

# Chapter 11

## Diversity and Ecology of Edible Mushrooms from Patagonia Native Forests, Argentina



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### 11.1 The Macrofungi and the Patagonian Andean Forest

The eastern slope of the Andean-Patagonian forests covers a wide altitudinal, latitudinal, soil, and rainfall variation, conditioned by a marked decrease of the latter toward the east, with annual average values varying from 3500 mm to 500 mm in few kilometers. This variability offers a broad spectrum of “niches” for mushrooms. There is a great diversity of species of macroscopic fungi with large proportion of endemisms (Singer 1969; Moser and Horak 1975; Horak 1979; Garrido 1986; Rajchenberg 2006), including some edible species with interesting organoleptic characteristics and nutritional value (Gamundi and Horak 1993; Barroetaveña and Toledo 2016a; Barroetaveña et al. 2016; Toledo et al. 2016a, b). In a similar way, the Chilean Patagonian region, with higher precipitations, presents a high fungal diversity with several reported edible species (some shared with those of the Eastern side of the Andes), from the Agaricales, Boletales, Russulales, Aphyllophorales, Gasteromycetes, and Ascomycetes, associated with different trees and forests (Valenzuela-Flores 1993, 2003).

Temperate forests of southern Argentina begin in the North of Neuquén Province, at 36° 25' South Latitude, extending 2088.7 km to Tierra del Fuego Province, at 54°

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53'SL. It has a maximum width of 107.56 km in the continental sector, and 225.9 km in Tierra del Fuego, covering a total area of 3,350,786 ha (SAyDS 2007). They form pure or mixed forests. The predominant tree species belong to the genus *Nothofagus*, such as Coihue (*N. dombeyi* (Mirb.) Oerst.), Ñire (*N. antarctica* (G.Forst.) Oerst.), Lengua (*N. pumilio* (Poepp. and Endl.) Krasser), Raulí (*N. alpina* (Poepp. and Endl.) Oerst.), Pellín oak (*N. obliqua* (Mirb.) Oerst.), and Guindo (*N. betuloides* (Mirb.) Oerst.), along with conifers *Austrocedrus chilensis* (D.Don) Pic.Serm. and Bizzarri and *Araucaria Araucana* (Mol.) C. Koch.

## 11.2 Why Is It Interesting to Meet New Wild Edible Mushrooms?

Wild edible mushrooms (WEM) currently have a huge gastronomic interest as they are foods that can be easily certified as ecological and organic, given their provenance of ecosystems with little or no tillage. In addition, they are collected and processed for sale at very low cost. On the other hand, they are categorized by those people who appreciate delicate tastes and flavors as “delicatessen” products, for which a higher price can be paid (Deschamps 2002). Additionally, consumption of edible fungi has increased in recent years mainly because they are considered natural and healthy foods, due to their high protein and low calories content (Barroetaveña and Toledo 2016b; Toledo et al. 2016b; Barros et al. 2007). Also, several mushrooms species are being considered functional foods, those food included in the diet which has one or more targeted functions in the human body, being able to reduce/prevent the likelihood of health disorders (Martins et al. 2017; Morris et al. 2017). Several mushrooms present proven functional properties related to the improvement of digestive and immune functions, reducing risk of cardiovascular disorders and certain tumors, antioxidant properties, antidiabetic effects, and neurogenerative potential. Bioactive compounds responsible for these beneficial effects can be extracted, isolated, and/or purified to prepare dietary supplements known as nutraceuticals, leading to the new era in medicine and healthcare (Morris et al. 2017).

To determine the edibility of a particular species, several works in the field of ethnomycology, which address aspects related to cultural perception, classification and traditional use of fungi, show that effective consumption is the given evidence of edibility (e. g. Ruan-Soto et al. 2007; Garibay-Orijel et al. 2006, 2007) and possibly potential for consumption, if the registry is very isolated. Boa (2004), in his extensive work of global collection on WEM species, uses the same criteria to consider its edibility: “The only reliable guide to edibility is the knowledge that someone has eaten a particular type and survived”. However, information available in different field guides in relation to the species reported as edible can be contradictory. As an example, *Gyromitra esculenta* (Pers.) Fr., considered a delicacy in Finland (Härkönen 1998) and Chile (Valenzuela-Flores 2003) is considered toxic and even lethal if consumed raw in the United States (Hall et al. 2003). The knowledge on different ways of preparation or cooking might also determine that the same species is edible or not.

