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SHORT COMMUNICATION

Short-term movements and strong dependence on figs of binturongs (*Arctictis binturong*) in Bornean rainforests

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Abstract
We evaluated short-term movements of three radio-collared binturongs in relation to food distribution in Bornean rainforests, in addition to the basic ecological information on their home-range size and diet. Mean 95% fixed kernel and 95% MCP home-range size were 4.24 ± 0.79 km^2 and 1.54 ± 0.89 km^2, respectively (mean ± SD). We recorded 13 fig *Ficus* species and four non-fig species as their foods. Fig trees accounted for 87.5% of the feeding sites of the three collared binturongs, and 87.9% including uncollared individuals. Our results suggested that binturongs' short-term movements were strongly affected by food distribution, especially figs. They feed on various fig species and may remember the location and fruiting periods of fig trees. They may use the biggest fig species, *F. punctata*, as a fallback food when other foods are scarce. Although this is the first systematic study to describe movement and feeding habits of binturongs, further studies are needed to understand their ecology so that proper measures can be designed for their conservation.

Keywords Binturong · Diet · *Ficus* · Radio-telemetry · Home-range size

Introduction

Animal movement is largely affected by distribution of food patches (Pyke 1984). Frugivores are also affected by temporal distributions of food resources and fruiting duration is often limited (Strier 2011). Studies on the reaction of frugivores to spatiotemporal transitions of food resources is usually focused on inter-seasonal behaviour (e.g. home-range and diet shifts; Strier 2011), and short-term movements are rarely evaluated. The binturong (*Arctictis binturong*) is a frugivorous mammalian carnivoran that occurs in Asian rainforests. A few previous studies have investigated the movements and bed sites of this species (Grassman Jr et al. 2005; Chutipong et al. 2015), but its ecology, such as feeding and diet information, remains unclear. This species is listed as vulnerable by the IUCN, and its population is declining due to habitat loss and poaching (Willcox et al. 2016). Therefore, ecological information about this species is critically important for developing conservation actions and targets. In this study, we evaluated short-term movements of three radio-collared binturongs in relation to food distribution in Bornean rainforests, in addition to their home-range sizes and diet.

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Materials and methods

Study site

This study was conducted at the Danum Valley Conservation Area, from January 2013 to May 2014, and Maliau Basin Conservation Area, from February to November 2016, in the north-eastern part of Borneo. The Danum Valley Conservation Area (hereafter, called Danum) is a 438 km^2 protected zone consisting of mature lowland forest (Reynolds et al. 2011). The Maliau Basin Conservation Area (hereafter, called Maliau) is a 588 km^2 protected zone (Reynolds et al. 2011). The study area was outside the basin within a logged lowland forest.

Trapping and radio telemetry

We climbed fruiting fig trees, using the single rope technique (Houle et al. 2004), to set $60 \times 18 \times 18$ cm portable Havahart

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box traps (Woodstream Corp., PA, USA) on the branches. We used ripe bananas or chicken meat as baits. We attached radio-collars (M2940B; Advanced Telemetry Systems, MN, USA) to captured binturongs. Based on body size, tooth wear and reproductive condition, we categorised captured individuals into the following three age classes based on those of *Viverra tangalunga* by Colon (1999): juvenile (not full-sized, has milk teeth); sub-adult (almost full-sized but not yet sexually mature); adult (full-sized, with signs of reproductive activity, moderate tooth wear). Mean collar mass was about 60 g (0.8–2% of binturong body weight). The collars had breakable fabric, and all were removed from tagged individuals by the end of the study. When we captured subadults, we snicked the fabric so that it would fall off quickly. Trapping and handling of the animal conformed to guidelines of the American Society of Mammalogists (Sikes and Animal care and use committee of the American society of mammalogists 2016). We estimated the location of the radio-collared binturongs by triangulation. We located the feeding sites visually and sleeping sites when they were inactive. We used the LOAS software program (Ecological Software Solution, CA, USA) to estimate location fixes and generate error ellipses. We located radio-collared individuals a minimum of three times per week, and used telemetry fixes with intervals of > 12 h for estimation of their home ranges. Fixes with error ellipses greater than 1 ha were rejected. We tested each home range for whether it reached an asymptote with area-observation curves by calculating 100% minimum convex polygon (MCP) estimates by 30-day increments. We estimated home ranges using the 95% fixed kernel estimator and 95% MCP method, using the package 'AdehabitatHR' of R version 3.4.3 (R Development Core Team 2017). We calculated moving distances by measuring the linear distance between consecutive daily locations. We recorded the food items the binturongs were observed to feed on. We recorded the life form (tree, shrub, climber, hemi-epiphyte) of plants that were fed on, as well as the average fruit size (diameter and length) of 10 fruit samples from each tree. We also recorded food items of uncollared binturongs that were detected by random observations.

