roads and after burns'' said P. Montgomery (Anderson unpublished field notes 2010). Rosalie Bethel, North Fork Mono, said: ''When there was lightning, we let it burn. After the burn there were all kinds of mushrooms that grow better in forest areas under ponderosa pines, sugar pines, firs, and sequoias. I used to gather them after a fire'' (Anderson unpublished field notes 1989).

While some species of fungi likely evolved with lightning fires before human habitation, some California Indian tribes set fires in areas to foster the growth of certain types of mushrooms. Some Indians assert that burning of areas may heighten numbers, densities, size, and diversity of useful mushrooms. Individuals of the Foothill Maidu and Foothill Nisenan, for example, told anthropologist Erminie Voegelin (1942:176) that the ''ground [was] burned for [a] better crop'' of mushrooms.

Indigenous Management of Mushrooms and Their Habitats

Two case studies are presented here which provide ethnographic evidence that tribes managed specific mushrooms and habitats within two forest types: the lower montane mixed conifer forests of the Sierra Nevada and the mixed evergreen forests of northern California. These are followed by a discussion of the potential ecological effects in these ecosystems from a western scientific perspective.

Case Study 1: Lower Montane Mixed Conifer Forests of the Central and Southern Sierra Nevada

The lower montane mixed conifer forests of the central and southern Sierra Nevada form a distinct belt spanning an elevation of 1200–2400 m. Ponderosa pine dominates the more xeric sites, while white fir is found on more mesic sites (Rundel et al. 1988). Within these forests, stands of chaparral, streamside forests, meadows, and seeps occur (van Wagtendonk and Fites-Kaufman 2006). Early reports comment on the openness of these forests in many areas, featuring large-diameter trees, 12–18 m apart, and an absence of underbrush (Reynolds 1959). Other tree species include giant sequoia (*Sequoiadendron giganteum* (Lindl.) J. Buchholz), sugar pine, incense cedar (*Calocedrus decurrens* (Torr.) Florin), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*) and a major hardwood, California black oak. Both ponderosa pine and black oak are well adapted to light, regular surface fires and are intolerant of deep shade. Black oak needs bare mineral soil to germinate. While it is currently difficult to distinguish tree fire scars caused by lightning fires from those started by indigenous people in this region, some fire ecologists still assume that ignitions by native people were important but varied over the range of inhabited landscapes (Stephens et al. 2007; Swetnam et al. 2009; van Wagtendonk and Cayan 2008). However, indigenous burning in these forests is well documented in the historical literature and through oral interviews with California Indians (Anderson 1993; Baxley 1865; Clark 1894; Gordon-Cummings 1883).

For example, the Central Sierra Me-Wuk and other tribes in the Sierra Nevada mountains would ''burn off large sections of the land. This kept the brush down, and consequently helped the Indian hunter working in a communal hunt'' (Chisum 1967:203). Through oral interviews with Native Americans and non-Indians with long-term ties to the land, Anderson (1993) documented burning for at least ten reasons. These include reducing plant diseases, opening up the underbrush, and creating better habitats for useful plants and animals, but most important for this paper, they also deliberately burned areas to increase different kinds of mushrooms.

With regard to burning for mushrooms, the Mono and Tuolumne Band of Me-Wuk burned to stimulate the growth and abundance of at least four kinds in the forests including *Amanita calyptroderma, Morchella elata, Peziza sylvestris* and *Ramaria* sp. Eleven elders substantiate burning for mushrooms. All of these fungi have mycorrhizal relationships with hardwoods and/or conifers (Table 2). Common reasons for burning for fungi include enhancing size of the mushroom at the organism level, increasing numbers at the population level, and reducing the build-up of duff while leaving the mycelium intact, and keeping areas open to foster habitat for mushrooms at the community level. M. Beecher recalled: ''They'd burn under the black oaks for better mushrooms in October, November, and December. The mushrooms that come up better are ***cayaakē'*** [*Ramaria* sp.], ***naqa'*** [possibly *Peziza sylvestris*], and ***toopO''*** (Anderson unpublished field notes 1991). ''***Cuyu*** comes up better after a fire too,'' said Lydia Beecher, Mono (Anderson unpublished field notes 1991).

Dave and Ed Bowman, Wobonuch Mono, remembered burning to foster a diversity of mushrooms in what is now Sequoia National Forest in the Sierra Nevada:

> Our dad said the Indians used to burn in the mountains every year. When they go up to the mountains to pick those black oak acorns, they'd camp up there and before the winter set in they'd burn the grass and they'd do this year after year, about October, November. They burned the areas where they hunted for acorns. It's not like it is now. Now it's so brushy, if it caught fire everything would go up in smoke. They'd burn it every year to keep it open. When they'd go back the following season they'd have all kinds of mushrooms up there, like the cones which are all wrinkly [*Morchella elata*] —others look like elephants' ears [scientific identification lacking]. That's how come they burnt every year. The mushrooms grow under the pine trees and under the black oaks. They've got two, three, four different kinds. They burned in the same spots where they camped every year. They followed this acorn route, picking acorns here and there. They went all over for the black oaks (Anderson unpublished field notes 1991).

Fire may also affect the size of the mushrooms. A North Fork Mono elder, Nellie Williams, recalled that: ''When they'd burn, they'd really get big mushrooms'' (Anderson unpublished field notes 1991). Ruby Cordero, Chukchansi/Me-Wuk, said: ''Areas that had been burned they would go to. It fertilized the areas. The mushrooms would come back bigger and more of them. We used to dry mushrooms, and in the winter we'd cook them and then they'd be like fresh'' (Anderson unpublished field notes 1991). Dan McSwain, North Fork Mono, explained the effects of the fires this way: ''A lot of things grow a lot better when they burn in the fall. It's like fertilizer. The mushrooms up in the higher mountains grow better, like ***cuyu***'' (Anderson unpublished field notes 1991). Burning may affect mushrooms positively by reducing dense litter that would block mushroom emergence. According to Francys Sherman, North Fork Mono: ''I went to Yosemite in May, and those mushrooms that grow under the ponderosa pines around 4,000 ft. weren't there. There weren't any. It's because the duff is too thick and it needs to have a fire come through'' (Anderson unpublished field notes 1991). T. Carsoner said: ''Everything is overgrown today. Brush, incense cedar seedlings, and pine needles are inundating our mushroom gathering areas. My Aunt Etta said that they used to burn under the ponderosa pines, sugar pines, and black oaks for ***helli*** —the pine mushroom'' (Anderson unpublished field notes 2010).

Case Study 2: Mixed Evergreen Forests of Northern California

The mixed evergreen forests occur in the outer Coast Ranges and western Klamath-Siskiyou Mountains of northern California, spanning from sea level to over 2100 m elevation. They are composed of Douglas-fir, tanoak, and Pacific madrone (*Arbutus menziesii* Pursh), with differing proportions of giant chinquapin (*Chrysolepis chrysophylla* (Hook.) Hjelmq.), sugar pine, ponderosa pine, canyon live oak (*Quercus chrysolepis* Liebm.), California black oak, big-leaf maple (*Acer macrophyllum* Pursh), and redwood (*Sequoia sempervirens* (D. Don) Endl.). American matsutakes and other mushroom species are closely associated with this forest type and were gathered along with an array of many other products. A Karuk woman interviewed in 1981 illustrated this point:

> Bear-grass [*Xerophyllum tenax* (Pursh) Nutt.], hazel [*Corylus cornuta* Marsh. subsp. *californica* (A. DC.) E. Murray], chinquapin, and mushrooms are collected. Entire families would go gathering and hunting in the mountains in the fall. They would set up camps and dry part of their meat at the camps. The families would usually gather nuts at this time. [They would g]ather white acorns usually in special family-owned plots (USDA-FS 1981 Interview 299).

Redwoods, sugar pines, ponderosa pines, and California black oaks are well adapted to fire. The pines, oaks, and redwoods have thick insulated bark to protect them from fire damage, and the oaks and redwoods send up new shoots from various portions of the plant following fire injury (Spurr and Barnes 1980). Indigenous burning in the mixed evergreen forests is well-documented in the historical literature (Gifford 1939–1940; Kroeber 1939) and implied through dendrochronological studies that show short-enough fire return intervals to argue two sources of ignition: lightning *and* Indians (Lorimer et al. 2009; Skinner et al. 2006; Stuart and Stephens 2006; Taylor and Skinner 1998).

