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ECOLOGY OF THE GERMAIN'S LANGUR *Trachypithecus germaini* IN A PRE-RELEASE ENVIRONMENT AND THE IMPLICATIONS FOR ITS CONSERVATION

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ABSTRACT

We studied the behaviour of captive Germain's Langur *Trachypithecus germaini* (Milne-Edwards) housed in a 3,000 m^2 naturalistic enclosure near Siem Reap, Cambodia. We studied a group of five individuals from May to July 2014, yielding 186 hours of data. We used instantaneous focal sampling to collect data on activities, social proximity, forest strata use and weather. The langurs were resting in 47.2% of scans, feeding in 43.6% of scans, traveling in 5.0% of scans, and grooming in 4.2% of scans. They spent 18.2% of their time in social proximity and varied in their time spent in different forest strata: the canopy (17.0%), understorey (53.7%) and forest floor (29.2%). The daily activity pattern showed three stages, feeding – resting – feeding. Feeding was inversely related to resting and grooming. More time was spent in the canopy and less on the floor during rain, while the opposite applied to sunny weather. Langurs were more often in social proximity during sunny weather. We additionally observed mycophagy and geophagy. The findings conform to the ecology of other *Trachypithecus* species and differences were likely due to the captive environment. An optimal pre-release environment should comprise a sufficient size, high-quality vegetation and appropriate feeding times, which may adjust the activity budget and pattern to fit a wild environment.

Keywords: activity pattern, geophagy, langur, mycophagy, translocation, time budget, weather

INTRODUCTION

Trachypithecus spp. are folivorous monkeys distributed across Southeast Asia. The genus *Trachypithecus* belongs to the group of Asian Colobines, along with the two other langur genera, *Semnopithecus* spp. and *Presbytis* spp. Within the genus *Trachypithecus*, 20 species are acknowledged (Roos et al., 2014). The IUCN (2014) recognised 14 species as threatened with extinction; however, this number recently increased to 16 at the November 2015 IUCN Red List of Threatened Species List assessment workshop for Asian primates (Ramesh Boonratana, pers. comm.). Like most primates, the main threats to these langur populations are habitat loss, hunting and live capture (Chapman & Peres, 2001). One species that is particularly threatened is the Germain's Langur *T. germaini* (Milne-Edwards), sometimes known as Indochinese Silvered Langur. The species is found in Lao PDR, Vietnam, Thailand, Myanmar and Cambodia (Roos et al., 2014),

of which Cambodia holds the highest numbers of *T. germaini* (Moody et al., 2011; Timmins et al., 2013). The total population declined more than 50% over the past 36 years, or three generations, the period influencing the IUCN's threat status classification (Nadler et al., 2008). Although data on the impact of hunting on these primates are scarce, their near or complete absence in some highly suitable habitats signifies that they may have been hunted out (Moody et al., 2011; Timmins et al., 2013). Despite their Endangered status (Nadler et al., 2008), the species has received little conservation attention (Moody et al., 2011) and until now, no ecological or behavioural studies have been conducted on these langurs (Coudrat et al., 2011). The absence of baseline ecological data hampers suitable conservation action and management strategies for the dwindling populations of *T. germaini* (Moody et al., 2011; Phan & Stevens, 2012). It is therefore of critical

importance to increase our knowledge of the species.

Activity budgets and patterns provide this basic eco-logical information, which contributes to both ongoing and successive conservation efforts such as conservation translocation (Phan & Stevens, 2012). Conservation translocation (hereafter referred to as translocation) is defined as the international movement and release of a living organism where the primary objective is a conservation benefit (IUCN SSC, 2013). Before translocating animals into the wild, the IUCN urges that baseline data of the species' natural activity have been collected (IUCN SSC, 2013). Decent pre- and post-release studies are however scarce and both the quality and quantity of these studies should be enhanced (Mathews et al., 2005). Studies on activity budgets and patterns can include information on forest strata use (Bernstein, 1972; Schneider et al., 2010; Ampeng & Md-Zain, 2012; Workman & Schmitt, 2012) and examine ecological responses to external variables such as the weather (Bernstein, 1972; Altmann, 1974; Stelzner & Hausfater, 1986; Bronikowski & Altmann, 1996; Janmaat et al., 2006), which will not only enhance the quality of pre-release studies but also facilitate post-release monitoring.

The activity budgets of different species of wild *Trachypithecus* do not vary substantially; however, activity budgets between captive and wild langurs can differ significantly (e.g. Phan & Stevens, 2012). For conservation purposes, the pre-release activity budget should closely approximate that of wild conspecifics, since more 'natural' behaviours in pre-release primates are found to be an indicator for successful translocation (Soorae, 2008). To overcome or prevent a discrepancy in pre- and post-release activity budgets, one could provide a pre-release environment that closely represents the post-release environment. This will cause the primates to adapt to the new situation quicker, which increases their chance of survival and reproductive success (Kleiman et al., 1989; Mathews et al., 2005). It is therefore important to understand what parameters should be taken into account when constructing pre-release environments. In this study, we present pre-release ecological information of captive *T. germaini*. We analysed their daily activity budget, activity pattern and relationships between weather type and activity budget. We discuss the ecological correspondence with wild *Trachypithecus* species and implications for pre-release environments.

METHODS

Study area

The research was conducted at the Angkor Centre for Conservation of Biodiversity (ACCB), established in 2008 by Munster Zoo and the Zoological Society for the Conservation of Species and Populations (ZGAP) (Westfälischer Zoologischer Garten Münster AG, 2013). The centre is situated at the protected site of Kbal Spean, adjacent to Phnom Kulen National Park and located in Cambodia's north-western Siem Reap Province. ACCB is not open to the public but provides guided tours from Mondays to Saturdays at 9:00 h and 13:00 h.

Study animals

At the start of this study, ACCB housed five *T. germaini* individuals, of which three had been rescued from the illegal wildlife trade and two were born at the centre. ACCB aims to translocate the group of langurs when a suitable habitat is found.

The study group included one adult and three sub-adult females and one adult male. It was unknown whether the subadult females were related to either of the adults because reports on the animals were absent or incomplete. The langurs were situated in a naturalistic open enclosure measuring approximately 3,000 m^2 (Fig. 1-3). They could cross the entire enclosure through the canopy. One side bordered the enclosure of three female Pileated Gibbons *Hylobates pileatus* Gray. A satellite cage used for food provisioning was situated at the rear of the enclosure. Keepers entered the cage each day at 13:00 h to scatter vegetables (Chinese long beans, Thai eggplant, pumpkin, carrot, beetroot and turnip, cut in pieces of 5–10 cm) and monitor the langurs' condition. Visitors had little interaction with the animals: guided tours only passed the lower right corner of the enclosure and were separated 2 m from its border by a second fence. Additionally, the enclosure's dense vegetation prevented tour visitors from viewing the langurs during feeding time.

