Musky Rat Kangaroos and other vertebrates feeding from the flowers of the root parasite *Balanophora fungosa*

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Abstract

Balanophora fungosa subsp. *fungosa* (Balanophoraceae) is an animal-pollinated flowering angiosperm found in Queensland rainforests. The ecology of this root parasite is poorly known and a preliminary study was undertaken at Speewah to identify vertebrates that feed at *Balanophora* flowers and may thus be pollinators. Seventy-two vertebrate feeding events were filmed with motion-detecting cameras on two flowering clumps of *B. fungosa*. The two most frequent visitors to flowers were Bush Rats and Musky Rat Kangaroos, but other mammals and birds (honeyeaters) were occasional visitors. Some individually recognisable Bush Rats and Musky Rat Kangaroos were repeat visitors to the same plants where they fed gently and mainly from the male flowers. Honeyeaters of four species take a higher risk than is normal for them in coming to ground-level to feed, suggesting that the nectar and/or pollen of *B. fungosa* is of high value to them. Most feeding took place at male flowers. This study identifies flowering *B. fungosa* being visited by a broad guild of vertebrate visitors not previously known to visit these plants, but it is currently not clear how these animals or the plant benefit.

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Introduction

The flowering plant family Balanophoraceae comprises root parasites that occur primarily in tropical and warm temperate areas of the world. The sole representative of this basal family in Australia is *Balanophora fungosa* J.R. Forst. and G. Forst. where the subsp. *fungosa* is widely distributed in the forests of north-eastern Queensland including the Wet Tropics. Little is known of host species in Australia, but in Cambodia the Asian subspecies *B. f. indica* parasitises at least 12 plant species spanning eight families including the genera *Syzygium*, *Olea* and *Rapanea* (Kim & Won 2013). *Balanophora fungosa* has some of the smallest flowers of all angiosperms, with separate male and female clusters (Fig. 1; APG 111 2009; BSA 2017). In Queensland it flowers during June-November (Cooper & Cooper 2004).

Balanophora fungosa appears to be animal-pollinated. Although beetles have been documented as pollinators of *B. f. fungosa* in Australia (Irvine & Armstrong 1991), little is known about other visitors to the flowers. In Indonesia, numerous small animals visit the flowers of *B. f. indica*, including ants, springtails, flies, a moth of the family Noctuidae, workers of the Asiatic