### 11.3 Wild Edible Mushroom Species from Patagonian Forests

Mushroom species with good possibilities to be used as food, fruit on different substrates or on the forest floor, and establish different ecological associations with trees, either as parasites, symbionts, lignicolous, or humicolous. Their fruit bodies are of appropriate size, good availability, with attractive organoleptic characteristics in relation to color, flavor, and texture (Toledo et al. 2014, 2016a). Fruiting and development of WEM in forest environments is conditioned by various environmental factors, such as exposure on the slopes, tree age and cover, tree, and understorey species, all of which will determine the amount of light that enter the forest as well as temperature, content of organic matter, and soil moisture (Vogt et al. 1992; Bergemann and Largent 2000; Pilz et al. 2004). Knowing these environmental characteristics, along with fruiting phenology, finding frequency, availability, and biomass production (Straatsma et al. 2001; Garibay-Orijel et al. 2009; Toledo et al. 2014), allows to evaluate their economically and environmentally sustainable harvest and, eventually, suggest management options to increase their productivity within the framework of what has been called mycosilviculture (Savoie and Largeteau 2011). Studying the ecology of the highly valued *Cantharellus cibarius* Fr. and *Tricholoma magnivelare* (Peck) Redhead from western USA forests (Pilz et al. 1998, 1999, 2004) has allowed to generate tools and policies for sustainable use and monitoring actions (Pilz and Molina 2002). In the Andean Patagonian region of Argentina, the harvest and consumption of WEM has been largely limited almost exclusively to *Morchella* spp. species and, on a much smaller scale, *Cyttaria darwinii* Berk. and *C. hariatii* E. Fisch. (Deschamps 2002; Boa 2004; Albertó et al. 2010) and *Grifola gargal* Singer, by the Mapuche settlers in the San Martín de los Andes region (Neuquén, Argentina). Another species widely consumed in the region is *Suillus luteus* (L.) Roussel, associated with plantations of exotic conifers (Barroetaveña 2006; De Michelis and Rajchenberg 2007). Reports that address the traditional use of WEM as a food resource by indigenous communities include *Cyttaria darwinii*, *C. hariatii*, *C. hookeri* Berk., *C. berteroi* Berk. and *C. espinosae* Lloyd (Espinosa 1926; Martínez-Crovetto 1968; Vera 1991; Smith-Ramírez 1997; Molares et al. 2019), *Grifola gargal* Singer (Baeza and Manuel 1930; Gunckel 1959; Molares et al. 2019), *Morchella intermedia* Boud., *Fistulina antarctica* (as *F. hepatica* Martínez-Crovetto 1968; Smith-Ramírez 1997; Molares et al. 2019), *Lycoperdon* sp. (Zárraga and Vogel 2005), *Calvatia bovista* (L.) T. Macbr. and *C. lilacina* (Mont. and Berk.) Henn. (Martínez-Crovetto 1968; Vera 1991). However, there are other edible species that have been reported as of great edible interest in the region, such as *Grifola sordulenta* (Mont.) Singer, *Fistulina endoxantha* Speg., *Aleuria aurantia* (Pers.) Fuckel, *Cortinarius xiphidipus* M.M. Moser and E. Horak, *Lepista fibrosissima* Singer, and the coraloid fungus *Ramaria patagonica* (Speg.) Corner (Gamundi and Horak 1993; Toledo 2016; Toledo et al. 2016a). *Aleurodiscus vitellinus* (Lev.) Pat. also constitutes a species with potential gastronomic value, given its particular shape, bright color, good texture, and mild flavor that make it

interesting for consumption (Gamundi and Horak 1993; Gorjón et al. 2013). Of lower edible quality, *Cortinarius magellanicus* Speg.complex, *Camarophyllus adonis* Singer, *Hydropus dusenii* (Bres.) Singer, and *Tricholoma fusipes* E. Horak (Gamundi and Horak 1993) have been cited. Field observations during three seasons showed that *G. sordulenta*, *A. aurantia*, *L. fibrosissima*, *C. adonis*, and *T. fusipes* appeared very rarely in their natural habitat, while species such as *C. magellanicus* complex, *C. xiphidipus*, *G. gargal*, *C. hariotii*, *F. antarctica*, *F. endoxantha*, *H. dusenii*, *R. patagonica*, and *A. vitellinus* (all endemic to the Patagonian Andean forest) together with other cosmopolitan species such as *Macrolepiota procera* (Scop.) Singer, *Lycoperdon perlatum* Pers. and *Lepista nuda* (Bull.) Cooke did it frequently, which allowed going further into the study of those variables that favor its fruiting. To achieve this, we worked on 11 *Nothofagus* sp. stands located in a geographical gradient from 43° 20'08" S and 71° 45'06" W to 39° 25'28" S and 71° 19'00" W, in territories of Chubut, Río Negro and Neuquén provinces (Toledo et al. 2014). The species studied and their characteristics are presented below:

### 11.3.1 *Aleurodiscus vitellinus*. (Lév.) Pat

Phylum: Basidiomycota

Class: Agaricomycetes

Order: Russulales

Family: Steraceae

*Description:* Easily recognized by its cup-shaped gelatinous fruitbodies (Fig. 11.1), 2–6 cm in diameter and up to 4 cm height, orange or pink color, attached



**Fig. 11.1** Fruitbodies of *A. vitellinus* over a *Nothofagus dombeyi* branch

by a central, short, ribbed stem (Toledo et al. 2016a; Gorjón et al. 2013). On *N. dombeyi*, *N. betuloides* and *N. pumilio*.

*Lifestyle and habit*: Lignicolous. Fructifies abundantly on bark over dead or alive branches and trunks. Prefers open places, with low tree cover.

*Organoleptic characteristics*: Texture and color varies with its water content, being firm and of pink orange color when young, becoming gelatinous and strong orange at maturity. Aroma and fungal taste very pleasant.

### 11.3.2 *Hydropus dusenii* (Bres.) Singer

Phylum: Basidiomycota

Class: Agaricomycetes

Order: Agaricales

Family: Marasmiaceae

*Description*: Funnel-shaped fructifications with dry appearance, similar to a “trumpet” (Fig. 11.2), whitish to pale ochraceous in color (Toledo et al. 2016a; Singer 1978). Moderately abundant species mainly associated with *N. dombeyi*, and also *N. betuloides* and *N. pumilio* (Toledo et al. 2016a; Gamundi and Horak 1993).

*Lifestyle and habit*: Lignicolous. Fructifies on fallen logs with advanced degradation state. Usually in groups, rarely solitary.

*Organoleptic characteristics*: Very thin context, with a cartilaginous texture. Mild fungal aroma and taste.



Fig. 11.2 Fruitbodies of *H. dusenii* over fallen *Nothofagus dombeyi* wood





Fig. 11.3 Fruitbody of *F. antarctica* on *Nothofagus dombeyi* trunk

### 11.3.3 *Fistulina antarctica* Speg

Phylum: Basidiomycota  
 Class: Agaricomycetes  
 Order: Agaricales  
 Family: Fistulinaceae

*Description:* Commonly called “cow tongue,” produces fruitbodies that are striking for their large size, tongue-shaped, with bright reddish colour (Fig. 11.3). It is found on *N. pumilio*, *N. dombeyi*, *N. obliqua*, *N. alpina* and *N. antarctica* (Toledo et al. 2016a; Rajchenberg 2006).

*Lifestyle and habit:* Lignicolous, causing brown rot. Found on living trees with incipient degradation.

*Organoleptic characteristics:* Reddish flesh, very gelatinous, fleshy texture. Soft fungal aroma and sweet taste.

### 11.3.4 *Fistulina endoxantha* Speg

Phylum: Basidiomycota  
 Class: Agaricomycetes  
 Order: Agaricales  
 Family: Fistulinaceae



**Fig. 11.4** Fruitbody of *F. endoxantha* on *Nothofagus obliqua* trunk

*Description:* Large fruitbodies, tongue-shaped, chestnut-yellow color (Fig. 11.4). On standing *N. alpina* and *N. obliqua* (Toledo et al. 2016a, Rajchenberg 2006).

*Lifestyle and habit:* Lignicolous, causing brown rot. Found on living trees with incipient degradation.

*Organoleptic characteristics:* Chestnut-yellow flesh, firm, fleshy texture. Soft fungal aroma and sweet taste.

### 11.3.5 *Grifola gargal* Singer

Phylum: Basidiomycota

Class: Agaricomycetes

Order: Polyporales

Family: Meripilaceae

*Description:* Large, multi-layered fructifications arranged over each other, creamy white, with a dirty appearance (Fig. 11.5). It grows only on *N. obliqua* (Toledo et al. 2016a, Rajchenberg 2006).

*Lifestyle and habit:* Lignicolous, causing an alveolar white rot. Found on branches and stems of standing or fallen trees, in places with low tree crown cover.

*Organoleptic characteristics:* Very thin flesh, fleshy texture. Distinctive almond aroma and flavor.



