Colonisation of epiphytic ferns by skinks and geckos in the high canopy of a Bornean rainforest

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ABSTRACT - Nest site availability limits the fitness and survival of skinks and geckos, particularly in the canopy of tall tropical rainforests. We document the systematic colonisation and nest use of epiphytic bird's nest ferns (*Asplenium* spp) by the gecko *Hemiphyllodactylus typus* and the skink *Lipinia* cf. *vittigera*. As part of a controlled experiment we placed 32 ferns of similar sizes in the high canopy of a lowland dipterocarp rainforest in Sabah, Malaysian Borneo. Half of these ferns, sampled after six months, contained eggs. The remaining ferns, sampled after 12 months, contained both eggs and adults. Our results demonstrate the importance of epiphytes in providing a resource for reptile populations in the rainforest canopy.

INTRODUCTION

Reptiles play distinct ecological roles in tropical rainforests. Whilst the ecology of skinks and geckos is known for some rainforest species (Vitt et al., 1997; Vitt & Zani, 1997; Vitt et al., 2005; Akani et al., 2002; Teixeira et al., 2003; Huang, 2011), many species remain relatively understudied, particularly those associated with the high canopy. Understanding the ecology of these animals is becoming increasingly important in the face of climate change and habitat disturbance (Huang & Pike, 2011; Wanger at al., 2010).

Nest site availability is known to limit the fitness and survival of skinks and geckos (Ineich, 2010). In the canopy of tropical rainforests, epiphytic habitats are important as refuges for reptiles and amphibians (Huang & Pike, 2011; Scheffers et al., 2014). This study reveals the importance of epiphytic ferns as nest sites in the high canopy of a tropical lowland dipterocarp forest. Bird's nest ferns (*Asplenium* spp) (Yatabe & Murakami, 2003) are abundant at all heights throughout the canopy of Old World tropical forests (Fayle et al., 2009), and have been shown to support large numbers of invertebrates (Ellwood, Jones & Foster, 2002; Ellwood & Foster, 2004). The observations reported here are part of a larger experiment investigating the colonisation of bird's nest ferns by insects and other arthropods.

MATERIALS AND METHODS

The observations were made at Danum Valley in Sabah, Malaysian Borneo (4°58'N, 117°42'E, altitude ~170 m). This 43,800 ha area of undisturbed lowland dipterocarp forest experiences a wet equatorial climate, of low seasonal variation, with an average rainfall of 231.9 mm per month, and 2785.4 mm per year. Daily temperatures are on average 26.7 °C, with mean highs of 31 °C and lows of 22.5 °C (Reynolds et al., 2011). We removed the existing fauna from 32 ferns by flushing the existing roots with water, and collecting invertebrates as they emerged from the soil. Fern root soil was then standardised by repacking the roots with soil collected from other ferns, bound with a 2 mm nylon fishing net, resulting in a root ball with a diameter of 20 cm. Eight of these standardised ferns were placed into each of four *Parashorea tomentella* trees adjacent to the Danum Valley Field Centre. The tree crowns chosen for the experiment lacked existing epiphytes, or foliage such as lianas, and the branches of the upper crowns where ferns were attached were between 32-61 m in height (Fig. 1A).

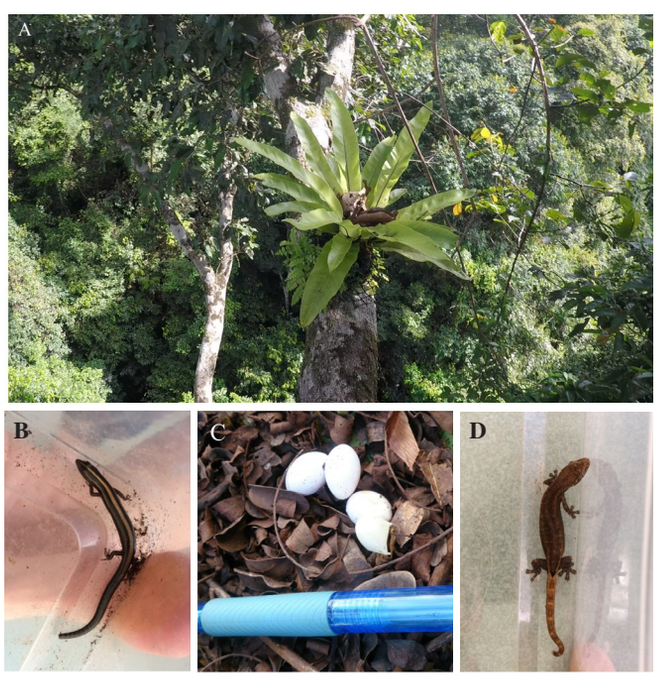

Figure 1. A. *Asplenium* bird's nest fern in the high canopy **B.** *Lipinia* cf. *vittigera* **C.** eggs **D.** *H. typus*

We sampled 16 ferns (four ferns from each tree) after six

Table 1. Number of eggs, adult skinks (S) and adult geckos (G) after 6 and 12 months of colonisation.