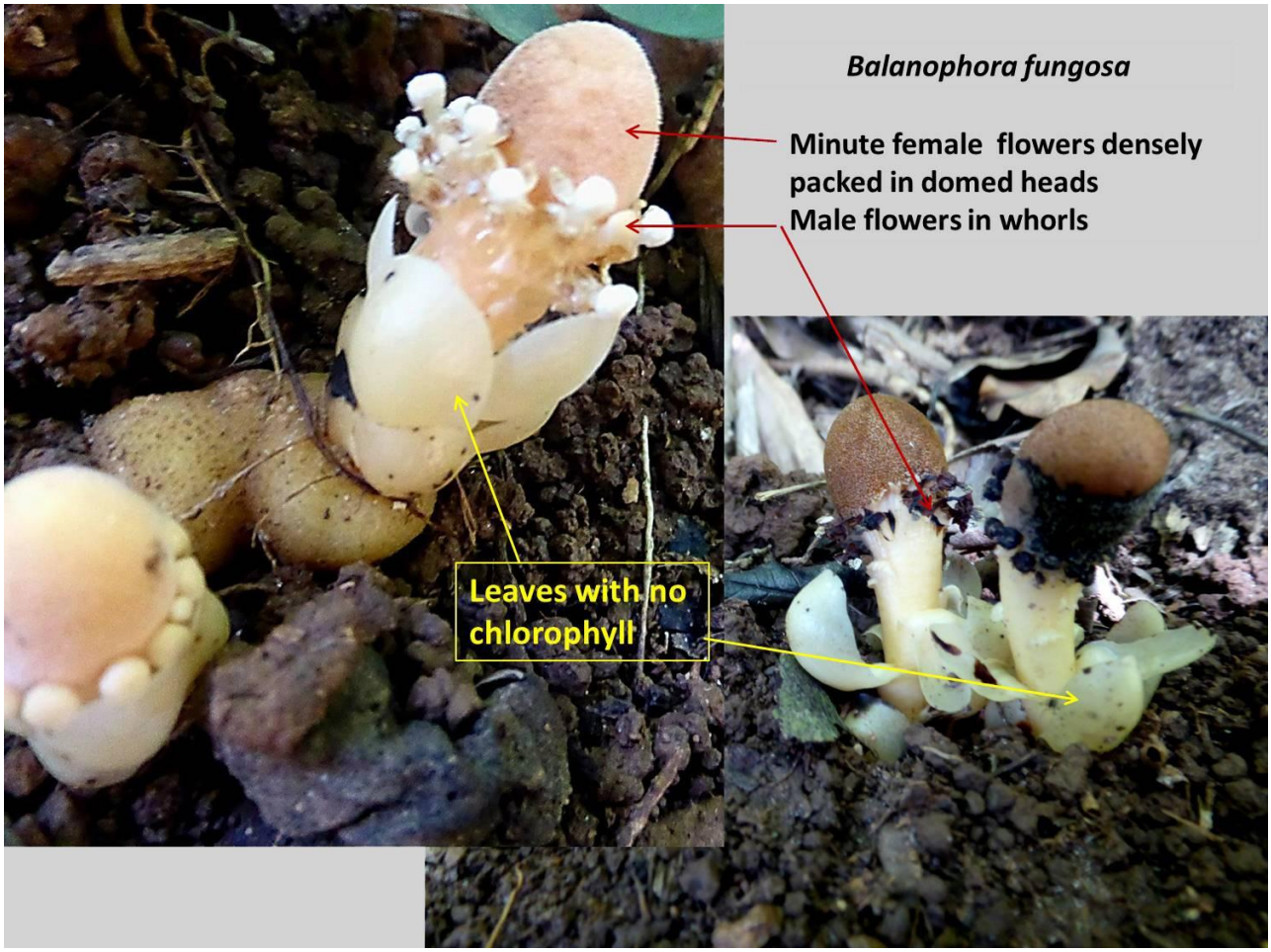

Figure 1. *Balanophora fungosa* on Bicton Hill near Mission Beach on 2 August 2016.
Ultra-high close-ups can be viewed at: *http://botany.org/Parasitic_Plants/Balanophora_fungosa.php*

Honeybee (*Apis cerana*) and rats (Suetsugu & Aoyama 2014). In New Zealand *Dactylanthus taylorii* Hook f., a root parasite in a related family Mystropetalaceae, is pollinated largely by the bat *Mystacina tuberculata* Gray (Daniel 1976; Ecroyd 1996). *Balanophora fungosa* is locally common in rainforest at Speewah, Queensland, where it is conspicuous immediately preceding and during the flowering period, which in 2016 occurred between August and October. We used motion-detecting cameras to test whether bats and other mammal species were attracted to clumps of flowering *B. fungosa* plants at Speewah during August and September 2016.

Study site and methods

Study site

The study site is regenerating rainforest on an east-west gently sloping ridge at 450 m asl. that is contiguous with the Barron Falls National Park at 16°53'11"S, 145°37'4"E. The flora is moderately diverse with c. 200 species of indigenous woody plants documented on the *c.* 0.5 ha block to date (Table 1). The numerically most common families are Apocynaceae (9 species), Euphorbiaceae (10), Lauraceae (11), Myrtaceae (11), Proteaceae (6), Rubiaceae (6), Rutaceae (8), Sapindaceae (11), and Arecaceae (6). Rainfall at the site averaged *c.* 2200 mm per annum in 2008-2015, mainly occurring in December-April, but rainfall was 60% lower than average in 2016 (RP personal observation). The two main observation sites (flower clumps) were in the forest interior c. 15-20 m from the forest edge, well shaded, and were beneath laurels and other large trees up to *c.* 20 m tall. Both sites were in disturbed areas (adjacent to a footpath), one of several types of site in which *B. fungosa* have been found locally.

This site has a correspondingly diverse vertebrate fauna, some of which are resident and others that

Table 1. Flora groups on a *c.*0.5 ha block of regenerating rainforest at 165 Stony Creek Road. Data courtesy of R. Jago and J. Beasley (R Jago, pers. comm. 2012) supplemented with observations from RP 2008-16.

Group	No. species recorded 2011	Total no. species recorded to 2016
Ferns and fern allies	8	12
Gymnosperms	2	2
Dicot angiosperms	157	184 (180 woody trees/shrubs/climbers)
Monocot angiosperms	27	28 (16 woody trees/shrubs/climbers)

visit seasonally. These include 16 amphibians, 23 reptiles, 29 mammals and 167 birds (RP personal observation; 2008–2016).