Fig. 11.5 Fruitbody of *G. gargal* on *Nothofagus obliqua* trunk



Fig. 11.6 Fruitbodies of *R. patagonica* on *Nothofagus dombeyi* forest soil

### 11.3.6 *Ramaria patagonica* (Speg.) Corner

Phylum: Basidiomycota

Class: Agaricomycetes

Order: Gomphales

Family: Gomphaceae

*Description:* Fruitbodies with branches bifurcated on the apex, in the form of a coral (Fig. 11.6), bright yellow to orange color. It grows on soil in *N. dombeyi*,



*N. pumilio*, *N. antarctica*, *N. obliqua* and *N. alpina* forests (Toledo et al. 2016a; Corner 1966).

*Lifestyle and habit*: Mycorrhizal. It is frequently observed in groups, fruiting mainly in open areas, with abundant mulch; can form rows of more than five specimens on the ground, rarely solitary.

*Organoleptic characteristics*: Pale orange flesh, dry velvety texture. Soft fungal aroma and sweet woody flavor.

### 11.3.7 *Cortinarius magellanicus* Speg. Complex

Phylum: Basidiomycota

Class: Agaricomycetes

Order: Agaricales

Family: Cortinariaceae

*Description*: Fruitbodies of medium size, from bright lilac to purple (Fig. 11.7), very glutinous, with argillaceous to white lamellae (Toledo et al. 2016a). A recent phylogenetic analysis showed that *C. magellanicus* represents a species complex with strong regionalism and distinct host associations, including *C. roblerauli* Salgado Salomon and Peintner, *C. magellanicus* Speg., and *C. magellanicolbus* Salgado Salomon and Peintner in South America, where also exists other two species morphologically very similar: *Cortinarius capitellinus* E. Horak and *Cortinarius ai-capitiae* Speg. (Salgado Salomón et al. 2018). They grow on soil associated to *N. dombeyi*, *N. betuloides*, *N. pumilio*, *N. obliqua*, *N. alpina* and *N. Antarctica* forests.

**Fig. 11.7** Fruitbodies of *C. magellanicus* on *Nothofagus dombeyi* forest soil



*Lifestyle and habit:* Mycorrhizal. It is found frequently in places covered by ferns, forming large groups.

*Organoleptic characteristics:* Cap with white flesh and delicate, mucilaginous texture. Strong fungal aroma and mild sweet taste.

### 11.3.8 *Cortinarius xiphidipus* M.M. Moser and E. Horak

Phylum: Basidiomycota

Class: Agaricomycetes

Order: Agaricales

Family: Cortinariaceae

*Description:* It is a pretty large mushroom, the cap usually up to 10 cm diam., pale yellowish to light chestnut color, usually covered by leaf litter due to their glutinous layer; lamellae argillaceous. Long stem (up to 15 cm.), white, solid, with remnants of veil, very diagnostic for its rooting shape (Fig. 11.8). Very abundant species, associated with *N. dombeyi*, *N. pumilio*, and *N. antarctica* (Toledo et al. 2016a; Horak 1979).

*Lifestyle and habit:* Mycorrhizal. It fructifies in clusters of numerous specimens, on leaf litter, usually in relatively open places.

*Organoleptic characteristics:* Cap with white flesh, of mucilaginous texture and firm stem. Strong fungal aroma and mild sweet taste.



**Fig. 11.8** Fruitbodies of *C. xiphidipus* on *Nothofagus dombeyi* forest soil

### 11.3.9 *Macrolepiota procera* (Scop.) Singer

Phylum: Basidiomycota

Class: Agaricomycetes

Order: Agaricales

Family: Agaricaceae

*Description:* Commonly called “parasol,” it is a very characteristic species in mixed forests of *N. dombeyi* and *Austrocedrus chilensis* (D.Don) Pic.Serm.& Bizzarri. It is easily recognized by its typical large, convex cap in the form of umbrella, with pale brown colour covered by dark flattened scales (Fig. 11.9); it has a long, double ringed stem that separates easily from the cap (Toledo et al. 2016a).

*Lifestyle and habit:* Saprophytic. Fruits mainly in clearings of the forest and sometimes on the roadsides. It appears individually or in large groups.

*Organoleptic characteristics:* Cap with white flesh, light corky texture, while the stem is fibrous and inconsistent. Yeast aroma and soft fungal taste, very pleasant with nuances of nuts.