Through oral interviews, Native Americans in the Karuk, Yurok, Hupa and other tribes remember multiple reasons for burning in this forest type among which is to increase different kinds of mushrooms that grow on the forest floor and on dead wood of trees killed by fire (Lake 2007). According to a Karuk elder (Karuk Tribe and Cultural Solutions 1999:Appendix 1:30): ''Fire was one of the Karuk's main management tools. Fire was used to encourage vegetation growth in plants that were used for food and medicine. Fire was used to create animal habitat. Fire was used for healthier tanoak groves.'' L. Glaze remembered her dad telling her that the Karuk burned after the acorns had dropped, ''to clear the brush and open things up'' (Anderson unpublished field notes 2005). Her grandmother, Catherine Ferris, talked about burning specifically under the tanoaks where the American matsutakes grow in late October or November, and ''from everything I've ever heard,'' said Glaze, ''fire helped the oaks.''

Edible mushrooms gathered by Northwestern tribes that may have benefited from Indian-set fires include American matsutakes, golden chanterelles, corals, black trumpets, and hedgehogs. All of these mushrooms are mycorrhizal with hardwoods and/or conifers (Table 2). Hupa elder Wilfred Colegrove remembered that after the Megram wildfire in 1999 all different types of mushrooms did well ''the third and fourth year after the burn'' (Lake 2007:433). Burning may have helped certain mushrooms by eliminating insect pests that attack host trees and reducing duff layers, as a Yurok woman relayed to Lake (2007:649):

> Oh I think a lot of the underbrush should be taken out everywhere, you know. Those light burns, controlled burns. They don't need a lot of these bugs and beetles they're [e.g., federal agencies] always trying to save. I think a lot of those eat up the trees and there's a lot of bad ones that need to be burned. And take the surface layer off, and let the mushrooms grow and whatever.

Grant Hillman, Karuk, also remembered a much more open forest in an earlier time: ''…that was our gathering grounds for the acorns and the mushrooms, and at that time [prior to fire suppression and vegetation densification] you could walk any place in there. And the deer, everything was in there'' (Lake 2007:488). When asked if mushrooms liked fire, Hillman replied: ''Yeah, you bet they liked it'' (Lake 2007:491). Burning also created greater access to mushroom gathering grounds, which today is an issue because the forest is so overgrown. According to Glaze:

> Where I go, you know you go to the tanoaks, to get tanoak [American matsutake] mushrooms, I know down below on the ridge you can't get through it now because all the older oaks have fallen over, you know. We used to pick [mushrooms] clear down to the creek and walk the creek clear up, pickin' mushrooms but you can't get through anymore. So if

> any place needs to be burned, that needs to be burned too (Lake 2007:463).

Charlie Thom, Karuk, agrees that mushrooms do better after a fire, and with fire suppression, he lamented: ''Nowadays you can't find the mushrooms'' (Lake 2007:631).

Discussion

According to the scientific literature, fire can be either beneficial or detrimental to populations of fungi, both their above ground fruiting bodies and their below-ground networks of mycorrhizae in different habitats (Duchesne and Weber 1993; Hosford et al. 1997; Molina et al. 2001; Pilz et al. 2004; Southworth and Gibson 2010; Stendell et al. 1999; Trappe, Cromack et al. 2009; Waters et al. 1994). Fire ecologists and mycologists stress that the ecological effects of fire on fungal community dynamics are complex and dependent upon factors such as the season of burn, intensity and resulting severity of a burn, and fire frequency (Molina et al. 2001). Although we have a fairly good idea of why indigenous people in California burned habitats in which valued mushrooms occur, we have not compiled the extensive data here about how they did so. These California Indian fire regime properties include: ignition strategies used, fire intensity, how frequently they burned, the time of year they chose for burning, and how they realized the different cultural goals of burning. We do not know if the habitat for some kinds of mushrooms were burned one way, and the habitat for others burned a different way, depending upon what else Indians were burning for —such as opening habitat, increasing forage for game animals, or stimulating young shrub, forb, or grass growth for basketry. Hundreds of species of mushrooms occur within the two forest types discussed in the case studies, and thus, the useful mushrooms sought by California Indians are a small subset of that diversity. Potential detrimental ecological effects of Indian-set fires are that they probably did not equally benefit all groups of fungi; the fires were harmful to some while benefiting others.

Potential positive ecological effects of Indian-set fires are that they may reduce plants that compete with useful mushrooms (Hebel et al. 2009). The introduction of exotic grasses, for example, may hinder mushroom emergence as Dr. Michael Allen (personal communication 2005) pointed out:

> My observation has been that if there is a dense stand of invasive grasses under the oaks, then the mushrooms don't tend to fruit, particularly the mycorrhizal mushrooms. So it makes a lot of sense to do these burnings. The fungi are there in the microscopic threads in the soil and they are associated with the trees, but they won't actually produce a fruiting structure if the grass is dense.

Additionally, explained Allen (personal communication 2005): ''Enhancing numbers and size of mushrooms may not only increase mushroom numbers, but heighten genetic diversity in these mushrooms as well.'' Beyond benefiting the useful mushroom —a single life-form— at the genetic, organism, and population level, Indian-set fires could also have positive effects at higher levels of biological organization at the plant community and watershed scales. Many of the mushroom species consumed by Indians are also delectable to wildlife as M. Beecher pointed out: ''Bears, coyotes, foxes, raccoons —the four-legged animals all like ***toopO*** '' (Anderson unpublished field notes 2006). N. Turner Behill said: ''***Cayaakē'*** grows under the pines. We take the bigger ones. They were dried. It grows like a cauliflower. The deer and bears eat all of these mushrooms'' (Anderson unpublished field notes 2006).

Enhanced numbers of sporocarps of certain species resulting from burning might have provided an important source of nutrition by enriching the food web for wildlife such as squirrels, chipmunks, bears, elk, black-tailed and mule deer, and foxes. More open areas provided greater animal access to these mushrooms, and in turn, these animals may play a role in mushroom spore dispersal (Hosford et al. 1997). Furthermore as outlined in the two case studies, there is a significant body of evidence indicating that Indians set fires in the montane mixed conifer forests and mixed evergreen forests for different broader purposes, and achieving some of these other goals could also enhance useful mushroom habitat at the community scale. There are reasons to believe that the regime of Indian burning in these forests contributed to the benefit of certain edible mushrooms through the enhancement of the forest trees.

Many native elders talk today about Indian burning to keep the forests open and the trees healthy and disease-free. In both earlier anthropological accounts and in more recent interviews, native consultants sometimes mention control of disease as one of the many positive effects of burning under trees. After researching the management by fire practices of the Lassik and Pitch Wailaki in the Eel River basin and Yurok in the areas to the north of the North Fork of the Eel, Keter (1985; 1987) concluded that the people in these tribes viewed burning as a way of keeping down diseases of forest vegetation. When Sara Schenck and Edward Gifford (1952) visited the Karuk, Mamie Offield told them that the tanoak trees were ''better if they are scorched by fire each year'' because the fire, among other things, killed ''disease and pests.''

In our interviews with Miwok and Mono elders, they talk about the paradoxical effects of setting fires to prevent catastrophic fires that would kill big trees. ''They burned so they would not have big fires,'' said Virginia Jeff, Central Sierra Me-Wuk (Anderson unpublished field notes 1989). F. Sherman recalled: ''They set fires every year so it didn't harm the trees. That way it would burn the grass. A lot of bushes would burn'' (Anderson unpublished field notes 1991). Many of the pines and oaks undoubtedly would not have grown so large had it not been for indigenous burning practices, which kept the brush down and minimized the possibility of catastrophic crown fires (Anderson 2005b).

