

Seasonal truffle consumption by long-nosed bandicoots (*Perameles nasuta*) in a mixed rainforest–open forest community in north-eastern New South Wales

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Abstract. Scats of long-nosed bandicoots (*Perameles nasuta*) from north-eastern New South Wales were examined for seasonal occurrence of fungi. Fungus was detected in bandicoot diets in all seasons, but samples from autumn and winter were more likely to contain fungi, and more taxa were consumed in these seasons, compared with spring and summer. Individual scat samples also contained more spore types in autumn and winter than in spring and summer. My results support other work in temperate south-eastern Australia that indicate an autumn and winter peak in fungal availability, and a stronger focus on fungal consumption by mammals at this time of year.

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Introduction

Mycophagous ('fungus eating') mammals are an important component of healthy forest ecosystems. These mammals excavate and consume below-ground mycorrhizal fungi, thereby providing a spore-dispersal mechanism for fungi that are vital symbionts to forest trees (Johnson 1996). Despite mycophagy by mammals receiving increasing attention in recent decades (Maser *et al.* 2008), much remains to be understood about the relationship between mammals, fungi and trees in Australian forests, including a basic understanding of which mammals consume and disperse fungal spores (Vernes 2007).

The long-nosed bandicoot (*Perameles nasuta*) is a common medium-sized mammal of wet forest communities in eastern Australia from southern Victoria to north-eastern Queensland (Dickman and Stodart 2008). Although *P. nasuta* is known to include fungi in its omnivorous diet, few studies have focussed specifically on the fungal diet of this species. Claridge (1993) revealed the mycophagous dietary habits of *P. nasuta* by showing that at two wet forest sites in south-eastern Australia, *P. nasuta* consumed at least 25 different fungal taxa, including many hypogeous truffle-forming types. From just two opportunistically collected scat samples, Reddell *et al.* (1997) also showed *P. nasuta* to have consumed a range of truffle-forming fungi in north-eastern Queensland. Focusing only on arbuscular fungi (Phylum Glomeromycota), McGee and Baczocha (1994) detected a further three fungal species in the diet of *P. nasuta* at Sydney Harbour National Park. Most recently, using a combination of stable-isotope analysis of blood and microscopic analysis of scats, Thums *et al.* (2005) showed that *P. nasuta* on the New South Wales central coast was mycophagous, and that more fungi occurred in the winter diet than the summer diet; however, dietary diversity was low, with only two fungal taxa identified.

This paper documents the seasonal changes in fungal consumption by *P. nasuta* in wet forest at Gibraltar Range and

Washpool National Parks in north-eastern New South Wales. This is the first description of the fungal diet of *P. nasuta* in north-eastern New South Wales, and only one of a limited number that examines fungal consumption by the species anywhere in its range.

Methods

Fresh scat samples deposited by *P. nasuta* were collected from forest tracks at Gibraltar Range National Park (29°31'S, 152°18'E) and adjacent Washpool National Park (29°28'S, 152°20'E) on the Great Escarpment in north-eastern New South Wales at an elevation of ~1000 m (for a detailed description of the site, see Vernes *et al.* 2006). All samples came from areas that contained a mix of wet sclerophyll forest and warm temperate rainforest. Although *P. nasuta* was frequently seen during spotlighting surveys of the area, and had been trapped there on a few occasions (see Vernes *et al.* 2006), my inability to catch *P. nasuta* in traps as part of a larger study of mammal–fungal community dynamics constrained me to collecting scats from the forest floor in order to describe its fungal diet. Scats of *P. nasuta* have a smaller diameter (pers. obs.) than those of the northern brown bandicoot (*Isodon macrourus*), which also occurs in the broader region (Vernes *et al.* 2006). However, *I. macrourus* has not been recorded from the wetter forest localities we worked in at Gibraltar Range and Washpool; rather, it has only been recorded much further to the north of our collection sites (see Atlas of Living Australia, <http://www.ala.org.au>). We never saw (by spotlight) or captured *I. macrourus* in the study area, but we did see *P. nasuta* regularly. For these reasons, I am confident my samples are from *P. nasuta*, not *I. macrourus*.

