List of beetles (Coleoptera) associated with the oyster mushroom, *Pleurotus ostreatus* Fr., in the Onon-Balj National Park of Mongolia

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We present a list of the beetle species associated with the oyster mushroom, *Pleurotus ostreatus* Fr. in the birch forest of Onon-Balj National Park in Mongolia. A total of 21 species in seven families were found in this fungus, including fungivorous species: *Litargus japonicus* Reitter and *Mycetophagus antennatus* (Reitter) (Mycetophagidae), *Pseudamblyopus similis* (Lewis) (Erotylidae), and *Lordithon* sp. (Staphylinidae) etc. Both adult and larval forms are presented in the checklist along with the type of fungal association, of which approximately 52 percent are obligate mycetobionts. The main trends of the ecological and trophic specialization of the mycetophilic beetles are discussed.

Keywords: fungal host, fungivorous beetles, Mongolia, *Pleurotus ostreatus*

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INTRODUCTION

Basidiomycetes are the most commonly used foods of fungivorous Coleopteran beetles. Basidiomycetes which serves as hosts for beetles are composed mainly of two large groups; one of them is bracket fungi (order Aphyllophorales) which form spores within tubes and rarely on teeth, and the other is mushrooms (order Agaricales) which form spores on gill or rarely within tubes. Most Aphyllophorales are ligneous and most Agaricales are soft (Breitenbach and Kränzlin, 1986; Leschen, 1990; Kim *et al.*, 2004). Insects feeding on bracket fungi appear to be more host-specific than insects feeding on mushrooms (Lawrence and Milner, 1996; Jung and Lee, 2011). The long lifespan and ecological succession of fruiting bodies of Aphyllophorales would contain more beetle species than softer, fleshy, more ephemeral Agaricales, although the latter often has a greater number of or abundance of beetles at any given time (Cline and Leschen, 2005).

Some fungivorous beetles including Erotylidae, Mycetophagidae, Tetratomidae and some Tenebrionidae are observed to be obligatory inhabitants of Basidiomycetes. In particular, woody and thick fungi of the order Aphyllophorales and Agaricales provide microhabitats in which many arthropod species spend their entire lives (Klimaszewski and Peck, 1987; Leschen, 1990; Jung

and Kim, 2008; Jung and Lee, 2011). These fungi provide their inhabitants with food, shelter, and breeding places either directly or indirectly (Graves, 1960; Pavour-Smith, 1960; Klimaszewski and Peck, 1987; Wheeler, 1987; Cline and Leschen, 2005; Jung and Lee, 2011).

Among them, the oyster mushroom, *Pleurotus ostreatus* Fr. (Fig. 1) is distributed throughout temperate regions of the world (Lee, 1988; Kim *et al.*, 2004; Cline and Leschen, 2005). These mushrooms are edible and in high demand by mushroom collectors and individual growers (Kim *et al.*, 2004; Cline and Leschen, 2005).

Pleurotus ostreatus can be distinguished by the following combination of characters: caps laterally attached; cap 43-200 mm in length, fan-shaped to shallowly funnel-shaped; white to grayish or brownish color and rolled margin; slightly depressed in center; surface smooth and moist; fruiting bodies often conjoined and overlapping; stalk white, stout, smooth and short; gills descending stalk, close to nearly distinct and thick; spore print white (Lincoff, 1981; Lee, 1988; Kim *et al.*, 2004; Cline and Leschen, 2005). This fungus is a decomposer of wood and is most often encountered on dying or dead deciduous trees (Lee, 1988; Kim *et al.*, 2004), but rarely encountered on conifers (Vilgalys *et al.*, 1993). It also typically begins to appear in late spring and persist throughout the summer and fall, and so is most abundant on cool and damp days in early to late autumn in deciduous forests (Cline and Leschen, 2005).

Pleurotus ostreatus is an important fungal host for many mycophagous beetles in Europe and Asia (Donisthorpe, 1935; Scheerpeltz and Höfler, 1948; Benick,

1952; Rehfoos, 1955; Nobuchi, 1956; Höfler, 1960; Cline and Leschen, 2005).

The purpose of this study is to provide a list of Mongolian beetles associated with *P. ostreatus* in the birch forest of Onon-Balj National Park (Fig. 2). And we discuss this host fungus as an important resource for fungivorous and predatory beetles.

MATERIALS AND METHODS

Sampling

From 18 to 21 on July in 2012, we collected about 30 fruiting bodies of *Pleurotus ostreatus* Fr. associated with birch trees in the Onon-Balj National Park in Mongolia. To collect material effectively, we removed by hand the fruiting bodies from the substrate on the forest-floor with cloth or vinyl cloth and quickly transferred them into vinyl bags and sealed the bags. Eggs, larvae, and adults found on the fungi were brought to the laboratory for beetle extraction. And all adults, larvae and pupae were subsequently sorted, identified, counted, and fixed in 99% ethyl alcohol.

Terminology and Identification of Fungus

Several ecological classifications exist for fungivorous beetles, and we classify them into three main categories which the beetles were associated with their fungal host (Scheerpeltz and Höfler, 1948; Benick, 1952; Graves, 1960; Höfler, 1960; Lawrence, 1973; Newton, 1984; Klimaszewski and Peck, 1987; Lawrence and Milner, 1996; Cline and Leschen, 2005; Krasutskii, 2007; Jung and Lee, 2011), as follows: 1) Mycetobionts (MB) which are obligatory fungal inhabitants, feeding and breeding on the fun-

Figs 1-2. *Pleurotus ostreatus* in the Birch Forest of Onon-Balj National Park. 1. *Pleurotus ostreatus*. 2. Birch Forest.