Balanophora fungosa

Balanophora fungosa (Fig. 1) is a root parasite growing on the forest floor where it attaches to the roots of trees. Above the ground surface the plant is a tuber from which arise the 25-110 mm tall, cylindrical inflorescences surrounded by basal colourless leaves. The minute female flowers are packed in domed heads at the inflorescence tips, with male flowers in a circle around the base of each female head. After flowering, numerous minute nuts are borne on a club-shaped receptacle (Cooper & Cooper 2004).

Methods

Motion-activated cameras (Zero Glow, ScoutGuard, Australia) were operated beside two separate clusters of flowering *B. fungosa* at Speewah between 27 August and 3 September (cluster 1) and 5-11 September 2016 (cluster 2). These cameras have an infrared capacity invisible to most animals as well as reasonably good photographic and video resolution day and night. Initially, one camera was trialled with still photos at the first flowering cluster, but after two days we switched to using 30 second sequences of video footage for each activation at the clusters. The cameras were placed *c.* 2 m away from the flowering clusters and angled to capture visitors approaching from any direction. This close range resulted in very clear footage of feeding animals and this filming regime was maintained for the duration of the study period. Footage was checked and downloaded every 2–3 days and each still photo and 30 s sequence was subsequently examined on a computer screen. We regarded a feeding event as being an animal foraging at the flowering plant clusters during one video sequence or in each of four still photos taken at the start of the study. A representative video is available at the website: *raypiercepacific.com*.

Results

The cameras captured footage of vertebrate animals on 93 occasions. Of these, 72 were of at least 8 species feeding apparently from inside *Balanophora* flowers (Fig. 2), mainly male flowers. Of these, 54 (75%) were of at least four species of mammals, and 18 (25%) were of four species of bird. Vertebrates fed at the clusters of flowers an average of 6.5 times per cluster per day (n = 11 days, range 0 – 17 feeds). Mammal visits to each cluster of flowering *Balanophora* occurred throughout the day and night with apparent lulls around dawn and dusk, whereas honeyeaters only visited during the day (Fig. 3). No interspecific interactions were seen, although some honeyeaters flew off seconds before a mammal came into view in the same sequence.

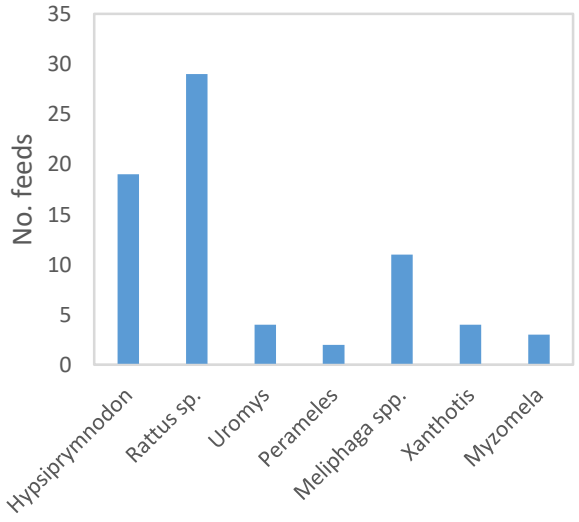

Figure 2. Number of feeding events detected for different animals at the flowers of *Balanophora fungosa* at Speewah.

