



## Mycophagy by small mammals: new and interesting observations from Brazil

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### Abstract

Events of mycophagy by Brazilian native mammals are not often reported in literature, and the identity of the consumed fungal species is not always available. Therefore, the aim of this article is to report two field observations of mycophagy in Southern and Northern Brazil, involving the black-capped squirrel monkey (*Saimiri boliviensis*) and the Azara's agouti (*Dasyprocta azarae*). The primates were observed eating ascomata of *Ascopolyporus* sp. (*Cordycipitaceae*, *Hypocreales*), while the rodents were consuming immature stages ('eggs') of *Itajahya galericulata* (*Phallaceae*, *Phallales*).

**Key words** – feeding behavior – fungivory – mushroom – mutualism – primates – rodents

### Introduction

The term mycophagous is applied to animals that have the consumption of fungi as part of their diets (Merritt 2010). Many species are known to have this habit, including birds (Simpson 2000, Trappe et al. 2009, Tanney & Hutchison 2010), invertebrates (Moore 1996, Boddy & Jones 2008), mammals (Fogel & Trappe 1978, Claridge 2002, Claridge & Trappe 2005), and turtles (Vasco-Palacios et al. 2008).

The fungivorous habit of small mammals, notably being more common among mammals weighing less than three kilos, is well documented in literature and the dependence on fungi as food resource may vary greatly according to the species (Claridge 2002). Mammal mycophagy has been reported for centuries (Trappe et al. 2009) and most records are from North America (Fogel & Trappe 1978, Claridge & Trappe 2005, Castillo-Guevara et al. 2012) and Australia (Claridge & May 1994, Claridge 2002), but there are also records from Europe (Schickmann et al. 2012, Kataržytė & Kutorga 2010) and Japan (Sawada et al. 2013, Sawada 2014).

In South America, mycophagy by mammals has been reported for rodents and the nine-banded armadillo (*Dasybus novemcinctus novemcinctus*) in Argentina (Perez Calvo et al. 1989, Nouhra et al. 2005); as well as deer (*Mazama* spp.) and the Amazon dwarf squirrel (*Microsciurus flaviventer*) in Colombia (Vasco-Palacios et al. 2008). Moreover, the mycophagous habit of small monkeys (marmosets and tamarins) has been continuously investigated in Bolivia (Porter 2001, Porter et al. 2007, Porter & Garber 2010, Hanson et al. 2003, 2006).

In Brazil, the consumption of fungi by native mammals has been reported a few times. Nevertheless, the name of the fungal species is not always available. For example, Peres (1993) reported that Amazonian tamarins of the genus *Saguinus* had “bracket fungi” as part of their diets, and Correa et al. (2000) stated that *Callithrix aurita* (buffy-tufted-ear marmoset) could spend up to 19% of their feeding time consuming fungi, but fungal species names were not mentioned.

Many studies regarding mammals and mycophagy involve sequestrate, hypogeous species, which lack mechanisms of spore discharge and are dependent upon external vectors to disperse their spores. Therefore, it has been shown that mycophagy is not only important for these mammals as a food source, but it is also important for forest ecosystems, since the process distributes mycorrhizal fungi to new tree roots and indirectly influence vegetation succession (Trappe et al. 2009, Schickmann et al. 2012). Epigeous basidiomata (e.g., mushrooms, stinkhorns, bracket fungi) are very diverse and abundant in forest environments; however, they have received much less attention than those hypogeous fungi consumed by mammals (Castillo-Guevara et al. 2012).

Different methodologies have been used to investigate the mycophagous diet of small mammals, including analysis of stomach contents and fecal pellets, feeding experiments and controlled feeding trials, and more rarely, fortuitous field observations (Fogel & Trappe 1978, Colgan et al. 1997). Here we report two different events of fungivorous behavior involving primates and rodents observed in the field in order to improve the knowledge about mycophagy by Brazilian mammals.