Western scientists recognize that mycorrhizal fungi are at least partially reliant on the number, growth, and health of their host tree species (Pilz 2011), and that prescribed burning can be an effective tool in opening up the structure of mixed conifer forests at the stand to landscape scale (van Mantgem et al. 2011). We hypothesize that frequent Indian-set surface fires in certain areas, along with lightning ignitions, opened up the structure of the forests and ''thinned'' the trees, leading to reduced stocking of trees. With reduced drought stress, less competition for water, nutrients or sunlight, and reduced defoliation by insects and pathogens, host trees were healthier and more vigorous. Additionally, we hypothesize that Indian-set fires that led to fewer trees per acre provided suitable environmental conditions for these trees to grow larger and older. These trees were of larger diameter and more widely spaced, and had canopies with greater leaf surface area, leading to enhanced tree photosynthesis. Trees with less plant competition and heightened photosynthesis would bring much more simple sugars and carbon to certain mycorrhizal fungi utilized for human purposes (Egli et al. 2010) than thickets of stressed, spindly firs, pines, or oaks, which are more common now in mixed conifer forests as the result of fire suppression and exclusion (Parsons and DeBenedetti 1979).

Pilz (2011) stated that young forest stands often do not produce large quantities of edible ectomycorrhizal fungi, whereas older trees with sufficient amounts of surplus carbohydrates foster edible species such as chanterelles, American matsutakes, and others. Pilz et al. 2006 (cited in Pilz 2011:146) speculated that ''thinning these forests to reduce competition might extend this period of abundant fruiting by prolonging the period of vigorous tree growth among the residual trees.'' Greater carbon available to the mycorrhizae, in turn, would lead to a potential extension of hyphae horizontally and vertically in the soil over wider areas beyond the depletion zones created by the tree roots themselves to bring more nutrients back to the trees, positively affecting host tree productivity (Southworth and Gibson 2010). Additionally, frequent surface fires that reduced duff/litter may have resulted in hyphae that were deeper in the humus layers and thus more protected from the penetrating heat of fire down in the soil matrix.

We do not have detailed explanations for exactly how mushrooms and ecosystems were enhanced by Indian-set fires. But if we look to countries in Europe, they have reported the integral role that humans have played in enhancing useful mushroom populations through the ancient techniques of burning and thinning to foster edible and medicinal mushrooms (Arnolds 1991). Additionally, Japanese researchers are improving mushroom populations through modern management that may simulate ancient techniques. Ideal conditions for fostering the Japanese matsutake (*Tricholoma matsutake*) are an open pine canopy that allows light to penetrate to a sparsely vegetated forest floor and warm, well-drained soils with thin litter and organic layers (Hosford et al. 1997). And Japanese foresters try to simulate these conditions through mild controlled burns to clear understory growth and reduce litter depth, and by thinning trees. These techniques increase Japanese matsutake production and may benefit American matsutake fruiting conditions as well (Hosford et al. 1997:46).

Conclusions

Fungi play an integral role in nutrient cycling and retention, mycorrhizal mutualisms, and are important in terrestrial food chains. Given that fungi are of great ecological significance to our forests —contributing to their health, resiliency, and sustainability— fungi should be considered in the management of our forest resources (Trappe, Molina et al. 2009). Today, our public lands are managed for multiple purposes to meet an array of public values including timber production, recreation, conservation of rare species, and wilderness (Molina et al. 2001). A relatively new value that has emerged is managing for non-timber products including floral greens from herbs, shrubs, and trees, wild fruits, weaving and dyeing materials, specialty wood products, and edible fungi (Davidson-Hunt et al. 2001; Vance and Thomas 1997).

As it is recognized that diverse fungi in wildland ecosystems require different host plant species, disturbance regimes, and environmental conditions, managers and conservationists stress stewarding at the ecosystem scale and put forth the principle of risk-spreading or not managing in the same manner everywhere (Cunningham 2011; Molina et al. 2001). In addition to disturbances created by abiotic factors, which tend to occur randomly across a landscape, there are disturbances attributable to indigenous peoples, which tend to occur non-randomly across the landscape and through time (Anderson and Barbour 2003). Examining tribal harvesting and burning practices that encourage useful mushrooms and other products which have evolved locally and regionally over long periods of time may offer us an important source of knowledge and experience for improving forest ecosystem management (Berkes et al. 2000).

Indigenous mushroom harvesters today still show concern for different fungi's inherent capacity for renewal. The quantity and quality of harvest are adjusted to the biology of the species —both its above-ground aspects (fruiting bodies) and its below-ground aspects (the mycelium). Attention to size and yields of mushrooms gathered and tools that preserve that abundance may well add up to sustained yields. Some of these same harvesting practices are already recommended in modern management contexts (e.g., do not disturb the mycelium, leave small mushrooms to grow larger and old mushrooms to spread their spores), pointing to common ground between traditional and modern management (Lepofsky 2009; Lertzman 2009; Pilz 2011). Burning practices of California Indians likely enhanced or maintained the abundance, density, size, and genetic diversity of different useful mushrooms. Thus, the maintenance of some species of fungi might be served by the continuation of these long-standing practices.

If ecological field experiments that simulate indigenous harvesting and burning demonstrate enhanced mushroom numbers and size, then integrating their management and sustainable harvest as part of multi-use forests would be an appropriate part of conservation and restoration plans (Anderson and Barbour 2003; Molina et al. 2001; Pilz and Molina 1996). Monitoring based upon the principles of adaptive management offers opportunities to evaluate the implications of the tribal management practices (Berkes et al. 2000; Shindler and Cheek 1999; Stankey et al. 2005).

Suggested Avenues of Research

Reintroducing fungi harvesting and management practices that simulate indigenous techniques in our forests needs to be guided by sound science. We propose multi-disciplinary research that combines ecological field experiments, ecological modeling, and indigenous, place-based forms of knowledge in order to simulate indigenous harvesting patterns and land management practices. New research findings could then be used to write management prescriptions for specific areas. These prescriptions would be modified as climate or other variables change. The management techniques are not static but rather are based on adaptive management. Potential research collaborations between scientists and tribal communities include the following topics:

- Conduct museum studies that identify edible and medicinal fungi useful to particular indigenous cultures. Mushrooms acquired from California Indian consultants in the early 20th century are housed in various museum collections around the country (Anderson 2005a). With new DNA analysis technology, these could be scientifically identified and would assist tribal cultures in reviving their ethnomycological knowledge. Through our taxonomic identifications of mushrooms currently used by tribes, we hope to assist tribes in the reconstruction of all species used in the past and heighten Western understanding and respect for native knowledge. Scientific identifications of mushroom species can lead to even greater knowledge exchanges as the tribes are given Western scientific articles and reports on the life history, habitat requirements, and interactions of the mushrooms of interest.
- Conduct nutritional and medicinal analyses of mushrooms harvested by California Indians that have no current data available. Results may reveal potential treatments for diabetes or other health ailments, or for first-aid/healing applications.
- Reconstruct indigenous burning regimes of specific areas of California through interviews, exhaustive literature reviews, and fire behavior modeling as closely as possible, specifying season, frequency, extent, severity, and purpose of Indian burning. Much indigenous mycological knowledge is already lost, as each year there are fewer living elders remembering these traditions.
- Measure ecological effects of indigenous gathering and tending practices through non-replicated adaptive management trials and if funding permits, replicated ecological field experiments. Studies could be designed to measure changes in mushroom numbers, mushroom genetic diversity and changes in mycorrhizal populations with simulated Indian gathering and burning regimes. Best management practices for harvest could be developed from field-based manipulative experimentation. Such data could demonstrate the effects of harvesting and burning for specific taxa and associated habitats. Note that it may be problematic to reintroduce low-intensity and localized burning simulating the historical practices of native people, which may produce different ecological effects today due to climate change, the presence of alien plant species, and the need to reduce fuels due to many years of fire suppression and exclusion in different parts of California. All of these factors may likely increase the severity and extent of wildfires, not at all similar to former Indian-set fires (Sugihara and Barbour 2006).
- Conduct socio-economic feasibility research of the value of integrated utilization of non-timber forest products, including mushrooms, versus short-term rotation silvicultural timber harvesting (Alexander et al. 2002).
- Research and monitor the abundance and productivity of edible mushroom taxa as indicators of climate change and forest health. Sampling fungi seasonally, along an environmental gradient, could provide details of how fungi may link soil productivity to forests within variable climate zones (Buntgen et al. 2011).
- Research and monitor how edible fungi and associated ectomycorrhizae are affected by exotic pathogen impacts on host trees and shrubs. For example, in

California, Sudden Oak Death (*Phytophthora ramorum*) affects many tree and shrub host species of culturally significant mushrooms (Ortiz 2008).