Data collection

I (the first author) observed the langurs from outside the enclosure from May to July 2014 on five randomised days per month, which were chosen by using an online random calendar date generator. I followed the primates from dawn to dusk (6:00 h–18:25 h), and collected 186 hours of observation data. I applied the instantaneous focal sampling method (Martin and Bateson, 1993) using 20-minute samples with 5-minute intervals. After each sample there were 5 minutes to search for the next individual. I used a stopwatch to
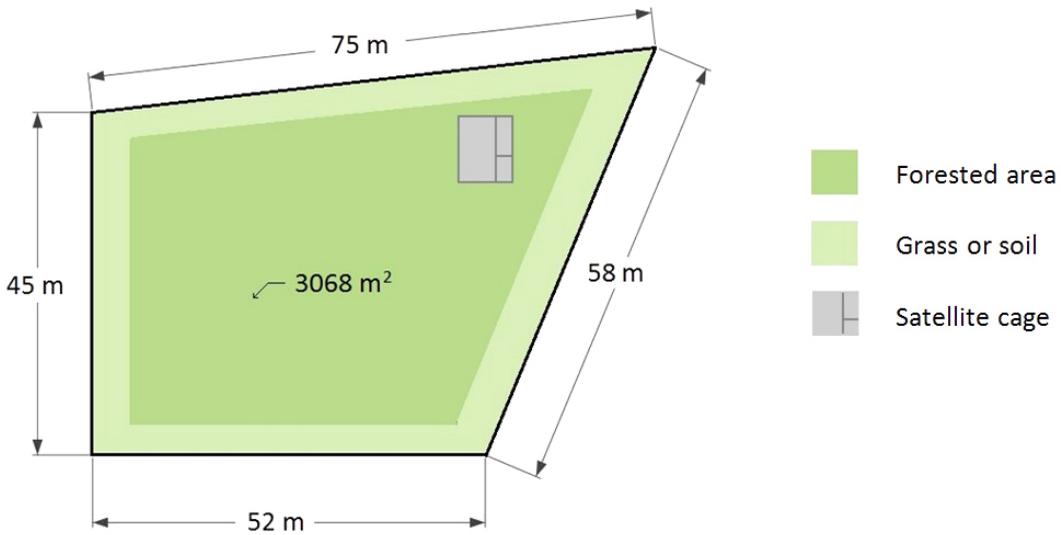
Fig. 1. Top view of the naturalistic open enclosure of *T. germaini* at Angkor Centre for Conservation of Biodiversity, Cambodia.
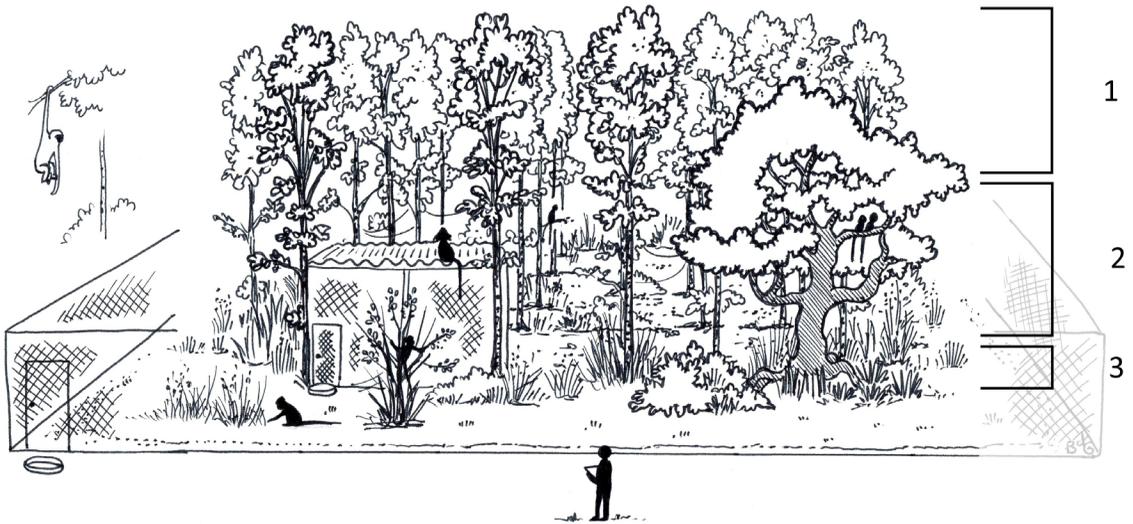
Fig 2. Illustration of the enclosure of *T. germaini* at Angkor Centre for Conservation of Biodiversity, including vegetation strata (1: canopy, >6m; 2: understorey, 1-6m; 3: floor <1m). Illustration by B. de Groot.

keep track of time, which signalled sampling instants through vibrations. Each individual was observed six times in a predetermined randomised sequence, of which the order was obtained through an online random sequence generator, adding up to 30 samples per day. I used Celestron Nature DX 8x42 binoculars when behaviours were too ambiguous to determine with the naked eye. The oldest subadult female died from pneumonia and colitis after the 11th day of ob-

servation; hence I observed each individual seven or eight times on days 12–15. I calculated inter-observer reliability from a synchronised observation session of eight samples, with the help of the second observer, Gabrielle Nussbaum (the Assistant Project Manager of ACCB). Following the method of Caro et al. (1979), with a sample size of five observations x five individuals (=25 observation samples), inter-observer agreement proved to be 95%.

I collected data on activities, social proximity, forest strata use and weather (Altmann, 1974) and refer to the first three categories together as the activity budget. Activities included feeding, resting, locomotion, grooming, playing, agonistic behaviour and other behaviour. If the individual was not visible, it was scored 'out of sight'. A sample was excluded from analysis when the focal animal was out of sight for more than one recording (>20%), which did not happen during this study: I was able to keep all individuals within sight as all areas in the enclosure were visually accessible from a certain place around the fence. This was facilitated by the way the trees in the enclosure formed parallel rows (Fig. 2). I additionally collected data on social proximity ('social', i.e. within one arm's reach of another individual; 'non-social'), forest strata use (floor; understorey; canopy) and weather (sunny; cloudy; raining).

Data analysis

We pooled the raw data into thirteen hourly time-intervals from 06:00 (5:30–6:30) h to 18:00 (17:30–18:30) h for each day (N=195). We calculated the proportion of records that the langurs spent (a) feeding, resting, locomoting or grooming; (b) in social proximity or not; (c) on the floor, understorey or canopy; (d) in sunny, cloudy or rainy weather, and (e) out of sight, as percentages of the total count of (1) activities; (2) social proximity; (3) forest strata use; (4) weather; and (5) visibility respectively. We used a Kruskal-Wallis test to analyse variation in activities over the hours of the day and applied a Spearman's rank correlation to explore associations between activities. Finally, we applied Spearman's rank correlation to explore the relationship between the three weather variables and nine activity budget components ('non-social' excluded; 'out of sight' included). The significance level was 0.005 after a Bonferroni correction. Since this correction decreased the test's statistical power, we present all correlational findings and consider their effect sizes (García, 2004; Nakagawa, 2004). Although the percentages reported in the following findings represent proportions of instantaneous recordings (Altmann, 1974), we refer to them as 'percentages of time' to facilitate comprehension.