## Materials & Methods

### Observation areas

Present reports are based on direct observation of fungivorous behavior. Events were observed in Northern and Southern Brazil (Fig. 1).

The first observation was made in the Catuaba Experimental Farm (10°4'36"S, 67°37'0"W), which belongs to the Federal University of Acre (UFAC). This farm is located in the municipality of Senador Guimard, (State of Acre) and has an area of ca. 850 ha, most of which of original Amazon Forest or secondary forest under natural recovery. Most common trees and palm species found in the area are *Allophylus floribundus* Radlk., *Bertholletia excelsa* O. Berg, *Carapa guianensis* Aubl., *Couratari* sp., *Euterpe precatoria* Mart., *Quararibea guianensis* Aubl., *Rinoreaocarpus ulei* Aubl. and *Tetragastris altissima* (Aubl.) Swart. Also, there are several spots of open forest dominated by the native bamboo *Guadua weberbaueri* Pilg. (Silveira 2005, Duarte 2006, Costa et al. 2012).



**Fig. 1** – Field observation sites. A. City of Senador Guimard, State of Acre. B. City of Blumenau, State of Santa Catarina. Map modified from <https://www.wikipedia.org/>

The second observation was made in the city of Blumenau (26°54'32"S, 49°4'20"W), State of Santa Catarina, which is situated in the Atlantic Forest Biome. The place where the observation occurred is under natural recovery and is dominated by the trees and palm species *Alchornea glandulosa* Poepp., *Campomanesia reitziana* D. Legrand, *Eugenia brasiliensis* Lam., *Euterpe edulis* Lam. and *Psychotria velloziana* Lam.

### ***Taxonomic identification***

Mammal species were identified by zoologists from the Federal University of Acre and Federal University of Santa Catarina. All data collection was non-invasive and animals were not captured for this study. Fungal species were photographed and identified following traditional methods of taxonomy of macrofungi based on field experience and taxonomic literature (Möller 1895, 1901, Miller & Miller 1988, Trierveiler-Pereira 2015). Immature stages of *Phallales* were kept in a moist chamber until basidiomata were completely expanded.

## **Results**

### ***Primates and ascomycetes***

During a study involving the feeding habits of *Saimiri boliviensis* (common names: black-capped squirrel monkey and Bolivian squirrel monkey) (Fig. 2A) accomplished 2012 in the Brazilian Amazon Forest, a group of about eight individuals was observed at the end of the day foraging on native bamboo (*Guadua weberbaueri*) (Fig. 2B). The monkeys were removing from the substrata small ascomata of *Ascopolyporus* spp. (Fig. 2C–D), an ascomycete species which is parasitic on scale insects that, in turn, are parasitic on the bamboo.

The fungal species are morphological similar to *A. polyporoides* Möller and *A. polychrous* Möller, but since the ascomata were not examined microscopically, we cannot assert their identities. This feeding behavior was observed during the dry season in the Amazon (May–September), when there is scarcity of fruits. As a consequence, these small monkeys would search for fungi as an alternative food source.

### ***Rodents and basidiomycetes***

For at least five years it has been observed in the same area in Blumenau that some individuals of *Dasyprocta azarae* (common name: Azara's agouti) (Fig. 3A) have a voracious appetite for small, light-colored, gelatinous spheres that appear on the ground. The agoutis arrive in the early morning and/or at the end of the day and dig through the litter fall, searching for the spheres. The spheres, which are immature fungal fruiting bodies, would always grow at the same location during spring and summer (September–March), without completing their development since the agoutis would decimate them before they could finish the expanding process. The agoutis show a preference for the larger spheres, eating the inner contents and leaving the external, gelatinous layer.

After keeping some of these immature fungi in a moist chamber (April/2012), it was discovered that they developed into the basidiomata of *Itajahya galericulata* Möller (Fig. 3B).