Ethnoecological Restoration

In California and elsewhere, restoring species to viable population numbers and preserving or restoring ecosystems on wildlands revolves around the captive breeding and reintroduction of animals; the propagation, cultivation and out-planting of plants; establishing reserves; and restoring functioning habitats (Falk et al. 2006; McNeely et al. 1990; Morrison 2009). But ultimately with these kinds of restoration schemes, humans leave after implementation, as they are perceived as no longer being needed. In addition to these typical restoration schemes, we can re-create specific human-ecosystem associations within designated areas (Anderson 2005b). We propose a new kind of restoration that complements other forms of ecological restoration, called ''ethnoecological restoration.'' This kind of restoration holds as a premise that parts of the landscapes that we inherited from our forebears still bear the marks of former California Indian stewardship (Anderson and Wohlgemuth 2012). It recognizes that the direct witness and relationship with biological and physical phenomena in nature that Native Americans experienced day after day, year after year, generation after generation is a valid and important way of learning that complements our modern technologies and scientific methods to study and manage the environment.

David Egan, former editor of *Ecological Restoration*, defines this kind of restoration as ''the practice of re-establishing the historic plant and animal communities of a given area or region and renewing the ecosystem and *cultural* functions necessary to maintain these communities now and into the future'' (Anderson 2005b). Restoring the cultural functions would include vegetation management and cultivation practices such as seed-beating, burning, pruning, sowing, tilling, and weeding. In addition to tribal parks and community forests (California Forest Stewardship Program 2011; Trees Foundation 2008), there could be a new land use category on public lands devoted specifically to ethnoecological reserves that encourage sustainable harvesting, adaptive management, research, and restoration of indigenous stewardship practices or the simulation of such interactions with the natural world.

Note

[1] The map in this article is linguistic, identifying groups of people that spoke the same language or dialect. Today, tribes do not necessarily go by these names. ''Sierra Miwok'' on the map, for example, are made up of several sociopolitical groups that go by different names today, thus, the variation in spelling: Miwok, Me-Wuk, and Miwuk.

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References Cited

Aginsky, Burt W.
1943 Culture Element Distributions: XXIV, Central Sierra. *Anthropological Records* 8(4): 393–468.

Alexander, Susan J., David Pilz, Nancy S. Weber, Ed Brown, and Victoria Rockwell.
2002 Value Estimates of Commercial Mushrooms and Timber in the Pacific Northwest. *Environmental Management* 30(1):129–141.

Allen, Michael F.
1991 *The Ecology of Mycorrhizae*. Cambridge University Press, Cambridge.

Amaranthus, Michael P., David Pilz, Andrew Moore, Rick Abbott, and Daniel Luoma
2000 American Matsutake (*Tricholoma magnivelare*) across Spatial and Temporal Scales. In *Proceedings of the California Forest Soils Council Conference on Forest Soils Biology and Forest Management*, February 23–24, 1996, Sacramento, eds. Robert F. Powers, Donald L. Hauxwell and Gary M. Nakamura, pp. 99–108. General Technical Report, PSW-GTR-178. U.S. Department of Agriculture, Forest Service, Albany, CA.

Anderson, M. Kat
1988 Southern Sierra Miwok Plant Resource Use and Management of the Yosemite Region. Master's Thesis (Wildland Resource Science). University of California, Berkeley.
1993 Indian Fire-based Management in the Sequoia-mixed Conifer Forests of the Central and Southern Sierra Nevada. Final report to the Yosemite Research Center, Yosemite National Park. U.S. Department of Interior, National Park Service, Western Region. Cooperative Agreement Order No. 8027-002.
2005a Identification of the Fungi, Insects, and Plant Parts of the Charles P. Wilcomb Collection. Final report to the Oakland Museum, Oakland.
2005b *Tending the Wild: Native American Knowledge and the Management of California's Natural Resources*. University of California Press, Berkeley.
2009 Historical Native American Resource Use, Harvesting, and Management of California's Oak Communities. Report to the University of California Integrated Hardwood Range Management Program, Berkeley.

Anderson, M. Kat and Michael G. Barbour
2003 Simulated Indigenous Management: A New Model for Ecological Restoration in National Parks. *Ecological Restoration* 21(4): 269–277.

Anderson, M. Kat and Eric Wohlgemuth
2012 California Indian Proto-Agriculture: Its Characterization and Legacy. In *Biodiversity in Agriculture: Domestication, Evolution, and Sustainability*, eds. Paul Gepts, Thomas R. Famula, Robert L. Bettinger, Stephen L. Brush, Ardeshir B. Damania, Patrick E. McGuire and Calvin O. Qualset, pp. 190–224. Cambridge University Press, Cambridge.

Arnolds, Eef
1991 Mycologists and Nature Conservation. In *Frontiers in Mycology: Honorary and General Lectures from the Fourth International Mycological Congress, Regensburg, Germany, 1990*, ed. D.L. Hawksworth, pp. 243–264.

Commonwealth Agricultural Bureau International, Wallingford.

Arora, David
1986 *Mushrooms Demystified: A Comprehensive Guide to the Fleshy Fungi*. Ten Speed Press, Berkeley.
1995 The Impact of Gathering Mushrooms. *Mushroom: The Journal of Wild Mushrooming* 13(3):5–6.

Arora, David and Susie M. Dunham
2008 A New, Commercially Valuable Chanterelle Species, *Cantharellus californicus* sp. nov., Associated with Live Oak in California, USA. *Economic Botany* 62:376–391.

Baar, J., T.R. Horton, A.M. Kretzer, and T.D. Bruns
1999 Mycorrhizal Colonization of *Pinus muricata* from Resistant Propagules after a Stand-replacing Wildfire. *New Phytologist* 143:409–418.

Baldwin, Bruce G., Douglas H. Goldman, David J. Keil, Robert Patterson, Thomas J. Rosatti and Dieter H. Wilken, eds.
2012 *The Jepson Manual: Vascular Plants of California*. University of California Press, Berkeley.

Barrett, Samuel A.
1952 Material Aspects of Pomo Culture. *Bulletin of the Public Museum of the City of Milwaukee* 20(1):1–260.

Barrett, Samuel A. and Edward W. Gifford
1933 Miwok Material Culture. *Bulletin of the Public Museum of the City of Milwaukee* 2(4): 117–376.

Barros, Lillian, Telma Cruz, Paula Baptista, Leticia M. Estevinho, and Isabel C.F.R. Ferreira
2008 Wild and Commercial Mushrooms as Source of Nutrients and Nutraceuticals. *Food and Chemical Toxicology* 46(9):2742–2747.

Baxley, William H.
1865 *What I Saw on the West Coast of South and North America and at the Hawaiian Islands*. D. Appleton & Company, New York.

Beals, Ralph L.
1933 Ethnology of the Nisenan. *University of California Publications in American Archaeology and Ethnology* 31(6):335–414.

Bean, Lowell J.
1978 Cahuilla. In *Handbook of North American Indians*, California, Vol. 8, ed. Robert F. Heizer, pp. 575–587. Smithsonian Institution, Washington D.C.

Bean, Lowell J. and Katherine S. Saubel
1972 *Temalpakh: Cahuilla Indian Knowledge and Usage of Plants*. Malki Museum Press, Morongo Indian Reservation, Banning.

Bean, Lowell J. and Florence C. Shipek
1978 Luiseño. In *Handbook of North American Indians,* California, Vol. 8, ed. Robert F. Heizer, pp. 550–563. Smithsonian Institution, Washington, D.C.