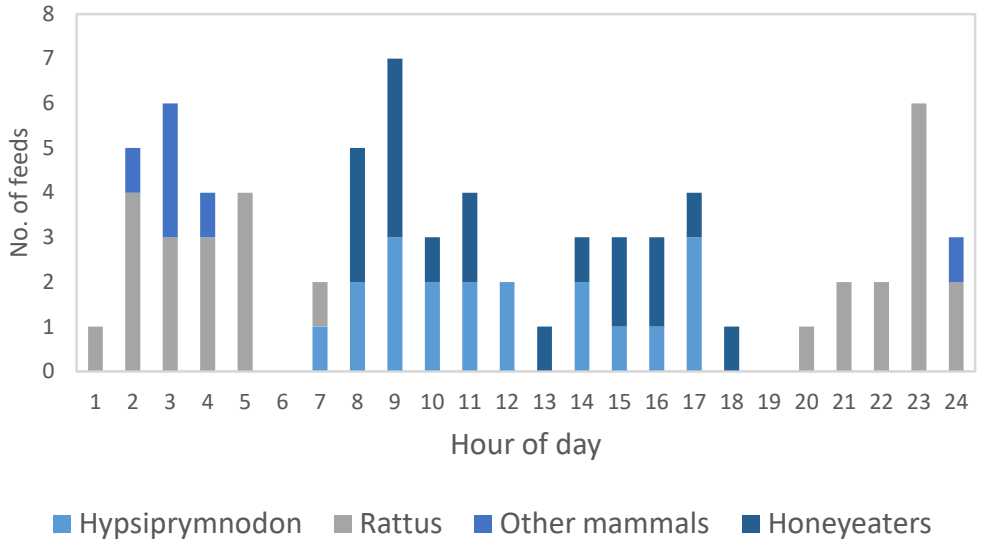

Figure 3. Hourly distribution of vertebrate feeding events filmed for all study days combined at Speewah. Note that 1 = midnight to 0100 h, 2 = 0100-0200, etc.

The two most frequently filmed animals attending *Balanophora* flowers were Musky Rat Kangaroo (*Hypsiprymnodon moschatus*) and rats (*Rattus* spp.). Although accurate identification of *Rattus* species from camera images is difficult (see later), the rat species encountered is probably the Bush Rat (*Rattus fuscipes*) which is known to occur at the site. These two species together accounted for 67% of feeding events (Fig. 2). Giant White-tailed Rat (*Uromys caudimaculatus*) and Long-nosed Bandicoot (*Perameles nasuta*) made up the balance of mammal feeding observations. Four species of honeyeaters (Meliphagidae), were also frequent visitors to the plants and collectively accounted for 25% of feeding events. They were the Yellow-spotted Honeyeater (*Meliphaga notata*), Graceful Honeyeater (*M. gracilis*), MacLeay's Honeyeater (*Xanthotis macleayana*) and Dusky Honeyeater (*Myzomela obscura*). Individual species' behaviours are described below.

The clumps of *Balanophora* were visited by Musky Rat Kangaroos on average 1.5 times per day (n = 11 days, range 0 - 4 per day). The 19 feeding events were mostly by the same large female with pouch young and there were also one or two slightly smaller individuals filmed. They all fed alone, throughout the day between the times of 0656 and 1655. An individual Musky Rat Kangaroo would typically circle most flowering plants in the clump during the 30 s videos. They fed almost entirely from the male flowers, tilting their head to one side as they circled (Fig. 4). The tiny female flowers were licked only rarely, via the individual crouching over the whole plant. The Musky Rat Kangaroos seemed to be careful/gentle feeders and we did not detect damage to the plants after feeding. Only one feeding event, by a large individual, seemed to be relatively vigorous, but the plant did not appear to sustain damage.

Rats (*Rattus* sp.) were the most common vertebrate visitors to *Balanophora* and all visits were at night, from just after dark (earliest 19:17 h) to dawn (latest 06:05 h). Some of those

Figure 4. A Musky Rat Kangaroo in typical feeding pose at male flowers of *Balanophora fungosa* at Speewah.

photographed were adjudged to be *Rattus fuscipes* on the basis of "Roman nose" on otherwise short snout (Fig. 5), similar to two trapped rats from this area in the past. However, the videos do not allow confident separation from the local subspecies of Cape York Rat (*R. leucopus cooktownensis*). The rats fed alone, but more than one individual visited the flowers because one individual was videoed being replaced by another. As with Musky Rat Kangaroos they were focussed on the male flowers and appeared to be gentle in their feeding actions.

Four feeds by Giant White-tailed Rats and two by an individual Long-nosed Bandicoot were filmed, the former involving one adult and one or two young, all feeding separately. All Giant White-tailed Rats were filmed on the same night between 11:17 and 03:28 h and a Long-nosed Bandicoot at the same clump on the same night fed between 02:55 - 02:57 h. Unlike the Musky Rat Kangaroos and rats, the single adult Giant White-tailed Rat was quite vigorous to the *Balanophora* plants.

Most honeyeater feeding events were of Graceful Honeyeaters (estimated 7–9 feeds, this imprecision being due to identification difficulties with Yellow-spotted Honeyeater). All foraging encounters by honeyeater species involved the individuals standing on the ground or on fallen branches immediately adjacent to the plant, or less frequently on the plant itself, and feeding from male flowers (Figs. 6, 7). Visits occurred throughout the day between 07:07 and 17:46 and lasted from a few seconds up to the full 30 s video length. All birds, and particularly the Graceful Honeyeaters, were clearly nervous, looking upwards between each of the brief feeding probes.