## **Discussion**

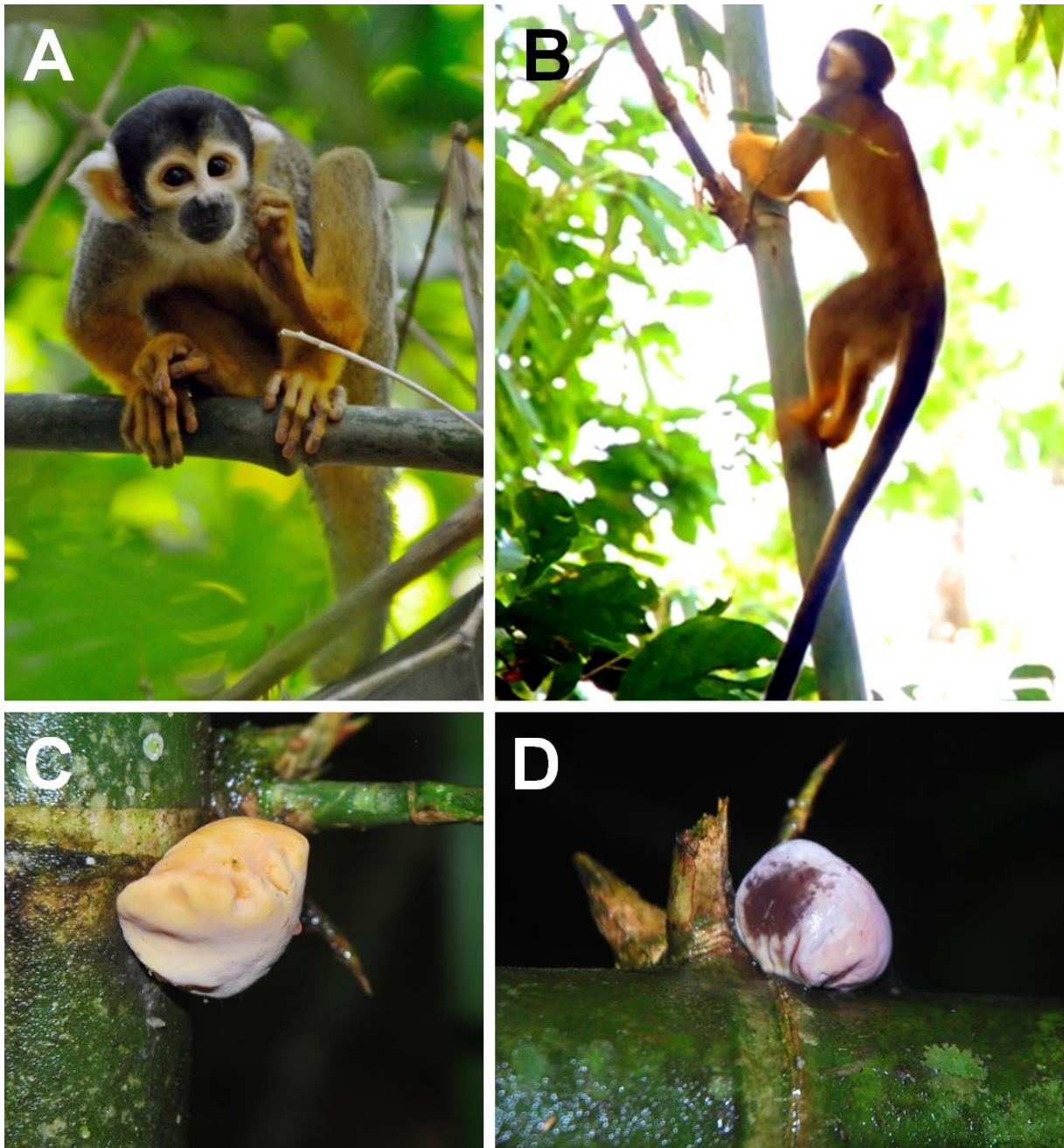
*Saimiri* monkeys are mainly frugivores, but they can also complement their diet with insects (Baldwin & Baldwin 1988). Here we report for the first time that *S. boliviensis* also have fungi as an alternative food source during the dry-season in the Brazilian Amazon, when fruits are not abundant.