**Fig. 11.9** Fruitbody of *M. procera* on *Nothofagus dombeyi* and *A. chilensis* mixed forest





Fig. 11.10 Fruitbodies of *L. nuda* on *Nothofagus dombeyi* forest soil

### 11.3.10 *Lepista nuda* (Bull.) Cooke

Phylum: Basidiomycota  
 Class: Agaricomycetes  
 Order: Agaricales  
 Family: Tricholomataceae

*Description:* Characterized by its blue-violet cap, same as the lamellae (Fig. 11.10). Commonly known as “blue foot” or “blewit,” it is a widely distributed species in North America (Toledo et al. 2016a; Lincoff 1991). In Patagonia it has been found fruiting associated with *N. dombeyi* and *N. obliqua*.

*Lifestyle and habit:* Saprophytic. It appears individually or in large groups, forming witch rings on the ground.

*Organoleptic characteristics:* White to lilac-buff flesh, thick with tender fleshy texture, especially the cap. Fruity aroma and soft fungal taste, very pleasant. The stem is fibrous and inconsistent.

### 11.3.11 *Lycoperdon perlatum* Pers.

Phylum: Basidiomycota  
 Class: Agaricomycetes  
 Order: Agaricales  
 Family: Agaricaceae





**Fig. 11.11** Fruitbodies of *L. perlatum* on *Nothofagus dombeyi* forest soil

*Description:* It has pear-shaped fructifications changing to globose with maturity (Fig. 11.11), up to 5 cm high and 2.5–3 cm in diameter; the surface whitish when young and brown at maturity, covered with small spines (Toledo et al. 2016a; Demoulin 1971). It has a wide global distribution; in Patagonia occurs it *N. dombeyi*, *N. antactica*, *N. pumilio*, *N. obliqua*, and *N. alpina* forests, in humid spots with shallow mulch.

*Lifestyle and habit:* Saprophytic. Fruits, solitary or in groups, on soils with abundant decaying wood.

*Organoleptic characteristics:* Fruits are consumed young, when the flesh is white and with soft texture. Aroma and taste fungal when immature, which is the only edible stage; when the gleba darkens, its qualities change and it must be discarded.

### 11.3.12 *Cyttaria hariotii* E. Fisch

Phylum: Ascomycota

Class: Leotiomycetes

Order: Cyttariales

Family: Cyttariaceae

*Description:* Commonly known as “llao-llao.” Their fructifications appear as “eyes” that are outlined on globose stroma of yellow-orange color, 3–7 cm in diameter (Fig. 11.12). At maturity they present circular holes in the surface, which correspond to the mature fruiting of the fungus (Gamundi 1971; Gamundi and Horak 1993).





Fig. 11.12 Fruitbodies of *C. hariatii* on *Nothofagus antarctica* trunk

*Lifestyle and habit:* Obligate parasite of several *Nothofagus* species, forming tumors, developing abundantly on the branches or stems of their hosts.

*Organoleptic characteristics:* Thick flesh, yellowish, soft fleshy texture, more pleasant in young specimens. Soft fungal aroma and sweet fungal taste.

#### 11.4 Ecological Aspects Associated with the Fruiting of Wild Edible Mushrooms

The study of the environmental variables associated with the fruiting of these saprophytic, mycorrhizal, and lignicolous edible species (Toledo et al. 2014; Toledo 2016) allowed to establish close associations between them. Mulch depth turned out to be positively associated with the fruiting of the mycorrhizal species *C. magellanicus* and *C. xiphidipus* (Table 11.1), in accordance with what was reported by Bergemann and Largent (2000) for the mycorrhizal species *Cantharellus formosus* Corner, with values that did not exceed 5 cm. The quality and quantity of mulch is an important factor for mycorrhizae formation in the forest soil, although many groups of mycorrhizal fungi do not fructify where there are large quantities due to inadequate soil aeration (Bergemann and Largent 2000). However, in the case of *C. xiphidipus*, all the species of this section (*xiphidipus* stirp, Moser and Horak 1975) are characterized by a long, radicate stipe, which probably constitutes an adaptation to the presence of litter layers or deep volcanic ash, frequent in the Patagonian Andes forests. On the other hand, the saprophytic species *L. perlatum*

**Table 11.1** Average values of environmental variables associated with the fruiting of humicolous and mycorrhizal edible species