RESULTS
Activity budget

The langurs spent most of their daily time resting (47.2%) and feeding (43.6%), while locomotion (5.0%) and grooming (4.2%) were scored less frequently (Fig. 4). Non-provisioned feeding objects included young
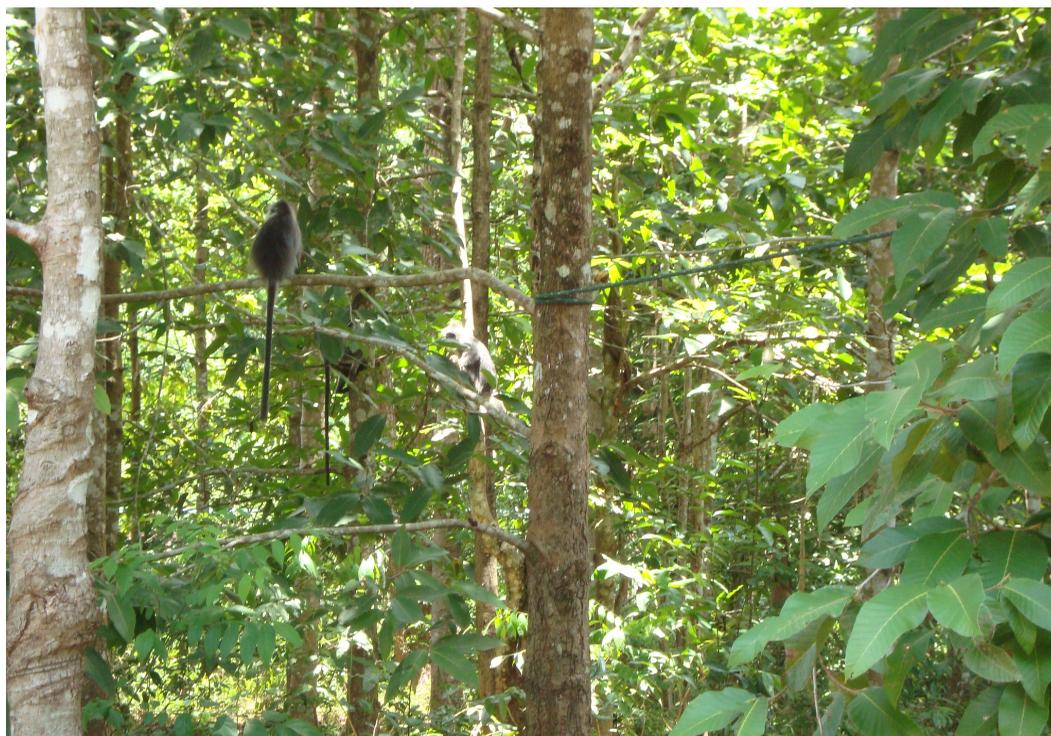
Fig 3. Three individuals resting in the understorey. Photo taken from the shortest side of the enclosure, by B. de Groot.
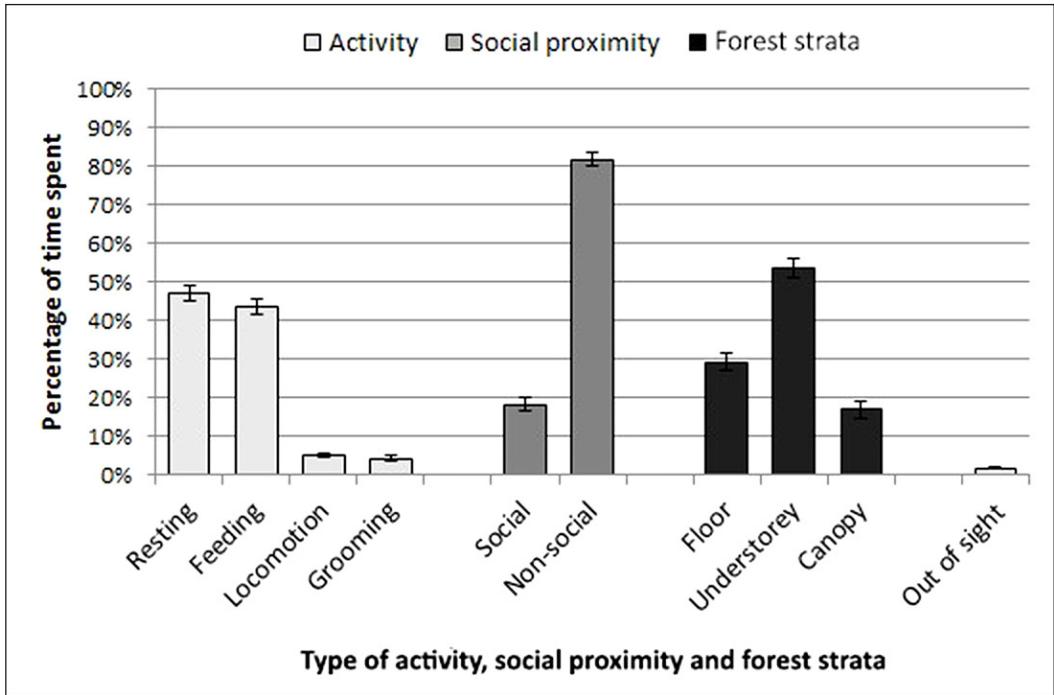
Fig. 4. Activity budget (mean± SE) of T. germaini, including time spent out of sight. Most time was spent resting and feeding, in a non-social context and in the understorey of the vegetation.
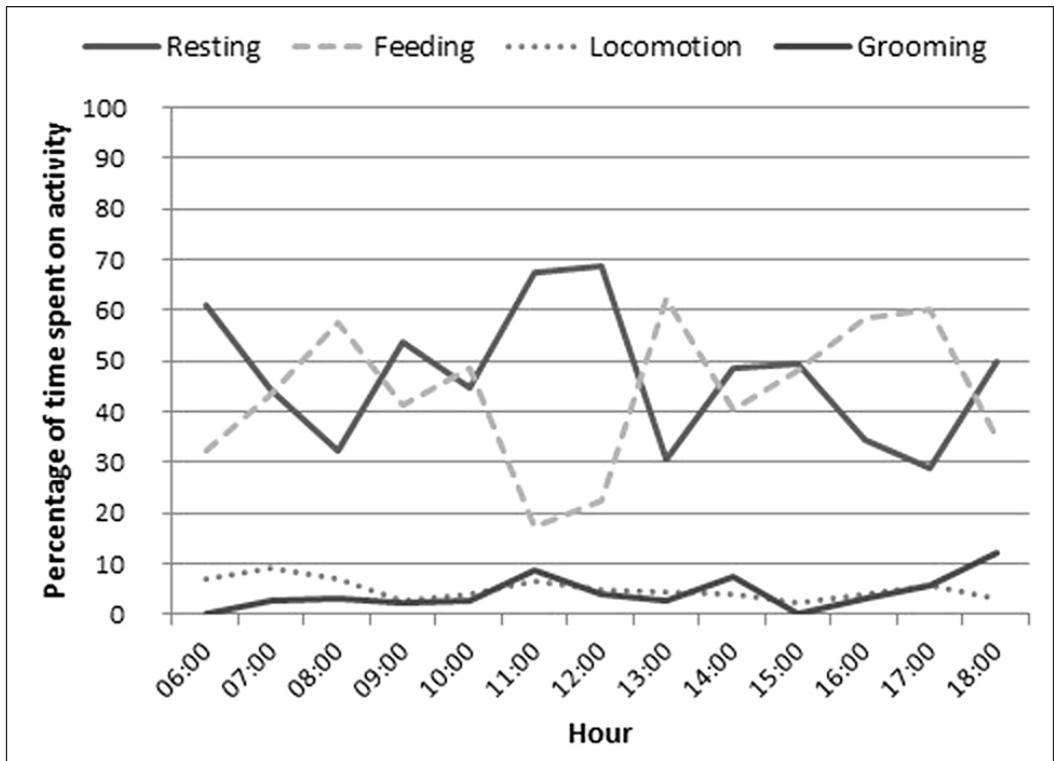
Fig. 5. Activity pattern of *T. germaini.* A peak in resting can be observed around noon; a peak in feeding around 13:00 h indicates time of food provisioning. Lines serve solely illustrative purposes since hours represent discrete data points.