Scats were briefly softened in 5% KOH, macerated, and then rinsed through a 125-µm mesh. A few drops of the filtrate was then mixed on a glass slide with a few drops of Meltzer's Reagent; when dry, the preparation was mounted in glycerine jelly and

sealed with a glass coverslip. Slides were scanned at 400 \times magnification; if necessary, spores were observed at 1000 \times under oil immersion to confirm identification. Photographs of representative spore morphotypes were taken using an Olympus CX microscope with digital capture capability. Samples were also examined with a scanning electronic microscope (JEOL JSM-5600 SEM operating at 10 kV and 8–48-mm working distance) to obtain representative photographs of as many morphotypes as possible. Using available guides, published papers, and assistance from expert mycologists, identification based on morphological characters (size, shape, ornamentation, wall thickness and symmetry) was made to genus where possible, although some spores could be identified only to family. For a few spore types no identification could be reliably assigned.

Results

A total of 45 samples from *P. nasuta* was analysed for the occurrence of fungal spores; 33 of these contained fungus. *P. nasuta* consumed fungi in all seasons, but peaks in the proportion of scats containing fungi occurred in autumn and winter (Fig. 1). The number of spore types per sample changed significantly with season ($F_{3,41} = 2.97$, $P = 0.043$), and this also peaked in autumn and winter. At least 34 types of fungi, most of them hypogeous spore-forming taxa, were recorded in the diet (Table 1). About a third of these fungi (11 taxa) were recorded only in winter diets, which had considerably higher taxon richness (28 taxa), compared with autumn (19 taxa), spring (9 taxa) and summer (5 taxa) diets.

Discussion

These data (although limited in terms of sample sizes and uneven numbers of samples between seasons) show that *P. nasuta* consumes many species of fungi over the course of a year, including many hypogeous truffle-forming mycorrhizal taxa. Although *P. nasuta* is omnivorous, eating a wide variety of non-fungal foods, including plant material and invertebrates (O'Hara *et al.* 2012), my results support the assertion by Claridge (1993) that *P. nasuta* also consumes much fungus, and is an important

spore disperser of hypogeous mycorrhizal fungi in eastern Australian forests.

These data also indicate that the fungal diet of *P. nasuta* in the study area shifted significantly over the course of a year, from low consumption of just a few species of fungus in spring and summer, to high consumption of many species in autumn and winter. Thums *et al.* (2005) determined that *P. nasuta* consumed more fungus in winter at their New South Wales central coast study site; my work supports this observation, but also adds support to a more general model of fungal consumption and dispersal by mammals in eastern Australia having a strong autumn and winter bias. In north-eastern New South Wales, several small mycophagous macropods consume fungus most often in autumn and winter, and the number of unique spore types

Table 1. Fungal taxa detected in diets of long-nosed bandicoots (*Perameles nasuta*) at Gibraltar Range and Washpool National Parks, north-eastern New South Wales

n, the total numbers of individual scat samples analysed for each season.
*, found in <25% of samples; **, found in 25–50% of samples