	<i>C. magellanicus</i>	<i>C. xiphidipus</i>	<i>R. patagonica</i>	<i>L. nuda</i>	<i>L. perlatum</i>	<i>M. procera</i>
% MO	19.23 <sup>a</sup> ± (0.29)	20.53 ± (1.20)	19.17 ± (0.67)	19.36 ± (0.27)	17.21 ± (0.35)	18.75 ± (0.31)
% H	18.27 ± (0.68)	16.38 ± (0.89)	18.38 ± (0.63)	16.88 ± (0.56)	21.91 ± (1.17)	16.12 ± (0.52)
CA	84.69 ± (0.97)	80.79 ± (1.04)	84.15 ± (0.80)	77.45 ± (1.71)	76.31 ± (1.22)	82.30 ± (0.81)
Ca	19.38 ± (4.70)	7.81 ± (2.41)	12.81 ± (2.58)	8.44 ± (2.31)	13.13 ± (3.90)	18.44 ± (3.41)
Ch	28.00 ± (7.14)	5.94 ± (2.51)	13.94 ± (3.16)	3.44 ± (1.87)	12.81 ± (2.81)	11.25 ± (3.04)
Cmant	76.25 ± (3.75)	80.00 ± (4.18)	80.63 ± (3.22)	89.38 ± (2.95)	75.94 ± (2.55)	83.13 ± (1.76)
Cmd	2.50 ± (0.65)	2.81 ± (0.79)	1.25 ± (0.56)	1.25 ± (0.72)	0.31 ± (0.31)	0.31 ± (0.31)
Pm	3.64 ± (0.25)	3.93 ± (0.21)	2.98 ± (0.13)	2.98 ± (0.16)	2.62 ± (0.14)	3.04 ± (0.16)

% MO organic matter percentage, % H soil moisture percentage, CA tree crown cover, Ca shrub cover, Ch herbaceous cover, Cmant mulch cover, Cmd wood debris cover, Pm mulch depth

<sup>a</sup>Values are averages of 16 replicates ± (SD)

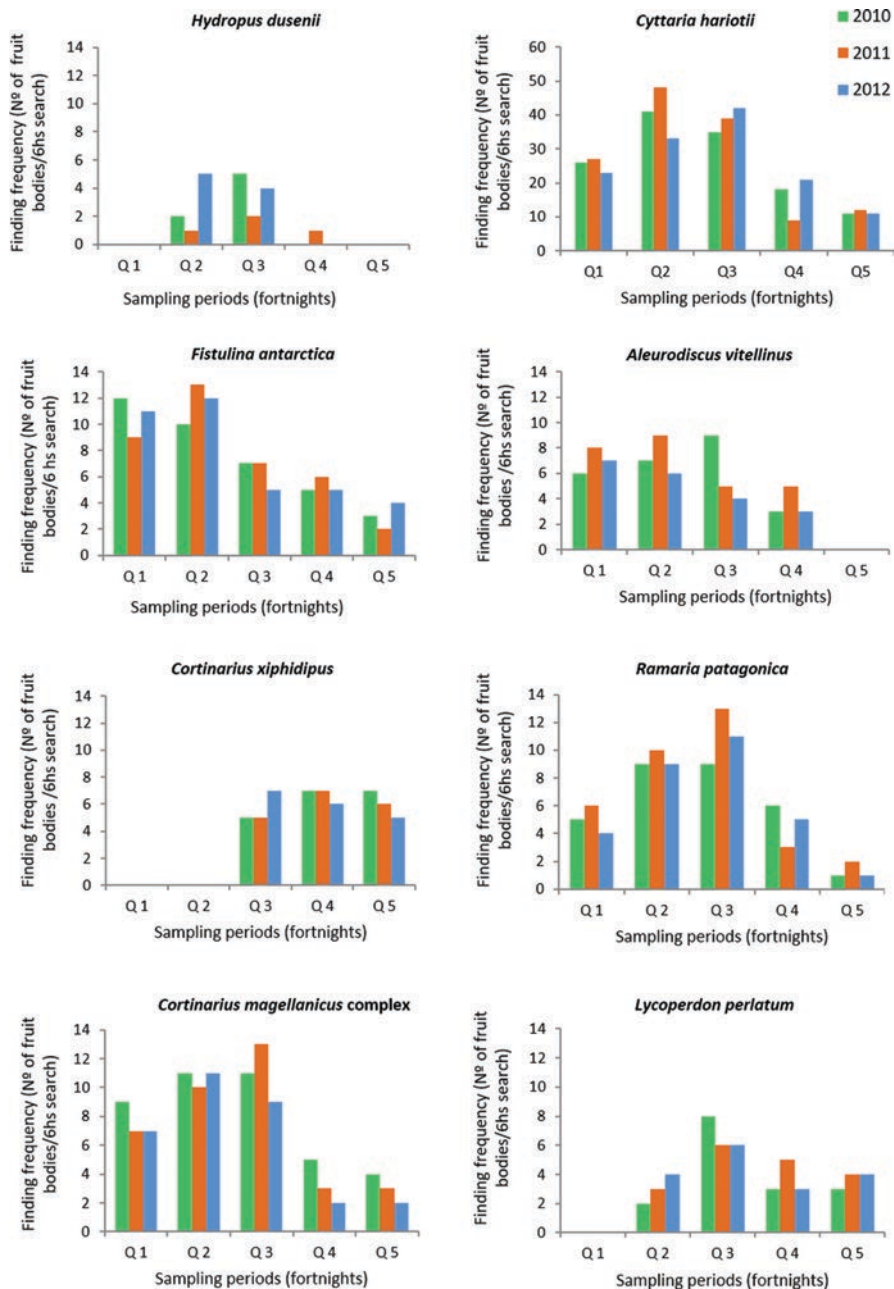
was negatively correlated with this variable, fruiting in sites with low mulch depth, in contrast to what was proposed by Vogt et al. (1992), who affirm that humic species develop on large amounts of organic waste.