Nearly 60 species of primates are known to have mycophagous behaviour (Sawada 2014), however, most of them spend less than 5% of their feeding time consuming fungi (Hanson et al. 2003). Some species, such as *Callithrix aurita*, could spend up to 19% of their feeding time consuming fungi (Correa et al. 2000). Hilário & Ferrari (2010) observed that the diet of the Brazilian buffy-headed marmoset (*Callithrix flaviceps*) is highly dependent on fungal resources,

and marmosets would consume two different *Clavicipitaceae* species, identified by the authors as *Mycocitrus* spp.

Goeldi's monkey (*Callimico goeldii*) also has a diet largely dependent on fungal ascomata and basidiomata (feeding time on fungi may reach 63%) of a few species: *Auricularia auricula* (L.) Underw., *A. delicata* (Mont. ex Fr.) Henn., *Ascopolyporus polyporoides* and *A. polychrous* (Hanson et al. 2003, 2006, Porter 2001). On the other hand, it has been reported that Japanese macaques (*Macaca fuscata yakui*) consume up to 67 different fungal species (Sawada et al. 2013).

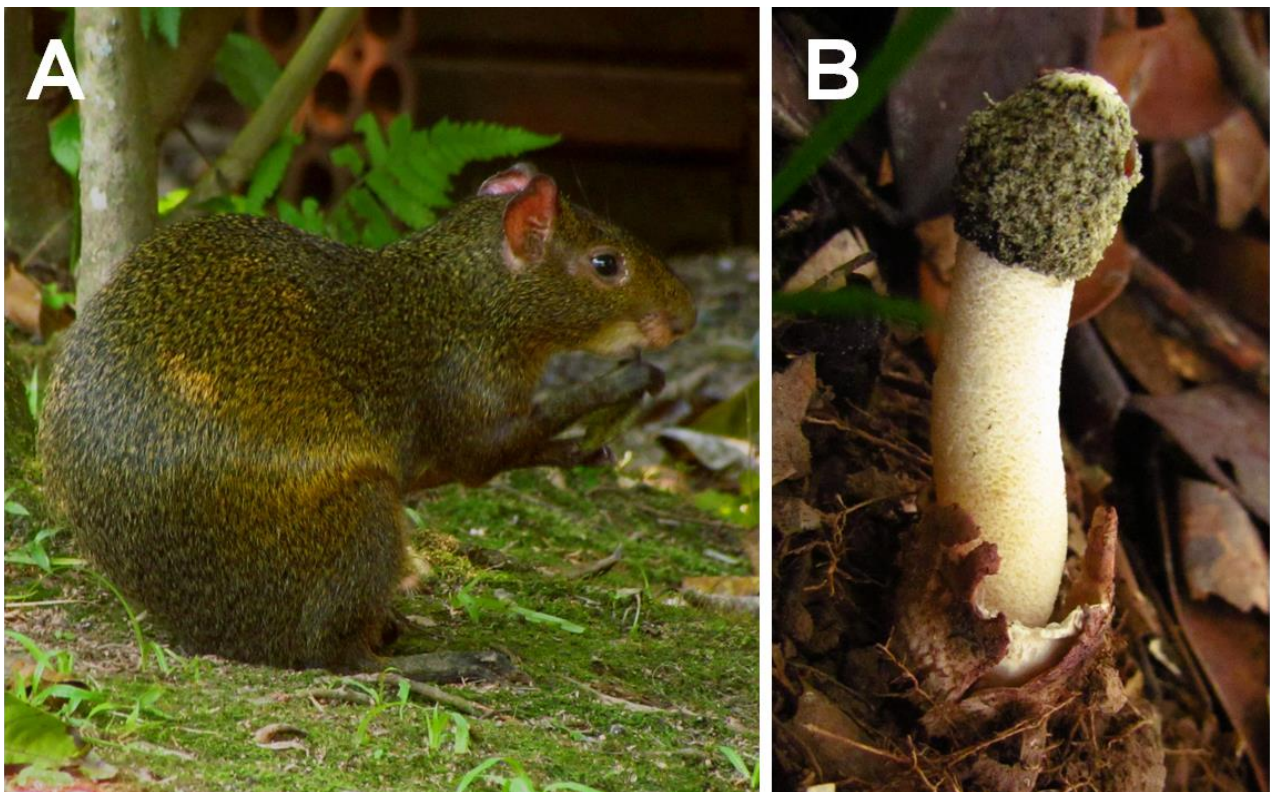
*Ascopolyporus* spp. and other members of *Clavicipitaceae* seem to be a common fungal food source for several species of small monkeys of the New World (e.g., *S. boliviensis*, *C. flaviceps*, *C. goeldii*). Further studies are necessary to discover if *S. boliviensis* also consumes other species or if its fungal ingestions are restricted to *Ascopolyporus* spp.