Table 1. Percentage (%) of time spent on activities, in social proximity and in forest strata, under different weather conditions. Relationships between activity budget variables (N=195) and weather type are measured in correlations (Spearman's rho, r_s). P-values of significant correlations (p<0.05) are given.

| Total Activity Budget	Weather								
	Sunny			Cloudy			Raining		
	%	r_s	p	%	r_s	p	%	r_s	p
Behaviour									
Resting	47%	-0.06		46%	-0.01		59%	0.18	0.014
Feeding	44%	-0.02		45%	0.04		39%	-0.07	
Locomotion	5%	0.12		4%	-0.04		2%	-0.15	0.032
Grooming	5%	0.14		4%	-0.06		0%	-0.19	0.008
Social proximity[a]									
Social	94%	0.20	0.004*	84%	-0.18		80%	-0.18	0.013
Forest strata									
Floor	38%	0.32	0.000*	25%	-0.14	0.045	1%	-0.36	0.000*
Understorey	53%	-0.02		59%	0.12		39%	-0.03	
Canopy	10%	0.29	0.000*	16%	0.08		61%	0.28	0.000*

[a]Non-social was left out of the analysis since it was mutually exclusive with Social.
Note. Significant correlations after Bonferroni correction (p<0.005) are indicated with an asterisk (*).

and mature leaves of *Xylia xylocarpa* (Roxb.) Taub., *Dipterocarpus alatus* Roxb. ex. G.Don., and *D. intricatus* Dyer, buds, bark, mushrooms and soil. On three days near the end of June for at least three consecutive hours we observed *T. germaini* feeding on mushrooms, a food source that until now was unknown to be included in their diet (e.g. Zinner et al., 2013). We never observed play behaviour, and agonistic behaviours were rare and did not occur on sampling instants. The animals were in social proximity to another individual for 18.2% of the time. They spent more than half of their time in the understorey (53.7%), followed by the forest floor (29.3%) and canopy (17.0%). The langurs were out of sight for 1.8% of the time.

Activity pattern

Resting and feeding were significantly related to time of day (Kruskal-Wallis test: H [12]=43.78, p<0.001; H [12]=51.41, p<0.001 respectively). The langurs fed most often on non-provisioned food in the early morning (8:00 h) and late afternoon (15:00 h–17:00 h), when on average feeding comprised more than 50% of their activities (Fig. 5). Resting increased around noon, but the peak in feeding at 13:00 h marks the time of food provisioning. As shown by the Spearman's rank correlation, there was a strong significant inverse relation

between feeding and resting r_s= -0.87, p<0.01, and, less strong, between feeding and grooming, r_s=-0.23, p<0.01. This indicates that grooming and resting occurred more frequently at times when feeding occurred less. Locomotion was fairly evenly distributed over the day and did not account for more than 10% of daily activities on any hour.

Weather and activity budget

The activity budget varied under different weather conditions (Table 1). The Spearman's rank correlation depicted the following significant associations between weather and activity budget variables. Time spent on the floor was positively correlated with sunny weather (r_s=0.32) and negatively correlated with rain (r_s=-0.36). Time spent in the canopy was positively correlated with rain (r_s=0.28) while it was negatively correlated with sunny weather (r_s=-0.29). Thus, langurs were more often on the floor during sunny weather and less during rain, while the opposite was true for rainy weather. Social proximity too was positively related to sunny weather (r_s=0.20). We present all findings (Table 1), however, the relationships found when no Bonferroni correction would have been applied all fell below r_s=0.20, indicating only small effects (Field, 2009).

Table 2. Daily activities in percentages (%) for various Trachypithecus species.

Species	Activity (%)				Source
	Resting	Feeding	Locomotion	Social	
Delacour's Langur[1] *T. delacouri* (Osgood)	45	29	13	13	Phan & Stevens, 2012
Francois' Langur[2] *T. francoisi* (Pousargues)	45	32	14	9	Yang et al., 2007
Francois' Langur[2] *T. francoisi* (Pousargues)	64	22	12	2	Yang et al., 2005
Indochinese Silvered Langur[3] *T. germaini* (Milne-Edwards)	47	44	5	4	Current study
Hatinh Langur[1] *T. hatinhensis* (Dao Van Tien)	57	17	19	7	Phan & Stevens, 2012
Capped Langur[2] *Trachypithecus pileatus* (Blyth)	40	35	18	7	Stanford, 1991
White-headed Langur[2] *T. leucocephalus* Tan	50	13	18	19	Li & Rogers, 2004
Cat Ba Langur[2] *T. poliocephalus* (Trouessart)	66	15	11	8	Schneider et al., 2010
Dusky Leaf-monkey[2] *T. obscurus* (Reid)	35	40	23	2	Md-Zain & Ch'ng, 2011

[1] Captive individuals inhabiting semi-free ranging enclosures of 2–5 ha.

[2] Free-ranging individuals in a wild environment.

[3] Captive individuals inhabiting a naturalistic open enclosure of 1/3 ha.

Note. We collapsed behaviours if studies had more than four behavioural categories. Social activities included grooming and playing; Resting included all other stationary behaviour such as autogrooming, vocalization, huddling and other non-moving behaviour.

DISCUSSION
Ecological correspondence with other Trachypithecus species

The activity budget of the *T. germaini* largely agrees with the overall pattern found in *Trachypithecus* species, with high percentages of feeding and resting, and low percentages of social behaviours (Table 2). Their folivorous diet requires obligatory resting time for the process of rumination (Korstjens et al., 2010), which restricts the time that can be spend on social activities. The low amount of locomotion may be a result of the higher abundance of leaves over fruit (Huang et al., 2003). We would like to note that the absence of information on the preferred food sources and feeding behaviour of *T. germaini* in the wild prevents a well-founded explanation of their activity budget.

Kirkpatrick (2011) describes Asian colobines as rather unsocial primates, based on the percentage of their time spent grooming. Although being social is the least time-consuming activity of *Trachypithecus* species (Table 2), they show higher percentages of social time than the colobine species described in Kirkpatrick (2011), which were social for around 2% of their time. Although *T. germaini* groomed only 4.2% of their time, they were 18.2% of the day in close social proximity with another individual. Being in social proximity was not a matter of chance; the langurs actively searched for each other's company, would then sit down within each other's reach and rest together.

We did not observe play behaviour in *T. germaini*, presumably since all langurs were independent individuals. Agonistic behaviour seldom occurred. It has been argued that the generally low rate of intragroup agonistic behaviours in folivorous primates, as compared to frugivorous species, is a consequence of their diet (McKenna, 1979; Isbell, 1991; Sterck & Steenbeek, 1997). Fruits are fairly scarce and clumped (Janson & Chapman, 1999) and therefore easier to monopo-

lise than a more abundant and dispersed food source such as leaves (Wrangham, 1980; Whitten, 1983; Harcourt, 1987; Cowlishaw & Dunbar, 2000). The group composition (age and sex classes of the individuals) may form an additional explanation of the absence of play and agonistic behaviours.

Weather and activity budget

We found that *T. germaini* spent more time in the canopy and less time on the floor during rain, while the reverse was true for sunny weather. Sitting in the canopy during rain likely protected the langurs from the heavy showers that fell down from water-saturated leaves, while during sunny weather they may have preferred the shade of lower forest strata. The langurs never came down to the floor during or soon after rain, presumably since the ground was wet and muddy. Although Southern Pig-tailed Macaques *Macaca nemestrina* (Linnaeus) did not spend less time on the floor during rain, perhaps due to the discrepancy in their behavioural ecology compared to langurs, the macaques did show less social behaviours such as grooming and playing (Bernstein, 1972). In line with this finding, *T. germaini* never groomed in rainy weather, which without the applied Bonferroni correction would have led to a significant negative relationship between the two variables. Rain may make grooming less enjoyable for the receiving individual, as the water may reach the skin which most likely is an unpleasant experience. This may also explain why *T. germaini* spent more time in social proximity during sunny weather.

Ecological inconsistencies with other *Trachypithecus* species

T. germaini shows the highest percentage of feeding and lowest percentage of locomotion compared to the other *Trachypithecus* species (Table 2). This inconsistency was likely due to their captive environment, relating to (1) the relatively small size of the enclosure; (2) the low quality of the vegetation; and (3) food provisioning.