Results

We captured one female binturong (Pasui, body weight 7.7 kg) in Danum and two females (Manuk 3 kg, Punti 4.7 kg) in Maliau. Pasui and Punti were adult, while Manuk was a sub-adult. All the radio-collars were confirmed to have dropped from their necks 8 to 14 months later. We tracked Manuk, Punti and Pasui for 232, 278 and 441 days, and we used 81, 118, 92 telemetry fixes to estimate home-ranges of the three individuals, respectively. For Manuk and Punti, 120 and 210 telemetry days represented 80% of the home range sizes of total days (Fig. 1). The home-range size curve for Pasui increased rapidly after 270 telemetry days. All the home-ranges of three individuals reached an asymptote during the tracking period. The mean 95% fixed kernel and 95% MCP home-range size were 4.24 ± 0.79 km^2 and 1.54 ± 0.89 km^2, respectively (mean ± SD). The 95% fixed kernel home-range range size of Manuk, Punti and Pasui were 4.90 km^2, 3.13 km^2 and 4.68 km^2, respectively (Fig. 2a, b). The 95% MCP home-range sizes were 272.8 km^2, 57.0 km^2 and 133.2 km^2, respectively. Mean 1-day moving distance was 228.0 ± 282.1 m (mean ± SD, range 0–908 m). Mean distance between feeding and sleeping sites was 90.1 ± 166.1 m (mean ± SD, range 0–297 m) and we observed the binturongs resting at the feeding sites five times. All the sleeping sites were above the ground, and were usually found under thick vegetation cover with leaves and lianas. We observed all the collared binturongs lying on large branches and/or large tree forks of feeding trees or near these trees in the daytime at least once.

We detected 14 feeding sites for Manuk, 14 sites for Punti, and 12 sites for Pasui (Table 1). We recorded 13 fig species and four non-fig species as their foods. Figs accounted for 87.5% (35 sites) of the feeding sites of the three collared binturongs (40 sites), 87.9% (58 sites) of the feeding sites including observations of uncollared individuals (66 sites). Although we could not find other feeding sites besides *Ficus stupenda* for Manuk, she left the *F. stupenda* covered with figs for 4 days before she returned there (Fig. 2c). We observed that Manuk and Punti were feeding in the same trees on three occasions without any agonistic behaviours, but their movements after they fed in the same trees were quite different (Fig. 2d, e). Manuk stayed around the feeding tree (*F. forstenii*) until the tree finished fruiting, only then she moved to other fruiting fig tree (*F. borneensis*) (Fig. 2d). Meanwhile, Punti fed on at least two fig trees (*F. punctata* and *F. delosyce*) before she returned to the same *F. forstenii* individual, where she had fed with Manuk (Fig. 2e). Punti fed on at least three different fruiting figs alternately. She also visited the fig tree (*F. stupenda*) that had just finished fruiting (Fig. 2f). We observed that Manuk feeding in the same non-fig tree (*Koordersiodendron pinnatum*) for six continuous days, while Punti fed continuously for 13 days on a *F. punctata*.

Discussion

All three radio-collared binturongs strongly relied on figs for their diet during the study period. In Bornean rainforests, many animals use figs, mostly as fallback food (Shanahan et al. 2001). Fig nutritional quality is generally low (Shanahan et al. 2001), but this is compensated by the fruiting characteristics of fig trees: they have a large crop size and year-round availability (Harrison et al. 2003). Binturongs

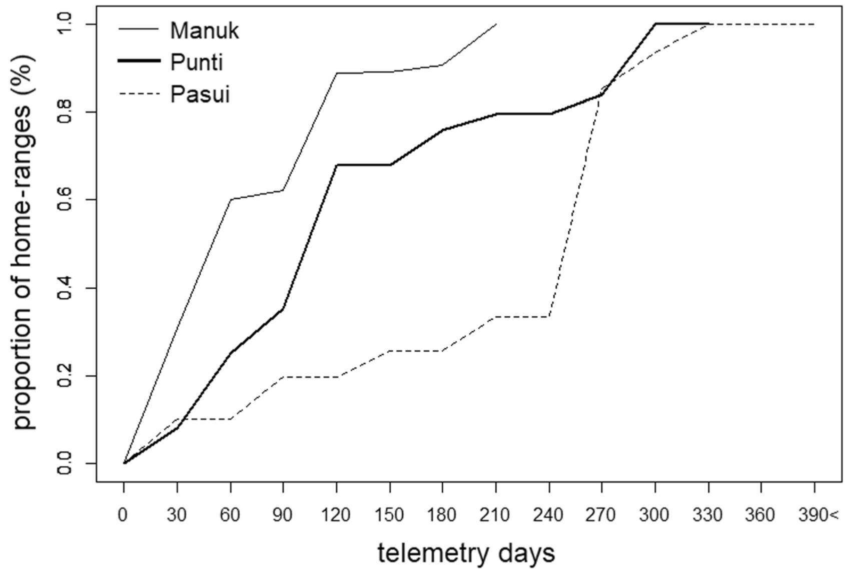

Fig. 1 Incremental home-range size by sampling duration based on 100% MCP estimates of the three radio-collared binturongs