Bergemann, S.E. and M. Garbelotto
2006 High Diversity of Fungi Recovered from the Roots of Mature Tanoak (*Lithocarpus densiflorus*) in Northern California. *Canadian Journal of Botany* 84(9):1380–1394.

Berkes, Fikret, Johan Colding, and Carl Folke
2000 Rediscovery of Traditional Ecological Knowledge as Adaptive Management. *Ecological Applications* 10(5):1251–1262.

Bethel, Rosalie, Paul V. Kroskrity, Christopher Loether, and Gregory A. Reinhardt
1984 *A Practical Dictionary of Western Mono*. The American Indian Studies Center, University of California, Los Angeles.

Bocek, Barbara R.
1984 Ethnobotany of Costanoan Indians, California, Based on Collections by John P. Harrington. *Economic Botany* 38:240–255.

Boddy, Lynne, Juliet C. Frankland, and Pieter van West
2008 *Ecology of Saprotrophic Basidiomycetes, Vol. 28*. Academic Press, London.

Brubaker, Florence
1926 Plants Used by Yosemite Indians. *Yosemite Nature Notes* 5(10):73–79.

Buckskin, Floyd J.
1986 Letter and Plant List of Plant Resources Native to the Ajumawi Lava Springs State Park to W. Dreyer. Department of Anthropology, Chico State University, California.

Buckskin, Floyd and Arlene Benson
2005 The Contemporary Use of Psychoactive Mushrooms in Northern California. *Journal of California and Great Basin Anthropology* 25(1):87–92.

Burk, William R.
1983 Puffball Usages among North American Indians. *Journal of Ethnobiology* 3:55–62.

Buscot, F.
1994 Ectomycorrhizal Types and Endobacteria Associated with Ectomycorrhizas of *Morchella elata* (Fr.) Boudier with *Picea abies* (L.) Karst. *Mycorrhiza* 4:223–232.

California Forest Stewardship Program.
2011 New Directions in Community-based Forestry, Forestland Steward. Available at: http://www.tcrcd.net/wcf/pdf/articles/CFSP_Forestland_Steward_Winter-2011.pdf (verified 22 May 2012).

Castetter, Edward F. and Willis H. Bell
1951 *Yuman Indian Agriculture: Primitive*

Subsistence on the Lower Colorado and Gila Rivers. The University of New Mexico Press, Albuquerque.

Chang, Shu-Ting
2008 Overview of Mushroom Cultivation and Utilization as Functional Foods. In *Mushrooms as Functional Foods*, ed. Peter C.K. Cheung, pp. 1–34. John Wiley & Sons, Inc., Hoboken.

Chesnut, V.K.
1974 *Plants Used by the Indians of Mendocino County California.* Reprint of 1902 edition. Contributions from the U.S. National Herbarium Government Printing Office 1900–1902, vol. 7, pp. 295–422. Mendocino County Historical Society, Fort Bragg.

Cheung, Peter C.K.
2008 Nutritional Value and Health Benefits of Mushrooms. In *Mushrooms as Functional Foods*, ed. Peter C.K. Cheung, pp. 71–110. John Wiley & Sons, Inc., Hoboken.

Chisum, Gary L.
1967 Ethnography of the Sierra Miwok: Preliminary Notes. *The Quarterly of the Tuolumne County Historical Society* 6(4): 201–206.

Clark, Galen
1894 Letter to the Board of Commissioners of the Yosemite Valley and Mariposa Big Tree Grove, August 30. Yosemite Research Library, Yosemite National Park.

Cooke, W. Bridge
1958 The Ecology of the Fungi. *The Botanical Review* 24(6):342–375.

Cunningham, Anthony B.
2011 Fungi and the Future: Policy and Practice for Sustainable Production and Conservation. In *Mushrooms in Forests and Woodlands: Resource Management, Values and Local Livelihoods*, eds. Anthony B. Cunningham and Xuefei Yang, pp. 175–203. Earthscan, London.

Dahlstrom, J.L., J.E. Smith, and N.S. Weber
2000 Mycorrhiza-like Interaction by *Morchella* with Species of the Pinaceae in Pure Culture Synthesis. *Mycorrhiza* 9:279–285.

Davidson-Hunt, Iain, Luc C. Duchesne and John C. Zasada, eds.
2001 Forest Communities in the Third Millennium: Linking Research, Business, and Policy towards a Sustainable Non-Timber Forest Project Sector. Proceedings of Meeting Held October 1–4, 1999, Kenora, Ontario. General Technical Report NC-217. U.S. Department of Agriculture Forest Service, North Central Research Station, St. Paul, Minnesota.

Dixon, Roland B.
1905 The Huntington California Expedition: The Northern Maidu. *Bulletin of the American Museum of Natural History* 17(3): 119–346.

Douhan, G.W., C. Petersen, C.S. Bledsoe, and D.M. Rizzo
2005 Contrasting Root Associated Fungi of Three Common Oak-woodland Plant Species based on Molecular Identification: Host Specificity or Non-specific Amplification? *Mycorrhiza* 15:365–372.

Driver, Harold E.
1936 Wappo Ethnography. In *University of California Publications in American Archaeology and Ethnology* 36(3):179–220.
1939 Cultural Element Distributions: X, Northwest California. *Anthropological Records* 1(6):297–433.

Duchesne, Luc C. and Michael G. Weber
1993 High Incidence of the Edible Morel *Morchella conica* in a Jack Pine, *Pinus banksiana*, Forest Following Prescribed Burning. *The Canadian Field-Naturalist* 107:114–116.

Duncan III, John W.
1964 Maidu Ethnobotany. Master's Thesis (Anthropology). California State University, Sacramento.

Egli, Simon, Francois Ayer, Martina Peter, Britta Elimann, and Andreas Rigling
2010 Is Forest Mushroom Productivity Driven by Tree Growth? Results from a Thinning Experiment. *Annals of Forest Science* 67(5):Article 509.

Egli, Simon, Martina Peter, Christoph Buser, Werner Stahel, and François Ayer
2006 Mushroom Picking does not Impair Future Harvests —Results of a Long-term Study in Switzerland. *Biological Conservation* 129(2):271–276.

Elsasser, Albert B.
1981 Notes on Yana Ethnobotany. *Journal of California and Great Basin Anthropology* 3(1): 69–77.

Essene, Frank J.
1936 Ethnological Documents Collection of the Department and Museum of Anthropology, University of California, Berkeley, BANC FILM 2216 (Originals: CU-23.1). Item No. 206.4, Ethnographic Material by Jennie Newlan. University Archives, The Bancroft Library, University of California, Berkeley.
1942 Culture Element Distributions: XXI, Round Valley. *Anthropological Records* 8(1):1–97.