Firstly, the majority of the *Trachypithecus* species described in Table 2 were wild, and the semi-free ranging Hatinh Langur *T. hatinhensis* (Dao Van Tien) and Delacour's Langur *T. delacouri* (Osgood) had significantly larger enclosures than *T. germaini* (5 ha; 2 ha and 1/3 ha respectively). Indeed, caged *T. hatinhensis* and *T. delacouri* in 10 m x 5 m x 3 m enclosures spent more time feeding and less time locomoting than their semi-free ranging conspecifics (Phan & Stevens, 2012). Langurs in larger enclosures may benefit from traveling farther distances since this would lead them to new food sources. Traveling equally long distances

in smaller enclosures implies visiting the same areas over again, which would cost energy without gaining any benefits. As the limited size of the enclosure may have significantly affected the observed behaviours, extrapolation of the findings to the wild must be treated with caution.

Secondly, the low quality of the vegetation in the enclosure could have caused *T. germaini* to spend more time feeding to gain enough nutrients (c.f. Li & Rogers, 2004; Zhou et al., 2007). Apart from two trees, the langurs´ enclosure solely contained trees of the species *D. alatus*, and leaves of dipterocarp trees are generally not favoured by colobines as they have a low protein to fibre ratio and contain high levels of terpenes (Bennett & Davies, 1994; Gupta & Chivers, 1999). Fibre delays the passage of food in the stomach of foregut fermenters like *Trachypithecus* (Janson & Chapman, 1999); secondary compounds like terpenes have been negatively related to primate feeding behaviour (Glander, 1982). The langurs fed often on more digestible vegetation like grass and young leaves on shrubs, which contain more protein and less fibre (Davies et al., 1988). This is reflected by the large amount of time that the langurs spent on the floor (29.3%) compared to other Asian colobines (e.g. Nilgiri Langur *T. johnii* [Fischer]: <14%, Poirier, 1969; Northern Plains Gray Langur *Semnopithecus entellus* [Dufresne]: <1.2%, Oppenheimer, 1976; Gee's Golden Langur *T. geei* Khajuria: 0%, Mukherjee, 1978). Colobine feeding behaviour is subject to seasonal influences (Stanford, 1991; Li et al., 2010; Kirkpatrick, 2011) and since some dipterocarp trees shed their leaves annually during the dry season, it might be worthwhile to investigate how the activity budget of *T. germaini* and forest strata use may be affected by the sprouting of young leaves, which are known to be a preferred food item of many colobines (Kirkpatrick, 2011).

The low quality of the vegetation may additionally have led to the consumption of other forest-floor food items such as mushrooms (Fig. 6) and soil, which are suggested to supplement dietary deficiencies (Krishnamani & Mahaney, 2000; Hanson et al., 2003 respectively). For most fungi-consuming primates, mycophagy only occurs at low rates of around 5% of the daily feeding time (Hanson et al., 2003). *Trachypithecus germaini* however would spend the entire afternoon feeding time foraging on mushrooms (Fig 6). The langurs would move quickly through dense undergrowth to collect the mushrooms (c.f. Hanson et al., 2003) and then ascend to higher forest strata to consume them while seated in a typically crouched position (Fig. 6b-d). Mushrooms provide little energy for most animals
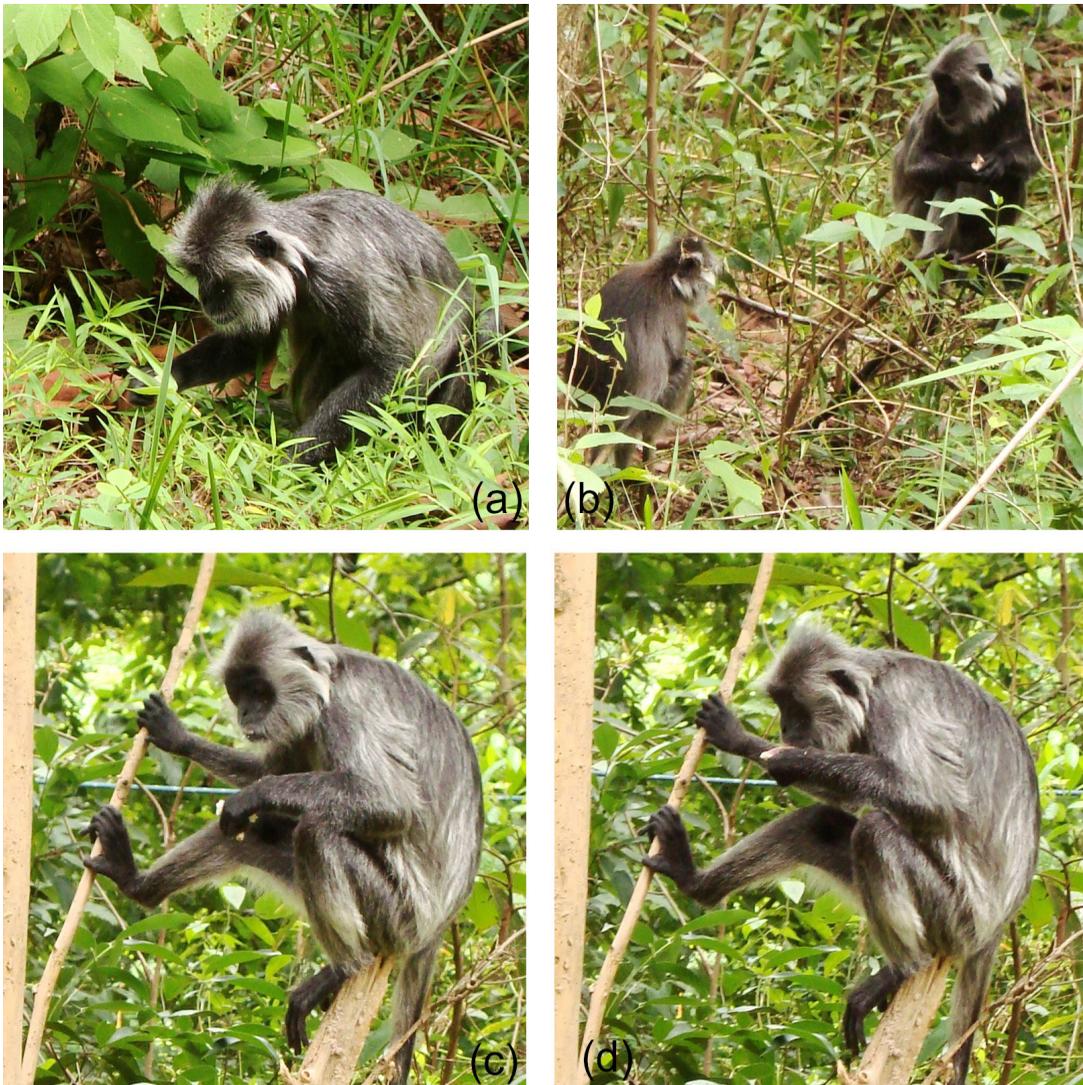
Fig. 6. Mycophagy in *T. germaini*, including 'hunting' (a) and ingesting mushrooms (b-d). Photos were taken on 16 June 2014 (a-b) and 24 June 2014 (c-d) by B. de Groot.

since they are difficult to digest (Claridge et al., 1999). Yet foregut fermenters are able to extract most of the mushrooms' protein, as is the case in marsupials (e.g. Claridge & Cork, 1994; McIlwee & Johnson, 1998). This finding might also apply to the foregut-fermenting *T. germaini*.