		6 months		12 months	
	FERN	eggs	adults	eggs	adults
TREE 1	F1	3	0	0	0
	F2	1	0	0	0
TREE 2	F1	0	0	0	S 1
	F2	0	0	0	0
TREE 3	F1	0	0	1	G 3
	F2	0	0	1	S 1
TREE 4	F1	10	0	0	G 1
	F2	0	0	0	G 1

months and the remaining 16 ferns after 12 months. Ferns were removed from the branch and placed immediately into large plastic bags. These were transferred directly to the laboratory, where they were sampled exhaustively for the presence of eggs and adults (Fig. 1B, C, D). Photographs of each adult were taken to assist identification before releasing them (Zug, 2010). Although the species from which the eggs were derived could not be confirmed, it is presumed that they were produced by the adults sampled from within the same ferns.

RESULTS

Rapid colonisation of empty ferns confirms the high demand for epiphytic habitats for skinks and geckos to lay eggs in the high canopy. After six months, three of the 16 ferns contained eggs, but no adults (Table 1). After 12 months, two of the 16 ferns contained eggs, and five of the ferns contained adults (Table 1). Following consultation with regional experts, the adult geckos were identified as the Indo-Pacific gecko, *Hemiphyllodactylus typus* (Bleeker, 1860), and the skinks tentatively identified as the yellow striped tree skink, *Lipinia* cf. *vittigera* (Boulenger, 1894). In total, across all 32 ferns we collected 16 eggs, two adult skinks and five adult geckos.

DISCUSSION

The Indo-Pacific gecko is a small gecko (snout-vent length ca. 35 mm) with a widespread distribution across south-east Asia and Oceania (Zug, 2010). There is a distinct lack of ecological knowledge surrounding this genus, almost certainly linked to its secretive nature and difficulty of observation (Holden et al., 2013). This species was documented colonising myrmecophyte 'ant plants' in Bako National Park in Sarawak (Janzen, 1974), but to our knowledge this is the first account of colonisation of *Asplenium* ferns in the upper canopy of a primary rainforest. The yellow striped tree skink is an arboreal skink known to occur at Danum Valley (Das & Austin, 2007), but until now its presence in the high canopy was unconfirmed. Based on our observations, we suspect that the bird's nest fern may be just one of a number of epiphytes that allow these species to persist in the rainforest canopy of Danum Valley and probably elsewhere.

Nest site availability is thought to be the biggest limiting factor for arboreal skink and gecko populations (Ineich, 2010). Epiphytes in general have been shown to provide nest sites for a range of gecko species including *Lepidodactylus buleli* (Ineich, 2008), *Gehyra vorax* (Ineich ,2010), *Woodworthia chrysosireticus* and *Mokopirirakau granulatus* (Henwood et al., 2014). In the Philippines, bird's nest ferns in particular were shown to provide cool, moist microhabitats for *Platymantis* arboreal frogs within the relatively hot and dry canopy (Scheffers et al., 2014). Elsewhere, bats have been shown to use bird's nest ferns as a roost (Tan et al., 1999). Our work suggests that bird's nest ferns are as attractive to skinks and geckos as they are to other animals, such as annelids, molluscs and arthropods (Ellwood et al., 2002; Ellwood and Foster, 2004).

Not only do bird's nest ferns provide a refuge in the canopy, they also act as an important food source. Although the ferns often contain aggressive, predatory arthropods such as centipedes (*Scolopendra* spp), they also support large amounts of invertebrate biomass (Ellwood & Foster, 2004). In particular, bird's nest ferns support large colonies of social insects such as ants and termites (Ellwood et al., 2002; Ellwood et al., 2016). The high rate of colonisation of those ferns observed in this study confirms the importance of bird's nest ferns as a valuable resource for arboreal skinks and geckos.

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