could potentially be the most significant consumer of figs in the Indo-Malayan region, as other fig feeders are often much smaller volant animals, such as birds and fruit bats (Shanahan et al. 2001). Energy expenditure of binturongs is considerably low for their body size (McNab 1995). The short distances between sleeping sites and feeding sites, and the long time

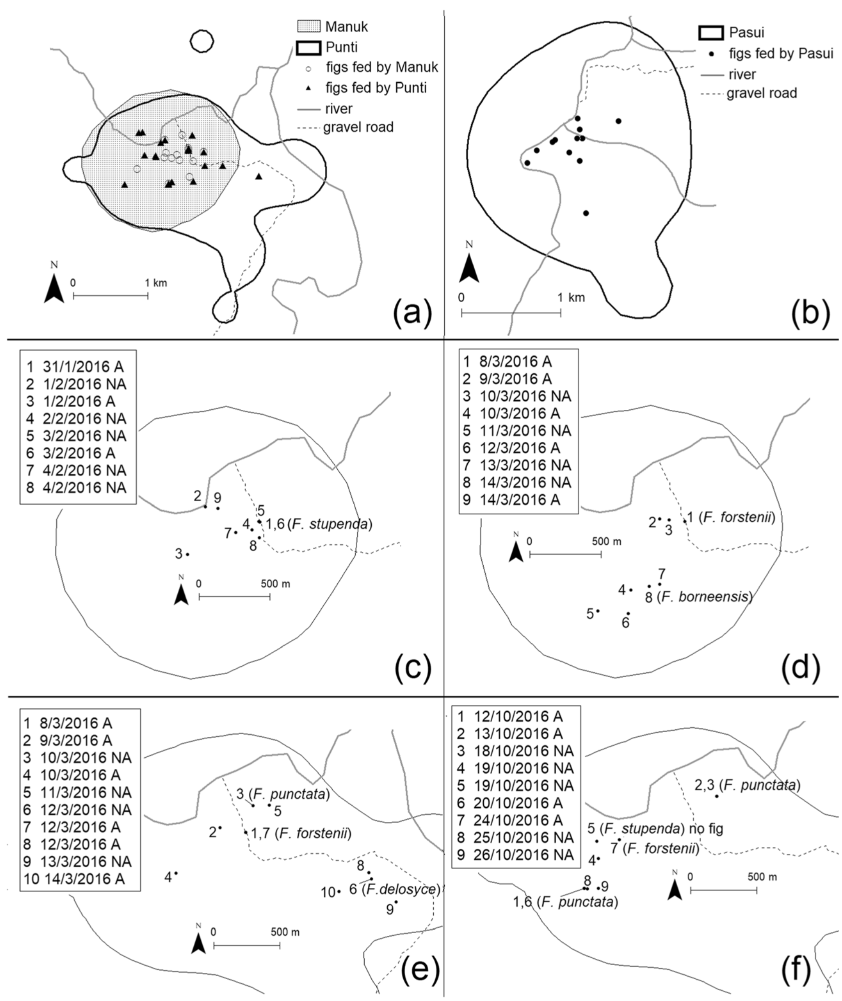

Fig. 2 The 95% kernel home-range of the radio-collared binturongs in Maliau (**a**) and Danum (**b**) and short-term movements of the two individuals in Maliau (**c**–**f**); **c** and **d** show movements of Manuk, and **e** and **f** show those of Punti. The black points in (**c**–**f**) indicate location of each binturong. "A" in the frame indicates active periods, while "NA" indicates inactive periods. Note that **d** and **e** were recorded in the same periods and *F. forstenii* is the same tree

Table 1 Characteristics of binturongs' food and number of food patches observed during the study period