The langurs additionally fed on soil on four occasions. They would dig up moist soil and kneaded the sand before ingesting it. Geophagy is frequently observed in other primates as well and is performed mainly for mineral supplementation, adsorption of toxins, to control diarrhoea or to adjust the pH of the gut (Krishnamani & Mahaney, 2000). Geophagy may play an important role in the diet of wild *T. germaini* as well. Phayre's Langur

T. phayrei ssp. *phayrei* (Blyth) travel further, faster and with fewer stops on days they visit salt licks (Lloyd & Suarez, 2005), indicating the dietary value of soil consumption for this langur species. Although camera traps recorded wild *T. germaini* near salt licks (Rawson & Bach, 2011; Edwards et al., 2012), the act of geophagy was until now not yet directly reported for the species (but see Zinner et al., 2013).

Thirdly, food provisioning could also have had an influence on the amount of time the langurs spent feeding and locomoting. In contrast to the findings of this study, the provisioning of food generally leads to less feeding and more resting in food-provisioned primates compared to non-provisioned primates (e.g. Yellow Ba-

boon *Papio cynocephalus* [Linneaus]: Altmann & Muruthi, 1988; Olive Baboon *Papio anubis* [Lesson]: Eley et al., 1989; Barbary Macaque *M. sylvanus* [Linneaus]: El Alami et al., 2012). The timing of food provisioning could explain the present study's paradoxical finding. In addition to the two peaks in feeding behaviour in the morning and afternoon, food provisioning at 13:00 h caused a third peak at midday, thereby replacing resting time with feeding time. Since the provisioned food was most likely more nutritious than what the enclosure provided, *T. germaini* fed at midday even though Asian colobines normally rest at this time (e.g. Whiteheaded Langur *T. poliocephalus* ssp. *leucocephalus* Tan: Huang et al., 2003; Black Snub-nosed Monkey *Rhinopithecus bieti* [Milne-Edwards]: Ding & Zhao, 2004; Francois Langur *T. francoisi* [Pousargues]: Zhou et al., 2007; Cat Ba Langur *T.p.* ssp. *poliocephalus* [Pousargues]: Schneider et al., 2010). The decrease in locomotion may be caused by the clumped nature of the provisioned food, which did not require much locomotion to obtain.

Implications for captive care and reintroduction

We have shown that the pre-release environment affects the ecology of *T. germaini* in such a way that their activity budget and activity pattern deviates from wild *Trachypithecus* species, which could have consequences for successive captive management and reintroduction efforts. To overcome potentially harmful dissimilarities between the pre- and post-release environment, first the enclosure should be of sufficient size so that there is enough vegetation to satisfy their dietary needs. Secondly, the foliage in the enclosure should represent the vegetation they would forage on in the wild. For organisations that lack the capacity to facilitate these conditions, we recommend to transfer langurs to a pre-release environment that does suit the conditions, before reintroducing them into the wild. Thirdly, appropriate feeding times, such as in the early morning and late afternoon instead of noon, will likely make their daily activity pattern similar to that of wild conspecifics, which will increase the probability of a successful translocation. Considering the high level of interspecies ecological correspondence, these findings might be generalised to other *Trachypithecus* species as well. Similar studies could shed light on other primates' ecology and pre-release requirements, which would likewise aid in their conservation. For *T. germaini*, it is of vital importance that baseline data on their behaviour and ecology in the wild is gathered. Only then, we can determine their species-specific needs and facilitate a successful release.

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MULTI-FEMALE GROUP IN THE SOUTHERNMOST SPECIES OF *Nomascus*: FIELD OBSERVATIONS IN EASTERN CAMBODIA REVEAL MULTIPLE BREEDING FEMALES IN A SINGLE GROUP OF SOUTHERN YELLOW-CHEEKED CRESTED GIBBON *Nomascus gabriellae*

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ABSTRACT

Previous field studies of gibbon groups of the genus *Nomascus* have shown that multi-female polygynous groups are present and quite common in the northernmost species. Our research shows that multi-female groups are also present in the southernmost species, the Southern Yellow-cheeked Crested Gibbon *Nomascus gabriellae* (Thomas). Various gibbon groups are being followed and habituated in Seima Protection Forest by local and international researchers. Data collected during the first nine months of observations shows the presence of a stable multi-female family group in the study area, with two breeding females with infants. This is the first time this has been reported and confirmed for this particular species of *Nomascus*.

Keywords: Seima Protection Forest, social structure, range, extra-pair copulation, habituation

INTRODUCTION

The Southern Yellow-cheeked Crested Gibbon, *Nomascus gabriellae* (Thomas), like other members of the genus *Nomascus*, is only found east of the Mekong River (Geissmann et al., 2008). It is found only in eastern Cambodia and southern Vietnam, and inhabits mainly evergreen and semi-evergreen forest, but has also been found in mixed deciduous and bamboo forest (Rawson et al., 2008). It is listed as Endangered on the IUCN Red List of Threatened Species (Geissman et al., 2008); this assessment did not distinguish *N. gabriellae* from the Northern Yellow-cheeked Crested Gibbon *N. annamensis* (Thinh et al., 2010). Seima Protection Forest (SPF), in east Cambodia is a stronghold for *N. gabriellae*, the latest estimates indicating a population of 1,016 (95% CI [595, 1763]) individuals (Nuttall et al., 2013). It is likely this is the largest intact population of this species globally.

There have been few behavioural and ecological studies on this species (see Kenyon et al., 2007),

because of the difficulty of observing them in their natural habitat. A lack of habituated groups, their naturally shy and cryptic nature, and their preferred terrain (mainly hilly, dense forest) renders such studies challenging. *N. gabriellae* has been described as being territorial and monogamous (Traeholt et al., 2006; Rawson et al., 2008). Monogamy was believed to be predominant in most gibbon species, however studies on the genus *Nomascus* over the last decade have uncovered that many of the species in this genus have multi-female family groups, and some of these species have also been shown to have polygynous mating systems. Among the seven recognised species of *Nomascus* (Mootnik & Fan, 2011; Thinh et al., 2010) polygyny has been reported in three: the Hainan Gibbon *N. hainanus* (Thomas) (Zhou et al., 2008), the Cao Vit Gibbon *N. nasutus* (Kunkel d'Herculais)(Fan et al., 2010) and the Western Black-crested Gibbon *N. concolor* (Harlan) (Fan & Jiang, 2010; Huang et al., 2013). However polygynous mating systems have

not yet been observed in the remaining four species: the Northern White-cheeked Gibbon *N. leucogenys* (Ogilby) the Southern White-cheeked Gibbon *N. siki* (Delacour), the Southern Yellow-cheeked Crested Gibbon *N. gabriellae* and the recently described Northern Yellow-cheeked Gibbon *N. annamensis* (Thinh et al., 2010). In this study we introduce new field data to elucidate the social system of *N. gabriellae* and the presence of multi-female single-male groups that show polygynous mating patterns in this species.

STUDY SITE AND METHODS

Seima Protection Forest is composed of diverse forest types including evergreen and deciduous dipterocarp forest, and ranges in elevation from 60 to 750m asl. The forest has a tropical monsoonal climate with a distinct wet season from May to October and dry season from November to April. The mean annual rainfall is 2,200-2,800mm, with the majority falling during the wet season (Evans et al., 2013). The field site where the gibbon groups were observed is within the Core Zone of SPF, in an area less than 500m from

the indigenous Bunong village of Pu Klair, along a dirt road that runs through Andong Kralong village, Sen Monorom Commune, Ou Raing District, Mondulkiri Province (N12° 19', E107° 03') (Fig. 1).