Falk, Donald A., Margaret A. Palmer and Joy B. Zedler, eds.
2006 *Foundations of Restoration Ecology*. Island Press, Washington, D.C.
Forde C. Daryll
1930–1931 Ethnography of the Yuma Indians. *University of California Publications in American Archaeology and Ethnology* 28: 83–278.
Foster, George M.
1944 A Summary of Yuki Culture. *Anthropological Records* 5(3):155–244.
Garth, Thomas R.
1953 Atsugewi Ethnography. *Anthropological Records* 14(2):129–213.
Gayton, Anna H.
1948 Yokuts and Western Mono Ethnography I: Tulare Lake, Southern Valley, and Central Foothill Yokuts. *Anthropological Records* 10(1):1–140.
Gifford, Edward W.
1939–1940 Detergents. Karok Field Notes. California State Library Collections, Phoebe Apperson Hearst Museum of Anthropology, University of California, Berkeley.
Godfrey, Elizabeth H.
1941 Yosemite Indians Yesterday and Today. *Yosemite Nature Notes* 20(7):49–72. Yosemite Natural History Association.
Goldschmidt, Walter R.
1951 Nomlaki Ethnography. *University of California Publications in American Archaeology and Ethnology* 42(4):303–443.
Goode, Ron W.
1992 Cultural Traditions Endangered. Report to the U.S. Forest Service, Sierra National Forest, Clovis.
Goodrich, Jennie, Claudia Lawson, and Vana Parrish Lawson
1980 *Kashaya Pomo Plants*. American Indian Studies Center, University of California, Los Angeles.
Gordon-Cummings, Constance F.
1883 Wild Tribes of the Sierra. *The National Review* 2(8):412–421.
Grace Hudson Museum Archives.
n.d.a John Hudson's Manuscript Wooden Tools. Collection of Grace Hudson Museum and Sun House, Ukiah, California.
n.d.b John Hudson's Manuscript Botany Vocabulary. Collection of Grace Hudson Museum and Sun House, Ukiah, California.
n.d.c John Hudson's Pomo Linguistic Manuscript, Botany Folder. Collection of Grace Hudson Museum and Sun House, Ukiah, California.
Greene, David F., Michael Hesketh, and Edith Pounden
2010 Emergence of Morel (*Morchella*) and Pixie Cup (*Geopyxis carbonaria*) Ascocarps in Response to the Intensity of Forest Floor Combustion During a Wildfire. *Mycologia* 102(4):766–773.
Grove, Simon J.
2002 Saproxylic Insect Ecology and the Sustainable Management of Forests. *Annual Review of Ecology and Systematics* 33:1–23.
Grüter, A., U. Friederich, and F.E. Würgler
1990 Antimutagenic Effects of Mushrooms. *Mutation Research* 231(2):243–249.
Harrington, John P.
1986 John P. Harrington Unpublished Field Notes, Part 2: Northern and Central California. National Anthropological Archives, Smithsonian Institution, Washington, D.C. [Microfilm Edition, Kraus International Publications, Milwood, N.Y.].
Haslam, L.
1911 Retrospection, or Pioneer Days in Old Tuolumne. *Tuolumne County Magazine* 1(3): 9–11.
He, X.H., W.R. Horwath, R.J. Zasoski, Z. Aanderud, and C.S. Bledsoe
2007 Nitrogen Sink Strength of Ectomycorrhizal Morphotypes of *Quercus douglasii*, *Q. garryanna*, and *Q. agrifolia* Seedlings Grown in a Northern California Oak Woodland. *Mycorrhiza* 18:33–41.
Hebel, Cassie L., Jane E. Smith, and Kermit Cromack, Jr.
2009 Invasive Plant Species and Soil Microbial Responses to Wildfire Burn Severity in the Cascade Range, Oregon. *Applied Soil Ecology* 42(2):150–159.
Hedges, Ken and Christina Beresford
1986 *Santa Ysabel Ethnobotany* (Ethnic Technology Notes, no. 20). San Diego Museum of Man, Balboa Park, San Diego.
Heizer, Robert F.
1978 History of Research. In *Handbook of North American Indians, California* Vol. 8, eds. Robert F. Heizer and William C. Sturtevant, pp. 6–15. Smithsonian Institution, Washington, D.C.
Heizer, Robert F., ed.
1967a Ethnographic Notes on California Indian Tribes, II. Ethnological Notes on Northern and Southern California Indian Tribes by C. Hart Merriam. *Reports of the University of California Archaeological Survey*, no. 68, Part II. University of California Archaeological Research Facility, Department of Anthropology, Berkeley.

1967b Ethnographic Notes on California Indian Tribes, III. Ethnological Notes on Central California Indian Tribes by C. Hart Merriam. *Reports of the University of California Archaeological Survey*, no. 68, Part III. University of California Archaeological Research Facility, Department of Anthropology, Berkeley.

Hobbs, Christopher
1995 *Medicinal Mushrooms: An Exploration of Tradition, Healing and Culture*. Botanica Press, Santa Cruz.

Hosford, David, David Pilz, Randy Molina, and Michael Amaranthus
1997 Ecology and Management of the Commercially Harvested American Matsutake Mushroom. *General Technical Report* PNW-GTR-412. USDA Forest Service Pacific Northwest Research Station, Portland.

Hynes, Megan M., Matthew E. Smith, Robert J. Zasoski, and Caroline S. Bledsoe
2010 A Molecular Survey of Ectomycorrhizal Hyphae in a California *Quercus-Pinus* woodland. *Mycorrhiza* 20(4):265–274.

Karuk, Tribe and Cultural Solutions
1999 Karuk Forest Management Perspectives: Interviews with Tribal Members. Prepared for USDA Forest Service. Klamath National Forest, Yreka.

Kaul, T.N.
2002 *Biology and Conservation of Mushrooms*. Science Publishers, Inc., Enfield, New Hampshire.

Kennedy, P.G., A.D. Izzo, and T.D. Bruns
2003 There is High Potential for the Formation of Common Mycorrhizal Networks between Understory and Canopy Trees in a Mixed Evergreen Forest. *Journal of Ecology* 91(6):1071–1080.

Keter, Thomas S.
1985 On the Edge: Historic Settlement and Adaptation on the North Fork (Eel River). Paper Presented to The Society for California Archeology. On file at the USFS Six Rivers National Forest, Eureka.
1987 Indian Burning: Managing the Environment before 1865 along the North Fork. Paper presented to the Society for California Archaeology, Fresno.

Knudtson, Peter M.
1992 *The Wintun Indians of California and Their Neighbors*, American Indian Map-Book Series, Vol. 3. Naturegraph Publishers, Inc., Happy Camp.

Kroeber, Alfred L.
1939 Field Notes on the Yurok. University Archives, Bancroft Library, University of California, Berkeley.
1976 *Yurok Myths*. University of California Press, Berkeley.

Kuo, Michael
2001 *Agaricus campestris*: The Meadow Mushroom. Available at: http://www.mushroomexpert.com/agaricus_campestris.html (verified 15 February 2011).
2006 *Amanita lanei*. Available at: http://www.mushroomexpert.com/amanita_lanei.html (verified 15 February 2011).

Lake, Frank
2007 Traditional Ecological Knowledge to Develop and Maintain Fire Regimes in Northwestern California, Klamath-Siskiyou Bioregion: Management and Restoration of Culturally Significant Habitats. Ph.D. Dissertation (Environmental Sciences). Oregon State University, Corvallis.

Lakhanpal, T.N.
2000 Ectomycorrhiza —An Overview. In *Mycorrhizal Biology*, eds. K.G. Mukerji, B.P. Chamola and Jagjit Singh, pp. 101–118. Kluwer Academic/Plenum Publishers, New York.

Lando, Richard and Ruby E. Modesto
1977 *Temal Wakhish*:A Desert Cahuilla Village. *Journal of California Anthropology* 4(1): 95–112.

Lepofsky, Dana
2009 The Past, Present, and Future of Traditional Resource and Environmental Management. *Journal of Ethnobiology* 29: 161–166.

Lerch, Michael K.
1979–1981 Serrano Fieldnotes. Unpublished Manuscript in Possession of the Author, Statistical Research, Woodland, California.

Lertzman, Ken
2009 The Paradigm of Management, Management Systems, and Resource Stewardship. *Journal of Ethnobiology* 29:339–358.

Lorimer, Craig G., Daniel J. Porter, Mary Ann Madej, John D. Stuart, Stephen D. Veirs Jr., Steven P. Norman, Kevin L. O'Hara, and William J. Libby
2009 Presettlement and Modern Disturbance Regimes in Coast Redwood Forests: Implications for the Conservation of Old-growth Stands. *Forest Ecology and Management* 258:1038–1054.

Luoma, Daniel L., Joyce L. Eberhart, Richard Abbott, Andrew Moore, Michael P. Amaranthus, and David Pilz
2006 Effects of Mushroom Harvest Tech-

nique on Subsequent American Matsutake Production. *Forest Ecology and Management* 236:65–75.

Maniery, J. Gary
1983 A Chronicle of Murphys Rancheria (*Mol-Pee-So*): A Historic Central Sierra Miwok Village. *Journal of California and Great Basin Anthropology* 5(1&2):176–198.

Maser, Chris, James M. Trappe, and R.A. Nussbaum
1978 Fungal-small Mammal Interrelationships with Emphasis on Oregon Coniferous Forests. *Ecology* 59(4):799–809.

Mason, J. Alden
1912 The Ethnology of the Salinan Indians. *Publications in American Archaeology and Ethnology* 10(4):97–240.