**Fig. 2A.** – *Saimiri boliviensis* on native bamboo (*Guadua weberbaueri*). **B.** *Saimiri boliviensis* foraging on bamboo. **C–D.** Ascomata of *Ascopolyporus*. Photograph A by Tomaz Nascimento de Melo, B–D by Heberston Cristiano S. Silva.

Agoutis are forest-dwelling animals that in Brazil could appear in urban areas and become comfortable with the human presence. They are known for being frugivores, feeding on fruits, leaves, seeds, nuts, and roots (Catzefflis et al. 2008, Kaiser et al. 2011). In Blumenau, it was observed that the agoutis would return every year to the same place, expecting to find the phalloid's eggs. It would be interesting to investigate if *I. galericulata* is associated with *Jacaranda puberula* Cham., a tree that is present in this area, since in Africa it was observed occurring in association with the tree *Jacaranda mimosifolia* D. Don (Marincowitz et al. 2015).

In Mexico, Estrada Croker & Naranjo Piñera (1998) documented events of mycophagy involving *Dasyprocta mexicana* (Mexican agouti), which can consume up to 10 different fungal species of *Agaricales*, *Aphyllophorales* and *Auriculariales*. According to Fogel & Trappe (1978), several epigeous fungal species are known to be consumed by rodents, including members of the genera *Amanita*, *Clitocybe*, *Mycena*, *Paxillus*, *Polyporus*, and *Sparassis*, although most records are from rodents eating hypogeous, truffle-like fungi (Maser et al. 1978, Claridge 2002, Vernes & McGrath 2009, Schickmann et al. 2012). This appears to be the first known report of a rodent consuming a phalloid species.