A total of 134 survey days took place between 19 October 2014 and 27 June 2015, spanning both the dry and the beginning of the wet season. Starting at 05:00 h the research team located the target gibbon group by following their vocalizations into the forest, usually after sunrise. Data were collected on location (GPS coordinates, compass bearing and distance from observers), group size, age-sex categories of individuals, and response behaviour. Like all crested gibbons variation in fur colour is marked and changes visibly throughout the lifetime of an individual (Pocock, 1927). *N. gabriellae* is sexually dimorphic with the adult females having yellow pelage and a black crest, and adult males with black pelage and yellow cheeks. The infants of both sexes are born yellow, and both turn to black at approximately 1.5-2 years of age. The juveniles of both sexes exhibit the same coloration as adult males, with the females turning back to yellow
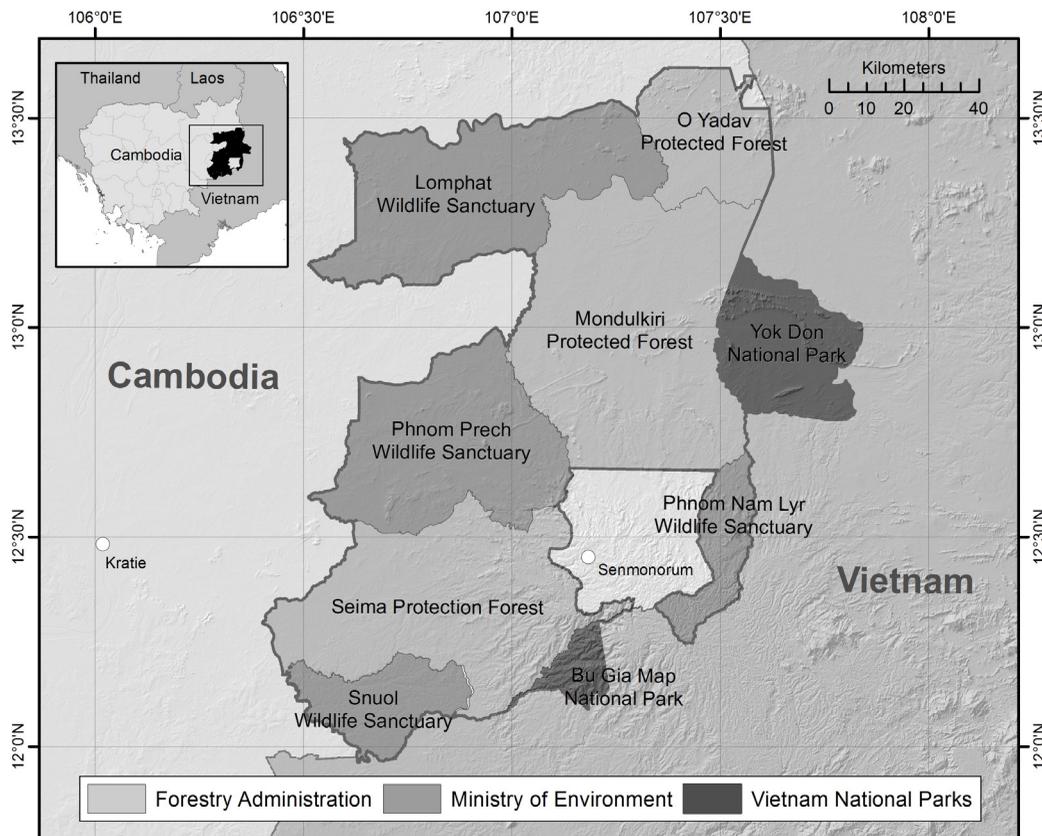

Fig. 1. Seima Protection Forest is located in Mondulkiri Province, Cambodia, and borders with Vietnam to the east.

once they reach sexual maturity at 6-8 years (Mootnik & Fan, 2011). Gibbons were classified into four categories based on age and sex: adult male, adult female, juvenile, and infant.

The focal group that was observed will be referred to as G2 and the area in which they were observed as A2. The group G2 was not yet fully habituated, and were thus only seen for short periods at a time (10-30 minutes), and only in the morning when the research teams were in the forest. The data collected regarding group composition varied between observations, however the researchers were able to obtain clear views of the whole group (inferred as the maximum number of individuals seen when considering all encounters) and thus account for the total number of individuals on regular occasions (about 50% of the time).

RESULTS

Based on field observations, we know that G2 was composed of one adult male, two adult females, both with infants of roughly the same age based on their similar body size and development, and two young juveniles (of approximately the same size). From a total of 86 observations made within A2, 40 observations were assumed to be of the focal group G2 based on the location of observations and the presence of two females with infants in the group. The remainder of the observations were of three distinct neighbouring groups, which were identifiable by differing group structures, one observation revealing three females in a single group. A lone male, possibly an older subadult or young adult male in its parental territory, was also observed within the range of G2 on various occasions in the first six months of surveys (November 2014 to April 2015); this individual later appeared to have moved out of the range of G2. Reports from tourist guides, who are currently guiding visitors in the forest around Andong Kralong village, have suggested that large gibbon groups in SPF are not uncommon. In the forest surrounding the village gibbon groups composed of up to eight individuals have been observed (Blong Mo-euk tourist guide, pers. comm.).

On 26 June 2015 the group G2 was seen feeding, and the two adult females were clearly observed as they fed separately. For the first time the infants, who had always been seen attached to their respective mothers, were seen playing and practising swinging around their mothers as they fed. A few days later,
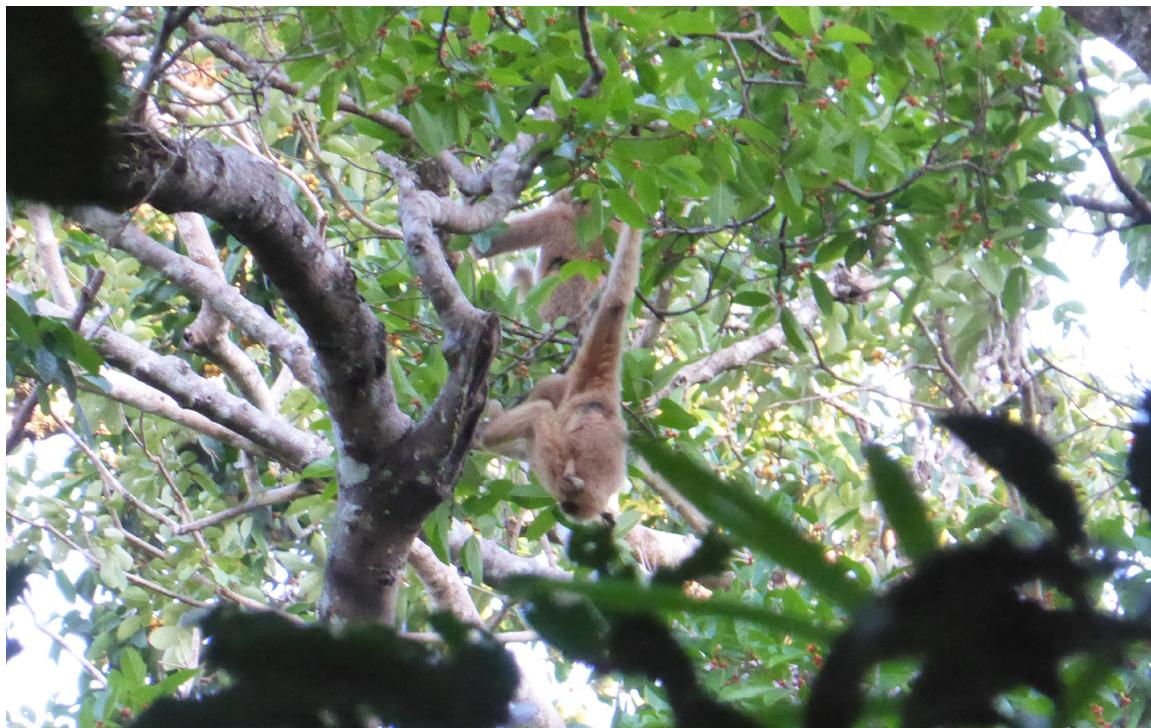
Fig. 2. The image shows the two females from G2 holding their respective infants. The infant in the foreground is more obvious and the arm and leg can be seen in the mother's fur. The second can be seen from the black colouring on the back of the female, which is the black hand of her infant clinging to her fur. Photo Credit: Claire Vincent, WCS (04.02.2015)

on a separate survey the two infants were again seen playing together in close proximity to their mothers. On 27 June 2015, whilst feeding on the same tree, observations were made of two same-sized juveniles of the group interacting: play-fighting and socializing. Two more similar observations were made on 29 June 2015. Such circumstantial evidence suggests that these juveniles, like the infants, may be half-siblings with same father and different mothers (Fig. 2). However there is presently no way to definitively say they are not twins, as twin births have been recorded, both in captivity and more rarely in the wild, in hylobatids.