In general, high values of organic matter were registered in soils associated to all the terricolous species (Table 11.1), coinciding with what has been reported for western- Patagonian Andes soils (La Manna et al. 2011). The range of variability of this parameter between species was narrow, indicating their intimate link with mushrooms fructification, as it has been reported for other forests (Vogt et al. 1992). The greater differences in organic matter were detected between the mycorrhizal *C. xiphidipus*, with the highest value, and *L. perlatum* (Table 11.1). The content of organic matter favors water retention capacity and nutrient availability while influencing mycorrhizal formation (Bergemann and Largent 2000). The presence of wood debris was also positively associated with the mycorrhizal species *C. magellanicus* and *C. xiphidipus*. Fallen wood shelters a large number of mycorrhizal roots (Harvey et al. 1996) and constitutes a reservoir of soil moisture that favours fruiting (Luoma et al. 2004). Soil moisture content for *C. xiphidipus* was relatively low (12.1–24.3%), probably because mulch accumulation, but associated with the presence of wood debris. On the other hand, *L. perlatum*, associated with less mulch depth and organic matter content, fructify at higher soil moisture values (14.50–27.50%).

All the humicolous and mycorrhizal species developed in sites with high tree cover, over 76%, coinciding with closed and humid sites reported by Gamundi and Horak (1993). These results match partially with those of Santos-Silva and Louro (2011) who found a strong association between mycorrhizal species and high tree cover, lower for saprophytic species, although clarifying that this last result could be conditioned by the high proportion of lignicolous and gasteroids species, the latest without representatives in our study. The coverage of herbaceous plants, however, was generally low, with a maximum of 30% for five of the six terricolous species, as compared with *Suillus luteus* fructification patches in *Pinus ponderosa* Dougl ex Laws. plantations in Patagonia, with values of 60% (Barroetaveña et al. 2008).

Fructification phenology was variable according to species. Lignicolous species showed a higher fructification abundance at the beginning of the season (fortnights 1, 2, and 3). *Aleurodiscus vitellinus* and *F. antarctica* were more abundant in the first two autumn fortnights, while *H. dusenii* was more abundant in fortnight 3 (Fig. 11.13). This could be explained by the fact that they receive moisture from the trunk or decomposing branches, which functions as reservoirs of water, and do not depend on accumulated precipitation. Terricolous species showed a more diverse fruiting pattern. *Ramaria patagonica* and *C. magellanicus* presented highest fructification abundance at the beginning of autumn, with peaks in fortnight 3 (Fig. 11.13), while *C. xiphidipus* and *L. perlatum* did so during the last 3 fortnights, quite homogeneously the former, and with a peak in fortnight 3 the latest (Toledo et al. 2014).

Therefore, a harvest plan should contemplate this variability in order to adapt harvesting and commercialization steps throughout the season. The finding frequency was also very variable between species, resulting *F. antarctica*, *C. magellanicus* complex, *R. patagonica*, and *C. hariatii* the more frequent (Fig. 11.13).