McMillin, James H.
1956 The Aboriginal Human Ecology of the Mountain Meadows Area in Southwestern Lassen County, California. Master's Thesis (Anthropology). California State University, Sacramento.

McNeely, Jeffrey A., Kenton R. Miller, Walter V. Reid, Russell A. Mittermeier, and Timothy B. Werner
1990 *Conserving the World's Biological Diversity*. International Union for the Conservation of Nature/World Resources Institute/World Wildlife Fund, Washington D.C.

Molina, Randy and James M. Trappe
1982 Patterns of Ectomycorrhizal Host Specificity and Potential among Pacific Northwest Conifers and Fungi. *Forest Science* 28(3):423–458.

Molina, Randy, Thomas O'Dell, Daniel Luoma, Michael Amaranthus, Michael Castellano, and Kenelm Russell
1993 Biology, Ecology, and Social Aspects of Wild Edible Mushrooms in the Forests of the Pacific Northwest: A Preface to Managing Commercial Harvest. General Technical Report PNW-GTR-309. United States Department of Agriculture Forest Service Pacific Northwest Research Station, University of Minnesota, Minneapolis.

Molina, Randy, David Pilz, Jane Smith, Susie Dunham, Tina Dreisbach, Thomas O'Dell, and Michael Castellano
2001 Conservation and Management of Forest Fungi in the Pacific Northwestern United States: An Integrated Ecosystem Approach. In *Fungal Conservation Issues and Solutions*, eds. D. Moore, N.N. Nauta, S.E. Evans and M. Rotheroe, pp. 19–63. Cambridge University Press, Cambridge.

Morris, Melissa H., Matthew E. Smith, David M. Rizzo, Marcel Rejmánek, and Caroline S. Bledsoe
2008 Contrasting Ectomycorrhizal Fungal Communities on the Roots of Co-Occurring Oaks (*Quercus* spp.) in a California Woodland. *New Phytologist* 178:167–176.

Morrison, Michael L.
2009 *Restoring Wildlife: Ecological Concepts and Practical Applications*. Island Press, Washington, D.C.

Neely, William
1971 Miwok uses of Yosemite Plants. Yosemite Research Library, Yosemite National Park.

Norvell, Lorelei L.
1992 Studying the Effects of Mushroom Harvesting on Chanterelle Productivity in Oregon's Mt. Hood National Forest. Abstract in *Northwest Scientific Association 65th Annual Meeting Program*, Bellingham, Washington.

O'Dell, Thomas E., Joseph F. Ammirati, and Edward G. Schreiner
1999 Species Richness and Abundance of Ectomycorrhizal Basidiomycete Sporocarps on a Moisture Gradient in the *Tsuga heterophylla* Zone. *Canadian Journal of Botany* 77(12):1699–1711.

Olsson, Jörgen and Bengt G. Jonsson
2010 Restoration Fire and Wood-inhabiting Fungi in a Swedish *Pinus sylvestris* Forest. *Forest Ecology and Management* 259: 1971–1980.

Ortiz, Beverly R.
2008 Contemporary California Indian Uses for Food of Species Affected by *Phytophthora ramorum*. In *Proceedings of the Sudden Oak Death Third Science Symposium,* General Technical Report PSW-GTR-214, eds. Susan J. Frankel, John T. Kliejunas and Katherine M. Palmieri, pp. 419–425. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Portland.

Parsons, David J. and S.H. DeBenedetti
1979 Impact of Fire Suppression on a Mixed-conifer Forest. *Forest Ecology and Management* 2:21–33.

Paulides, David
2008 *The Hoopa Project: Bigfoot Encounters in California*. Hancock House Publishers, Blaine, Washington.

Phoebe Apperson Hearst Museum of Anthropology (PAHMA)
1906-1948 Mushroom Specimen Collections. University of California, Berkeley.

Pilz, David
2011 Ensuring Sustainable Harvests of Wild Mushrooms. In *Mushrooms in Forests and Woodlands: Resource Management, Values and Local Livelihoods*, eds. Anthony B. Cunningham and Xuefei Yang, pp. 143–159. Earthscan, London.

Pilz, David and Randy Molina
2002 Commercial Harvests of Edible Mushrooms from the Forests of the Pacific Northwest United States: Issues, Management, and Monitoring for Sustainability. *Forest Ecology and Management* 155:3–16.

Pilz, David and Randy, Molina, eds.
1996 Managing Forest Ecosystems to Conserve Fungus Diversity and Sustain Wild Mushroom Harvests. General Technical Report PNW-GTR-371. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland.

Pilz, David, Rebecca McLain, Susan Alexander, Luis Villarreal-Ruiz, Shannon Berch, Tricia L. Wurtz, Catherine G. Parks, Erika McFarlane, Blaze Baker, Randy Molina, and Jane E. Smith
2007 Ecology and Management of Morels Harvested From the Forests of Western North America. General Technical Report PNW-GTR-710. U.S. Department of Agriculture, Forest Service, Northwest Research Station, Portland.

Pilz, David, Randy Molina, and Jim Mayo
2006 Effects of Thinning Young Forests on Chanterelle Mushroom Production. *Journal of Forestry* 104(1):9–14.

Pilz, David, Nancy S. Weber, M. Carol Carter, Catherine G. Parks, and Randy Molina
2004 Productivity and Diversity of Morel Mushrooms in Healthy, Burned, and Insect-damaged Forests of Northeastern Oregon. *Forest Ecology and Management* 198:367–386.

Pinna, Samuel, Marie-France Gévry, Mathieu Côté, and Luc Sirois
2010 Factors Influencing Fructification Phenology of Edible Mushrooms in a Boreal Mixed Forest of Eastern Canada. *Forest Ecology and Management* 260(3):294–301.

Plamboeck, Agneta H., Todd E. Dawson, Louise M. Egerton-Warburton, Malcolm North, Thomas D. Bruns, and José I. Querejeta
2007 Water Transfer via Ectomycorrhizal Fungal Hyphae to Conifer Seedlings. *Mycorrhiza* 17(5):439–447.

Powers, Stephen
1976 *Tribes of California.* [Reprint of 1877 Contributions to North American Ethnology, III. Department of the Interior, U.S. Geographical and Geological Survey of the Rocky Mountain Region.]. University of California Press, Los Angeles.

Reynolds, Richard D.
1959 Effect of Natural Fires and Aboriginal Burning Upon the Forests of the Central Sierra Nevada. Master's Thesis (Geography). University of California, Berkeley.

Richards, Rebecca T.
1997 What the Natives Know: Wild Mushrooms and Forest Health. *Journal of Forestry* 95(9):4–10.

Richards, Rebecca T. and Max Creasy
1996 Ethnic Diversity, Resource Values, and Ecosystem Management: Matsutake Mushroom Harvesting in the Klamath Bioregion. *Society & Natural Resources* 9:359–374.

Rinaldi, A.C., O. Comandini, and T.W. Kuyper
2008 Ectomycorrhizal Fungal Diversity: Separating the Wheat from the Chaff. *Fungal Diversity* 33:1–45.

Rundel, Philip W., David J. Parsons, and Donald T. Gordon
1988 Montane and Subalpine Vegetation of the Sierra Nevada and Cascade Ranges. In *Terrestrial Vegetation of California*, eds. Michael G. Barbour and Jack Major, pp. 559–599. John Wiley and Sons, Inc. New York.

Russell, Carl P.
1924 Some Notes Made on Sierra Miwok Food Plants. Yosemite National Park Research Library, Yosemite National Park.

Schenck, Sara M. and Edward W. Gifford
1952 Karok Ethnobotany. *Anthropological Records* 13(6):377–392.

Schigel, Dimitry S.
2009 Polypore Assemblages in Boreal Old-growth Forests, and Associated Colecoptera. Ph.D.. Dissertation (Biological and Environmental Sciences). University of Helsinki, Finland.

Shindler, Bruce and Kristin Aldred Cheek
1999 Integrating Citizens in Adaptive Management: A Propositional Analysis. *Conservation Ecology* 3(1):9.