Figs. 3-6. Fungivorous beetles associated with *Pleurotus ostreatus* in the Birch Forest of Onon-Balj National Park. 3. *Mycetophagus antennatus*, Mycetophagidae. 4. *Litargus japonicus*, Mycetophagidae. 5. *Pseudamblyopus similis*, Erotylidae. 6. *Dacne bipustulata*, Erotylidae.

Table 1. List of the fungivorous beetles associated with *Pleurotus* in the birch forest of Onon-Balj National Park in Mongolia.

Species	Khentii, Onon-Balj National Park, Dadal			Cate- gory
	18.vii. 2012 (pinus)	20.vii. 2012 (birch)	21.vii. 2012 (birch)	
Order Coleoptera				
Family Staphylinidae				
<i>Lordithon</i> sp.	0		0	MX
<i>Oxyporus</i> sp.			0	MB
<i>Gyrophana</i> (<i>Gyrophana</i>) sp.	0			MB
<i>Gyrophana</i> (<i>Phaenogyra</i>) sp.			0	MB
<i>Pselaphinae</i> sp.			0	MX
Athetini sp. 1	0	0	0	MX
Athetini sp. 2		0		MX
Athetini sp. 3		0		MX
Family Mycetophagidae				
<i>Liargus japonicus</i> Reitter	0			MB
<i>Mycetophagus hillerianus</i> Reitter		0		MB
<i>Mycetophagus antennatus</i> (Reitter)	0	0	0	MB
<i>Mycetophagus</i> sp. (larva)		0		MB
Family Erotylidae				
<i>Dacne bipustulata</i> (Thunberg)		0		MB
<i>Pseudamblyopus similis</i> (Lewis)	0	0	0	MB
<i>Triplax japonica</i> Crotch	0	0		MB
Erotylidae sp. (larvae)		0		MB
Family Trogossitidae				
<i>Leperina squamulosa</i> (Gebler)		0		MP
Family Nitidulidae				
<i>Haptoncus</i> sp.		0	0	MP
Nitidulidae sp.		0		MP
Family Silvanidae				
<i>Ahasverus advena</i> (Waltl)	0		0	MP
Family Tenebrionidae				
<i>Adesmia</i> sp.	0		0	MP
Total	7 families, 21 species			

*Category (type of association) indicates that the beetle is an obligate/mycetobiont (MB), a facultative/mycetophile (MP), an accidental/mycetoxene (MX).

gal host, 2) Mycetophiles (MP), which only feed on fungi at some point during their life, but do not require the fungus for development, and 3) Mycetoxenes (MX), which are found occasionally in and around fungi as a simple visitor for shelter.

Host fungi collected for this study were identified using several illustrated mushroom books (Lincoff, 1981; Imazeki and Hongo, 1987; Lee, 1988; Kim *et al.*, 2004) with the assistance of a mushroom taxonomist in the National Academy of Agricultural Science.

RESULTS

A total of 21 beetle species in seven families were observed to occur on *Pleurotus ostreatus* Fr. of Onon-

Balj National Park in Mongolia (Table 1). Many taxa were observed as a mycophagy. Fungal host, *P. ostreatus*, has been used by Mongolian beetles as follows: *P. ostreatus* provide approximately 52 percent of the total species with feeding and breeding habitats (mycetobionts), approximately 24 percent with only feeding diets (mycetophiles), and approximately 24 percent with shelters or predation (mycetoxenes).

Staphylinidae was the most common beetle family associated with *P. ostreatus* (eight species, representing five subfamilies, 38%). The staphylinid beetles listed are of mixed diets, therefore, most of the species are likely to be predaceous and only one species (*Oxyporus* sp.) is fungivorous. *Oxyporus occipitalis* typically lay eggs inside a chamber constructed within the gill layer of the host mushroom.

Of the remaining non staphylinoid families, mycetobionts comprised the largest proportion of beetles present, which included Erotylidae (four species, 19%), and Mycetophagidae (four species, 19%). And mycetophile comprised Nitidulidae (two species), Trogossitidae (one species), and Tenebrionidae (one species).

Especially, *Mycetophagus antennatus* (Reitter) (Fig. 3) of family Mycetophagidae (Fig. 4) is the most abundant species associated with *Pleurotus* in the birch forest of Onon-Balj National Park in Mongolia. Most of larvae and adults of Korean mycetophagids were confirmed to feed and breed in the fruiting bodies of Aphylloporales [e.g. *Stereum sanguinolentum* (Alb. et Schw.: Fr.); *Daedaleopsis tricolor* (Bull.: Fr.)] and dried Agaricales [e.g. *Armillaria mellea* (Vahl) P. Kumm.; *Omphalotus japonicus* (Kawam.) Kircham. & O. K. Mill.)], which are lignicolous and longevous. These host fungi are thick enough for this species to feed and breed in fruiting body (Jung and Park, 2013), such as *P. ostreatus*.

Pseudamblyopus similis (Lewis) in Erotylidae (Figs. 5, 6) is plentiful in the Onon-Balj National Park in Mongolia. Host fungal specificity on *Pleurotus* is known to some groups, such as the Holarctic *Triplax* (Erotylidae; Selley *et al.*, 1991). It is suggested that erotylids and mycetophagids are mycophagy because both the larvae and adults were found on the fruiting body of *P. ostreatus* in Mongolia.

Although many beetles that are mycophagous, such as the nitidulid *Pallodes*, may inhabit on *Pleurotus* in relatively broad funal host diets (Leschen, 1988), there were two species of family Nitidulidae which maybe considered as a mycetophile because they are commonly inhabit under the bark.

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