Plant species	Life form[a]	Fruit diameter (mm)	Fruit length (mm)	Number of feeding patches[b]			
				Maliau (Feb–Nov 2016)		Danum (Jan 2013–May 2014)	Uncollared binturongs
				Manuk	Punti	Pasui	
Ficus annulata	H	27.8	28.5			1 (Feb 2013)	2
Ficus benjamina	H	12.7	12.7	1 (Feb)		2 (Jun 2013, Feb 2014)	1
Ficus binnendijkii	H	20.8	19.3			2 (Jan 2013, Dec 2013)	1
Ficus borneensis	H	10.7	11.6	1(Mar)			3
Ficus callophylla	H	10.5	10.6	1 (Feb)	1 (Feb)		
Ficus delosyce	H	6.3	5.7		1 (Mar)		
Ficus forstenii	H	20.9	26.7	2 (Feb, Mar)	3 (Mar, Jul, Oct)		1
Ficus kerkhovenii	H	11.3	11.6	2 (Mar, Apr)	1 (Oct)		
Ficus punctata	C	70.0	77.0		3 (Mar, Jun, Oct)	1 (Aug 2013)	
Ficus stupenda	H	55.0	60.0	1(Feb)	1 (Feb)	3 (Oct 2013, Dec 2013, Jan 2014)	2
Ficus subcordata	H	38.1	40.2	1 (Feb)	1 (Feb)		
Ficus sundaica	H	12.7	13.2	2 (Jun, Jul)	1 (Oct)	1 (Mar 2014)	2
Ficus trichocarpa	C	25.9	22.9			2 (Mar 2013, Nov 2013)	2
Alangium javanicum	T	15.8	25.4	1 (Jul)	1 (Aug)		
Glenniea philippinensis	T	84.7	81.5		1 (Oct)		
Koordersiodendron pinnatum	T	17.6	25.5	1(May)			
Neonauclea sp.	T	17.9	17.3	1(Sep)			
Ficus caulocarpa	H	5.4	5.9				1
Ficus cucurbitina	H	32.5	39.6				2
Ficus dubia	H	25.0	27.7				1
Ficus fistulosa	T	43.5	38.7				1
Ficus pisocarpa	H	13.5	12.8				1
Ficus racemosa	T	45.2	38.1				1
Ficus variegata	T	22.7	17.2				1
Ficus xylophylla	H	23.6	32.1				1
Aglaia sp.	T	NA	NA				1
Lithocarpus spp.	T	NA	NA				2
			total[c]	14 (11 sp.)	14 (10 sp.)	12 (7 sp.)	26 (18 sp.)

[a] *H* hemi-epiphyte, *C* climber, *T* tree

[b] The numbers in parenthesis refer to months, and year for Pasui, of feeding observation

[c] Total number of feeding patches. The numbers in parenthesis refer to numbers of species

they spend in each feeding patch, suggest that binturongs reduce their energy expenditure when accessing food.

Binturongs feed on various fig species regardless of size and life form (Table 1). We observed binturongs feeding on one of the smallest figs, *F. delosyce*, even though there were patches of the largest fig species, *F. punctata* (Fig. 2e, Table 1). Considering their physiological limitations for digesting fruits (Crapo et al. 2002), the number of digestible fruits in a patch may be more important for them rather than size. Binturongs repeatedly visited patches of *F. punctata* while they fed in other fig patches (Fig. 2e, f), and when there were no other fruiting patches, they stayed at the same *F. punctata* patches for up to 2 weeks. The fruiting cycle of *F. punctata* is relatively quick ca. 3 months (M. Nakabayashi unpubl. data). Therefore, *F. punctata* may work as a fallback food for binturongs when other figs become scarce.

In this study, the movements of the collared binturongs were strongly affected by food distribution. As they moved directly to feeding patches, and Punti visited a fig tree that had just finished fruiting (Fig. 1, Nakabayashi et al. 2016), it is possible that binturongs might remember the location and fruiting periods of the fig trees that they visit rather than being directed by the figs' smell. Figs occur at low density in Bornean rainforests (Harrison et al. 2003); therefore, it may be more efficient for binturongs to utilise known feeding trees than to remain in particular areas. Asynchronous fruiting phenology of figs (Table 1), as well as a memory for location and fruiting periods may enable binturongs feed on figs continuously.

The home-range sizes of the binturongs in this study were smaller than those in the previous studies in mosaic forests of Thailand (2.4–6.9 km^2; Chutipong et al. 2015; Grassman Jr et al. 2005). In turn, the one-day movement in this study was much shorter than that in Thailand (688 m, Grassman Jr et al. 2005). These differences may relate to the differences in habitat types, body size (> 10 kg in Thailand), and density of food. Characteristics of the sleeping sites, within thick vegetation cover and above the ground, of the tracked binturongs were similar to those in Thailand (Chutipong et al. 2015). The vegetation cover probably reduces the risk of predation by animals such as clouded leopards (Lam et al. 2014).

This is the first systematic study to describe the movements and feeding habits of binturongs. However, further studies are needed to understand their ecology to be able to design proper measures for the conservation of binturongs.

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