Fungal taxa ^A	Summer <i>n</i> = 4	Autumn <i>n</i> = 21	Winter <i>n</i> = 9	Spring <i>n</i> = 11
Epigeous (above-ground, or 'mushroom-like') taxa				
Boletoid 1	*			
Coprinaceae		*		
Unidentified 'Mushroom'			*	*
Hypogeous (below-ground or 'truffle-like') taxa				
<i>Amylascus</i>		*		
<i>Andebbia/Gummiglobus</i>			*	
<i>Aroramycetes</i> 1			*	*
Ascomycete (Dicina-like 1)		**	*	
Ascomycete (Dicina-like 2)		**	*	*
<i>Austrogautieria</i>			*	
<i>Chamonixia</i>		*	**	*
<i>Cortinari</i>		*	*	*
<i>Descomyces stolonatus</i>		*	*	
<i>Descomyces</i> 2		*	*	
<i>Descomyces</i> 3		**	*	
<i>Descomyces</i> 5			*	
<i>Elaphomyces</i>			*	
<i>Endoptychum</i>			*	
<i>Gautieria</i>			*	
<i>Glomus</i>		**	*	*
<i>Hydnangium</i>			*	
<i>Hydnoplicata convoluta</i>		*	**	
<i>Hysterangium</i>	*	**	*	*
<i>Hysterogaster</i> 2		*	*	
<i>Hysterogaster</i> 3	**	*		
<i>Leucogaster</i>	*		*	*
<i>Protuber</i>		*		
Russuloid 1	**	*	*	
Russuloid 3			*	
<i>Scleroderma</i>		*	**	*
<i>Thaxterogaster</i> 1		*	*	
<i>Thaxterogaster</i> 2			*	
<i>Thaxterogaster</i> 3		*	*	
Unknown 1		*		
Unknown 10			*	
Total taxa consumed	5	19	28	9

^ATaxa correspond to those listed in Vernes (2010).

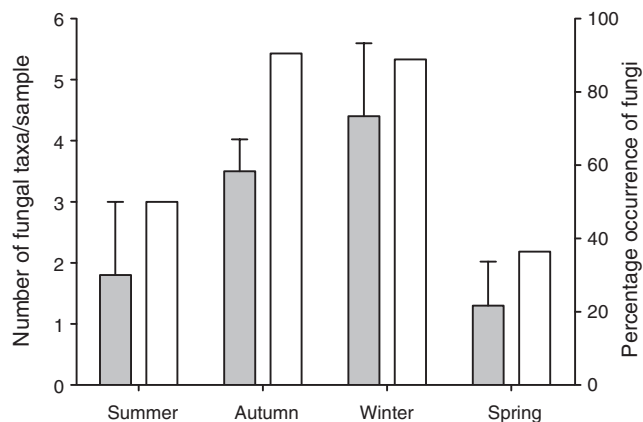


Fig. 1. Mean number (\pm s.e.) of fungal taxa (grey bars), and percentage occurrence of fungus in seasonal diets (open bars) from long-nosed bandicoot (*Perameles nasuta*) scats collected at Gibraltar Range and Washpool National Parks, north-eastern New South Wales.

per sample also peak at these times (Vernes 2010). This seasonal trend is also apparent in the tropics, where Vernes *et al.* (2001) showed that more fungal taxa were consumed by northern bettongs (*Bettongia tropica*) during the winter dry season than at other times of the year. Other researchers elsewhere in eastern Australia, working on a range of mycophagous mammals, have shown fungal consumption to be typically greatest in autumn and winter (Claridge *et al.* 1993a; Johnson 1994). These dietary observations reflect fruiting patterns in eastern Australia, with peaks in truffle production occurring during autumn and/or winter both in temperate regions (Claridge *et al.* 1993b, 2000; Danks *et al.* 2013) and in the tropics (Vernes *et al.* 2004; Abell *et al.* 2006).

At my Gibraltar Range study site in north-eastern New South Wales, previous work has revealed a diverse mycophagous mammal community that includes several forest rodents (bush rat, *Rattus fuscipes*; swamp rat, *R. lutreolus*; New Holland mouse, *Pseudomys novaehollandiae*; fawn footed melomys, *Melomys cervinipes*), a small dasyurid (brown antechinus, *Antechinus stuartii*), a range of medium-sized macropodids (red-necked pademelon, *Thylogale thetis*; parma wallaby, *Macropus parma*; swamp wallaby, *Wallabia bicolor*), the long-nosed potoroo (*Potorous tridactylus*) and two possums (bobuck, *Trichosurus caninus*; eastern pygmy possum, *Cercartetus nanus*) (Vernes and Dunn 2009; Vernes 2010; Vernes, unpubl. data). The current work confirms *P. nasuta* as an additional truffle spore-disperser at this site, and suggests that it is one of the more strongly mycophagous mammals in this community. Together with previous work, this paper highlights the complex interrelationships between mammals and fungi that are operating in Australian temperate forests.

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