**Fig. 11.13** Finding frequency per fortnight (No. fruit bodies observed/6 h search) (indicated on the axis of the ordinates), of eight wild edible mushrooms species during 2010, 2011 and 2012 fruiting seasons. *Spring season (C. hariotii)*: F1, beginning-mid October; F2, mid-end October; F3, beginning-mid November; F4, mid- end November; and F5, beginning-mid December. *Autumn season (H. dusenii, F. antarctica, A. vitellinus, C. xiphidipus, R. patagonica, C. magellanicus and L. perlatum)*: F1, mid-end March; F2, beginning-mid April; F3, mid-end April; F4, beginning-mid May; and F5, mid-end May

Thus, the autumn period would begin in mid-March with the offer of *F. antarctica*, followed by *A. vitellinus*, *C. magellanicus* complex, and *R. patagonica* which would extend until beginning of May. *Cortinarius xiphidipus* and *L. perlatum* could be offered from mid-April until the end of the season: *H. dusenii* in a more limited way, during April.

In relation to wood degrader species, it was observed that *F. antarctica* developed on live trunks of several *Nothofagus* species producing brown rot (Gamundi and Horak 1993; Rajchenberg 2006), associated with a high tree cover (80.23–87.56%) and an incipient state of wood degradation. *Fistulina endoxantha*, occurring on live trunks of *N. alpina* and *N. obliqua* producing brown rot (Rajchenberg 2006), was found to be mainly associated with *N. obliqua*, and a medium state of wood degradation. *Aleurodiscus vitellinus* was registered mainly growing under low tree cover (63.89–67.85%), on trunks and branches of dead *N. dombeyi*, although it has been reported associated also with *N. betuloides* and *N. pumilio* branches, on living and dead wood and on bark (Gamundi and Horak 1993). *Grifola gargal*, associated with high tree cover (82.56–86.89%), appeared restricted to branches and trunks of standing or fallen *N. obliqua*, causing white alveolar rot in the heartwood as reported by Pozzi et al. (2009). *Hydropus dusenii* appeared mainly associated with *N. dombeyi*, although it is also mentioned for *N. pumilio* (Gamundi and Horak 1993), fruiting on very degraded fallen trunks and under average tree cover values (72.87–76.43%).

## 11.5 Conclusions and Perspectives

The environmental variables conditioned fructification with different intensity according to the substrate where fungal species growth. Terricolous species were variably conditioned by soil water availability associated with tree cover, soil organic matter and mulch characteristics, with different fruiting moments according to temperatures and accumulated precipitations. Lignicolous species use the substrate as a reservoir of moisture for their fructification, being able to fructify early in the season. Wood degradation stages also showed association with the occurrence of lignicolous species fructification, while *F. antarctica* and *F. endoxantha* developed on almost unaltered and altered wood, respectively, *H. dusenii* did so on fallen, very degraded logs.

Saprophytic and lignicolous WEM species constitute a plausible product to be cultivated (Toledo and Barroetaveña 2017). Currently, there are many studies focused on the search for optimal parameters to cultivate novel species (Lechner and Albertó 2007; Reyes et al. 2009; Zhou et al. 2015). Since they fructify with an strictly seasonal pattern, in environments with reduced and difficult accessibility, with lower frequency of finding compared with species associated with pine plantations, such as *Suillus luteus*, their increased availability would improve the chances to place them as gourmet products, or take better advantage of their medicinal properties (Morris et al. 2017; Toledo et al. 2016b).



Results obtained for these species from Patagonia show the importance of the simultaneous evaluation of multiple issues associated with WEM fructification. Some species such as *A. vitellinus* register a high number of collections, but have small fructifications that result in very little weight, while species such as *R. patagonica* or *F. antarctica* become important due to the size and fresh weight of their fruiting, despite having a lower number of collections (Toledo et al. 2014).

The narrow ranges detected for certain environmental variables associated with fruiting of humicolous and mycorrhizal edible species from Patagonian forest, such as the presence of soil wood debris, organic matter percentage, mulch depth, and coverage and tree crown cover, suggest that the fruiting of these species could be affected by small variations of these parameters. Lignicolous species, on the other hand, require different stages of wood degradation for their development. In this sense, different forest uses such as firewood extraction, logging or cattle grazing in these environments generate impacts that could affect WEM productivity, as it has been reported for northwest USA forests under silvicultural management (Colgan et al. 1999; Luoma et al. 2004).

A detailed knowledge of WEM ecology, together with forest management policies that include them as a forest product, will allow to plan their harvest and conservation. In this framework, productivity estimates as well as detailed phenology of each species should be revalidated with local studies, given that both parameters have a close relationship with the latitudinal and pluviometric variation present in the vast Andean-Patagonian region.

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