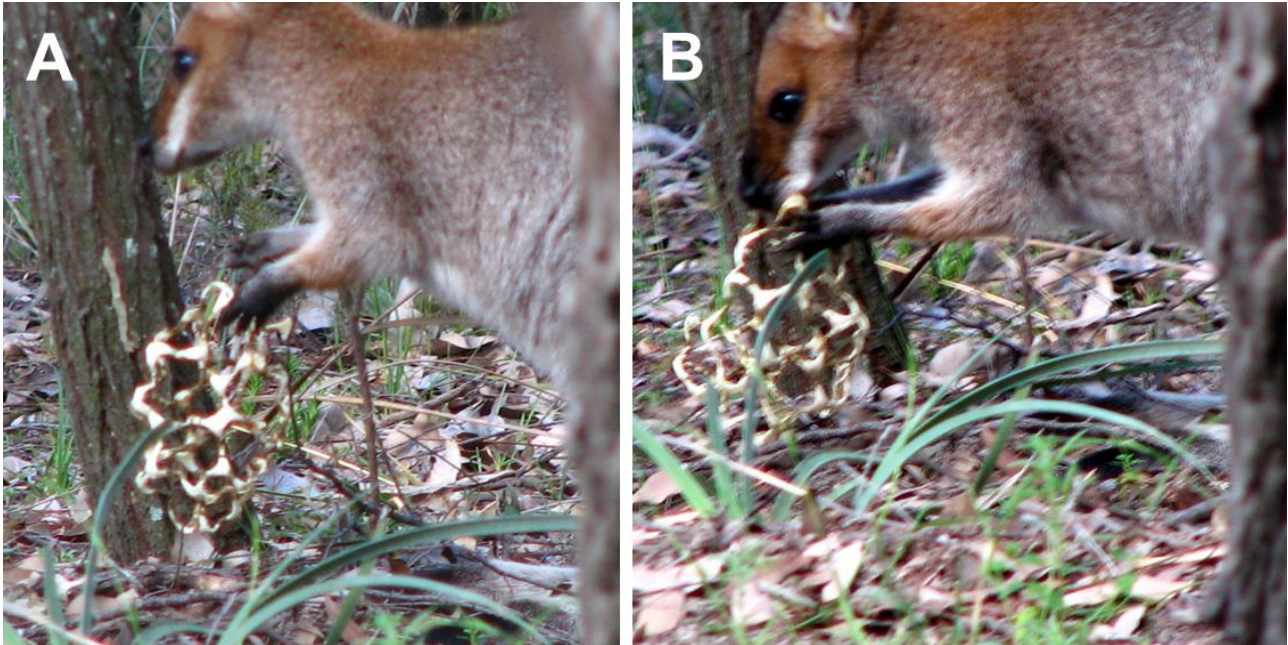


**Fig. 3A.** – Azara's agouti foraging. **B.** Expanded basidiome of *Itajahya galericulata* Möller. Photographs by Luís A. Funez.

Major reviews on mycophagy by mammals (Fogel & Trappe 1978, Claridge & May 1994) do not report the consumption of phalloid fungi, but Sawada et al. (2013) observed that Japanese macaques consume *Phallus impudicus* L.. In Australia, it was observed that the red-necked wallaby (*Macropus rufogriseus*) can consume basidiomata of *Ileodictyon gracile* Berk. (Fig. 4), although it hasn't yet been documented in literature, e.g., by Claridge & May (1994).

Basidiospores of *Phallales* are well known to be dispersed by insects and other arthropods (Hosaka & Uno 2012). When expanded, basidiomata usually emit a strong, fetid odor that attracts flies, beetles and ants (Nouhra & Dominguéz de Toledo 1994). Sometimes the attack of insects on these fungi is so intense that they can destroy the basidiomata within a few hours. Possibly because of the attack of insects, it's rare to witness mammals eating phalloid fungi.

Moreover, many records of mycophagy are based on fecal composition, instead of direct observation, and spores of *Phallales* are not documented from animal feces (Hosaka et al. 2006). Perhaps this is because the spores of truffle-like fungi consumed by mammals are usually large, pigmented, ornamented and therefore they are easier to identify, unlike phalloid basidiospores, which are mainly small, hyaline and smooth (Trierweiler-Pereira et al. 2014).



**Fig. 4** – Red-necked wallaby examining and eating a basidiome of *Ileodictyon gracile* Berk., in Girraween National Park, Queensland, Australia. Photographs by Melanie Cook.

Mycophagy can be categorized according to the dependence on ascomata and basidiomata for nourishment: obligate, preferential, casual or opportunistic and accidental (Claridge & Trappe 2005). In our study, it has been observed that both primates and rodents have ingested fungi as opportunists and most likely their diets do not depend on ascomata and basidiomata.

Future studies involving zoologists, ecologists, and mycologists, such as detailed feeding and foraging data, are desired to better understand the mycophagous behaviours reported here and to estimate how significant the fungal species are for the diet of these Brazilian mammals.

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