Skinner, Carl N., Alan H. Taylor, and James K. Agee
2006 Klamath Mountains Bioregion. In *Fire in California's Ecosystems*, eds. Neil Sugihara, Jan W. van Wagtendonk, Kevin E. Shaffer, Joann Fites-Kaufman and Andrea E. Thode, pp. 170–194. University of California Press, Berkeley.

Southworth, Darlene and Jennifer Gibson
2010 Going Underground: Studying Fuel Treatment Effects on the Mycorrhizal Com-

munity of Northern California. *Fire Science Brief*, Issue 105 of Project Number 05-2-1-87. Available at: http://www.firescience.gov/projects/briefs/05-2-1-87_FSBrief105.pdf April 2010 (verified 22 May 2012).

Southworth, Darlene, Elizabeth M. Carrington, Jonathan L. Frank, Peter Gould, Connie A. Harrington, and Warren D. Devine
2009 Mycorrhizas on Nursery and Field Seedlings of *Quercus garryana. Mycorrhiza* 19:149–158.

Sparkman, Philip S.
1908 The Culture of the Luiseño Indians. *University of California Publications in American Archaeology and Ethnology* 8(4):187–234.

Spurr, Stephen H. and Burton V. Barnes
1980 *Forest Ecology*. John Wiley & Sons, New York.

Stankey, George H., Clark, Roger N., and Bernard T. Bormann
2005 Adaptive Management of Natural Resources: Theory, Concepts and Management Institutions. General Technical Report PNW-GTR-654. U.S. Department of Agriculture Forest Service, Pacific Northwest Research Station, Portland.

Stendell, Eric R., Thomas R. Horton, and Thomas D. Bruns
1999 Early Effects of Prescribed Fire on the Structure of the Ectomycorrhizal Fungus Community in a Sierra Nevada Ponderosa Pine Forest. *Mycological Research* 103(10): 1353–1359.

Stephens, Scott L., Robert E. Martin, and Nicholas E. Clinton
2007 Prehistoric Fire Area and Emissions from California's Forests, Woodlands, Shrublands, and Grasslands. *Forest Ecology and Management* 251:205–216.

Storm
2004 The Usefulness of Polypores in Primitive Fire Making. *Mushroom: The Journal of Wild Mushrooming* 22(1):22–43.

Stuart, John D. and Scott L. Stephens
2006 North Coast Bioregion. In *Fire in California's Ecosystems*, eds. Neil Sugihara, Jan W. van Wagtendonk, Kevin E. Shaffer, Joann Fites-Kaufman and Andrea E. Thode, pp. 147–169. University of California Press, Berkeley.

Sugihara, Neil G. and Michael G. Barbour
2006 Fire and California Vegetation. In *Fire in California's Ecosystems*, eds. Neil Sugihara, Jan W. van Wagtendonk, Kevin E. Shaffer, Joann Fites Kaufman and Andrea E. Thode, pp. 1–9. University of California Press, Berkeley.

Swetnam, Thomas W., Christopher H. Baisan, Anthony C. Caprio, Peter M. Brown, Ramzi Touchan, R. Scott Anderson, and Douglas J. Hallett
2009 Multi-millennial Fire History of the Giant Forest, Sequoia National Park, California, USA. *Fire Ecology* 5(3):120–150.

Taylor, Alan H. and Carl N. Skinner
1998 Fire History and Landscape Dynamics in a Late-Successional Reserve, Klamath Mountains, California, USA. *Forest Ecology and Management* 111:285–301.

Timbrook, Jan
1990 Ethnobotany of the Chumash Indians, California, Based on Collections by John Harrington. *Economic Botany* 44:236–253.

Trappe, James M.
1962 Fungus Associates of Ectotrophic Mycorrhizae. *Botanical Review* 28(4):538–606.

Trappe, J.M., K. Cromack Jr., J.M. Trappe, D.D.B. Perrrakis, E. Cazares-Gonzales, Michael A. Castellano, and S.L. Miller
2009 Interactions among Prescribed Fire, Soil Attributes, and Mycorrhizal Community Structure at Crater Lake National Park, Oregon, USA. *Fire Ecology* 5(2):30–50.

Trappe, James M., Randy Molina, Daniel L. Luoma, Efren Cázares, David Pilz, Jane E. Smith, Michael A. Castellano, Steven L. Miller, and Matthew J. Trappe
2009 Diversity, Ecology, and Conservation of Truffle Fungi in Forests of the Pacific Northwest. General Technical Report PNW-GTR-772. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland.

Trees Foundation.
2008 The Unique Potential for EcoCultural Recovery. Forest and River News, Fall 2008. Available at: http://treesfoundation.org/publications/article-249 (verified 6 December 2010).

United States Department of Agriculture-Forest Service.
1981 Six Rivers National Forest. Interviews 281, 290, 293, 298, 299, 301, 303, 306, and 310. Interviews on File, Heritage Program, Eureka, California.
1983 Six Rivers National Forest. Interviews 353 and 359. Interviews on File, Heritage Program, Eureka, California.

Valentine, Lori L., Tina L. Fiedler, Stephen R. Haney, Harold K. Berninghausen, and Darlene Southworth

2002 Biodiversity of Mycorrhizas on Garry oak (*Quercus garryana*) in a Southern Oregon Savanna. General Technical Report PSW-GTR-184. U.S. Department of Agriculture, Forest Service, Albany, CA.

Vance, Nan C. and Jane, Thomas, eds.
1997 Special Forest Products: Biodiversity Meets the Marketplace. General Technical Report GTR-WO-63. U.S. Department of Agriculture, Forest Service, Washington, D.C.

van Mantgem, P.J., N.L. Stephenson, E. Knapp, J. Battles, and J.E. Keeley
2011 Long-term Effects of Prescribed Fire on Mixed Conifer Forest Structure in the Sierra Nevada, California. *Forest Ecology and Management* 261:989–994.

van Wagtendonk, Jan W. and Daniel R. Cayan
2008 Temporal and Spatial Distribution of Lightning Strikes in California in Relation to Large-scale Weather Patterns. *Fire Ecology* 4(1):34–56.

van Wagtendonk, Jan W. and Joann Fites-Kaufman
2006 Sierra Nevada Bioregion. In *Fire in California's Ecosystems*, eds. Neil Sugihara, Jan W. van Wagtendonk, Kevin E. Shaffer, Joann Fites-Kaufman and Andrea E. Thode, pp. 264–294. University of California Press, Berkeley.

Voegelin, Erminie W.
1942 Culture Element Distributions: XX, Northeast California. *Anthropological Records* 7:247–251.

Waters, J.R., K.S. McKelvey, C.J. Zabel, and W.W. Oliver
1994 The Effects of Thinning and Broadcast Burning on Sporocarp Production of Hypogeous Fungi. *Canadian Journal of Forest Research* 24:1616–1522.

Watling, Roy
1988 Larger Fungi and some of Earth's Major Catastrophies. *Proceedings of the Royal Society of Edinburgh* 94:49–59.

Werner, P.G.
2007 MycoDigest: Lee Bonar, Pioneer of California Mycology. *Mycena News* 58(7):1–7.

Wicklow, D.T.
1975 Fire as an Environmental Cue Initiating Ascomycete Development in a Tall Grass Prairie. *Mycologia* 67:852–862.

Yang, Zhu L.
2011 Mushrooms, Health and Nutrition. In *Mushrooms in Forests and Woodlands: Resource Management, Values and Local Livelihoods*, eds. Anthony B. Cunningham and Xuefei Yang, pp. 161–173. Earthscan, London.

Young, Marjorie and Vince Viverito
1998 *From Duff to Dinner: A Gourmet's Guide to Mushroom Cookery with Selected Recipes from Master Chefs*. Seasonal Feasts, Los Gatos.

Yurok Tribe Newsletter.
2010 *Yurok Today: The Voice of the Yurok People*. November 2010, Newsletter. Available at: http://www.yuroktribe.org/documents/november_newsletter.pdf (verified 21 December 2011).

Zak, John C. and D.T. Wicklow
1980 Structure and Composition of a Postfire Ascomycete Community: Role of Abiotic and Biotic Factors. *Canadian Journal of Botany* 58:1915–1922.