Figure 5. Rat (*Rattus* sp.) at *Balanophora fungosa* flowers at Speewah.

Figure 6. A probable Graceful Honeyeater feeding at *Balanophora fungosa* flowers.

Figure 7. A Macleay's Honeyeater feeding from *Balanophora fungosa* flowers.

Fifteen vertebrate sequences were filmed in which there was no feeding undertaken. Eleven of these encounters involved individual Musky Rat Kangaroos, Giant White-tailed Rats and *Rattus* rats. Three other bird species were also detected (two Little Shrike-thrushes (*Colluricincla megarhyncha*), a Brown-capped Emerald Dove (*Chalcophaps longirostris*) and a monarch flycatcher (*Monarcha* sp.)), which were either chance transients or possibly attracted to insects around the plants.

Discussion

A broad suite of vertebrate (and probably invertebrate) species take nectar and/or pollen of *Balanophora fungosa* and might in so doing provide the species with a pollination service. One of the most frequent visitors to *Balanophora* during this study, Musky Rat Kangaroo, has not previously been documented feeding at their flowers. Studies of Musky Rat Kangaroos at Wooroonoorran National Park, c.100 km SW of Speewah and elsewhere indicated that this macropod is primarily a frugivore, taking fruits and seeds of 40 species, and also taking fungi (mainly Agarics) and insects (Dennis 2002, 2015; Claridge *et al.* 2007). The current study indicates that *Balanophora* nectar may also be an important and energy-rich component of the Musky Rat Kangaroo diet at least for a short period of the year. Given that *Balanophora* is common in rainforest and at rainforest edges over a wide altitudinal range (0–1140 m; Cooper & Cooper 2004), it is possible that it provides an important seasonal resource for Musky Rat Kangaroos across much of the Wet Tropics. If the flowering season varies with altitude (and latitude) then the seasonal availability of this resource may vary across the Wet Tropics accordingly.

Feeding by rats (*Rattus* and *Uromys*) and Long-nosed Bandicoots on *Balanophora* is unsurprising given the attention and damage that rodents and especially the Brush-tailed Possum (*Trichosurus vulpecula*) inflict on its ecological analogue in New Zealand, *Dactylanthus taylorii* (Ecroyd 1996; Holzapfel 2001). Several other terrestrial mammals and possums frequented the Speewah site at this time, e.g. Northern Brown Bandicoot (*Isoodon macrourus*), Green Ringtail Possum (*Pseudochirops archeri*), Common Striped Possum (*Dactylopsila trivirgata*) and Long-tailed Pygmy Possum (*Cercartetus caudatus*), but none of these were detected by the cameras at *B. fungosa* clumps in September-October 2016. Skinks (*Carlia* spp.) were common and active at an artificial forest pool c. 20 m away at the time of study, but no reptiles were detected by the cameras.

That four species of honeyeaters were detected visiting *Balanophora* is interesting given that a terrestrial feeding station has inherent dangerous risks from predators for these normally arboreal species. This presumably means that *Balanophora* nectar or pollen is a rich source of energy favouring the reward-over-risk trade-off.

The observations presented here provide evidence for a much larger guild of animals feeding on *B. fungosa* than was previously suspected. Most visits were to male flowers, where pollen might be sourced either for consumption or incidentally, but it is unclear how this might be transferred to female flowers. That feeding visits occurred throughout the day and night raises the possibility that nectar is produced through the full diurnal cycle and that *B. fungosa* is relatively unspecialised with respect to pollinators. The regularity with which individual *Balanophora* were visited by Musky Rat Kangaroos and rats suggests that they are producing nectar and/or pollen in sufficient volumes to be profitable for individual animals to return repeatedly to forage. Further observations are needed to determine what these mammals are seeking in the male flowers and whether they do indeed visit female flowers as well, thus having the potential to be pollinators of *Balanophora*. However, it is currently unclear whether there is nectar in both the male and female flowers, and whether pollen is being transported by feeding visitors. Indeed, it is not certain that these vertebrate species perform any role in pollination or what the precise mechanism of pollination is in this *Balanophora* species. We propose further studies to examine some of these and related questions.

Acknowledgements

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