On 25 January 2015, the two adult females from G2 were seen while simultaneously duetting with the male in what could be defined as a trio-duet, however the male and juveniles were responding to the females calling at a distance of about 100-200m north-west from the calling females. Shortly afterwards, once the duet finished, the male and one of the juveniles were seen on their own, 100m north-east of the females. On a second occasion, during a 36 minute observation of G2, whilst feeding on a fig tree (*Ficus altissima*) on 4 February 2015, one of the adult females saw the research team and moved towards the second female. Together with their infants, they quickly disappeared into the forest. However, the adult male and juveniles remained in the feeding tree 30m away from the team for another 19 minutes after the females disappeared. A lone female with an infant was sighted on two occasions within the known range of G2, suggesting it was one of the females of the group that had detached from the main group. These observations suggest that this large group in some cases disperses into smaller units explaining why some of the observations in the G2 area did not account for all individuals in the group.

DISCUSSION

There has only been one published study looking at group composition and social structure in *N. gabriellae*. Kenyon et al. (2011), working in Cat Tien National Park, Vietnam, found that although most groups of *N. gabriellae* observed were pair-living and presumably monogamous, some multi-female groups persisted. However in all multi-female groups observed, only one of the females carried an infant at any one time. The results from this study confirm that *N. gabriellae* can be found in a multi-female group, and suggest, though cannot confirm, a polygynous mating system; further observations may help confirm this.

It is difficult to infer whether this is a regular pattern or if it could be a more isolated case and further research

of new groups, as well as continued habituation and observations of G2, will help to understand this better. The proportion of polygynous groups recorded in the genus *Nomascus* is higher than in all other gibbon genera (Malone & Fuentes, 2009). However, most of the observations of multi-female polygynous groups come from those species found at the northernmost border of the *Nomascus* range; *N. gabriellae* is the southernmost species of *Nomascus*, and so these preliminary findings are of particular interest and may add to the mounting evidence indicating high levels of inherent social flexibility in the family Hylobatidae (Sommer & Reichard, 2000).

Multi-female polygynous *Nomascus* groups, on average, are composed of more individuals than monogamous groups (Zhou et al., 2008; Fan et al., 2010). This can lead to increased resource competition but larger groups may also have multiple benefits, such as protection from predators, efficiency in foraging and range defence (Fan et al., 2015). Jiang et al. (1999) have suggested that large home ranges are less defendable, and can result in the formation of multi-female groups. Observations from this field site suggest that this is unlikely as G2 does not appear to have a large range (preliminary data suggest a home range between 15ha and 30ha) compared with those of *Nomascus* species in the northernmost range of the genus, whose home ranges can exceed 100ha (Fan & Jiang, 2010; Fan et al., 2010).

It is important to consider that this group has only been observed for eight months of the year and considerable range expansion or contraction may still be possible, depending on the seasons and resource availability (Brockelman et al, 2014; Fan et al., 2015). For example, gibbon species have been found to become particularly stressed during the dry season and this may affect their ranging behaviour and foraging strategies (Bartlett, 2009b). Kenyon et al. (2011) also found evidence of extra-pair paternity in *N. gabriellae*, using DNA from fecal samples. Further research may help identify the possibility of extra-pair copulations occurring within the population of *N. gabriellae* in SPF, as well as confirm the presence of other multi-female polygynous groups of *N. gabriellae* within the same population.

ACKNOWLEDGEMENTS

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PREDATOR MOBBING AND INTERSPECIES COOPERATION: AN INTERACTION BETWEEN GIBBONS, LANGURS AND A CLOUDED LEOPARD

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ABSTRACT

Anti-predatory interspecific communication is observed between cohabiting species, as well as between prey and predator to communicate detection of 'stealthy hunters'. Predator mobbing is an extension of this communication, with prey species approaching and investigating or harassing a predator. Sunda Clouded Leopard *Neofelis diardi* is a predicted predator of both Bornean White-bearded Gibbon *Hylobates albibarbis* and Maroon Langur *Presbytis rubicunda* in Sabangau Forest, Central Kalimantan, Indonesia. This study reports an event in which gibbons and langurs cooperated in mobbing a clouded leopard. During the event, observers noted that the known c. six-month-old gibbon infant was not with the family group. We explain and contextualise this event in terms of primate cooperation and predator mobbing, both of which are rarely observed phenomena. Further knowledge of these interspecific relationships may help us in creating conservation strategies.

Keywords: *Hylobates*, Interspecific communication, Predator, Prey, *Presbytis*, Primate

INTRODUCTION

Predator mobbing occurs when a prey species approaches and investigates a predator (Clarke, 2010). The likely function of this is to cause a predator to abandon its hunt and leave the area (Lee & Godin, 1992; Zuberbühler et al., 1999). The action of predator mobbing behaviour is described as 'movement towards the predator interrupted with stationary pauses and moves away from the predator' (Lee & Godin, 1992), usually while giving alarms, which are vocalisations produced when there is an urgent threat (Clarke, 2010). Approaching a predator seems illogical given the high potential costs that could occur, as described by Tórrez et al., (2012). The latter authors describe an event where a male White-throated Capuchin *Cebus capucinus* (Linnaeus, 1758) was almost certainly eaten by a Jaguar *Panthera onca* (Linnaeus, 1758) in a mobbing situation. Fatalities such as this are presumably rare otherwise predator mobbing would not have evolved. However, the benefit of predator mobbing is that the predator should leave the area once detected, thus the immediate, and potentially future, danger is reduced (Lee & Godin, 1992). Previous research has shown that when mobbed, Leopards *Panthera pardus* (Linnaeus, 1758) were likely to abort a hunting attempt and leave the area within 10 minutes of being detected (Zuberbühler et al., 1999). If individuals within a group aggressively threaten a predator, this may reduce the likelihood of that predator returning to that area in the future (Lee & Godin, 1992), potentially benefiting the individual attacker's long term fitness.

Alarm calling is described as inter- and intra-specific communication (Stanford, 1998; Zuberbühler et al., 1999; Uhde & Sommer, 2002; Zuberbühler & Jenny, 2002; Clarke, 2010; Burnham et al., 2012; Nijman & Nekaris, 2012), functioning to alert group members and nearby groups to a threat, as well as to communicate to the predator that they have been detected. This is particularly important regarding predators that hunt by stealth, which rely on an element of surprise to catch their prey (Zuberbühler et al., 1999; Zuberbühler & Jenny, 2002; Godin & Davis, 2016); thus predators with

different hunting methods are likely to elicit different responses from prey species. For example, various colobus monkeys have been recorded to alarm call in the presence of Leopards, which hunt by stealth, but not in the presence of Chimpanzees *Pan troglodytes* (Blumenbach, 1799) (Humble et al., 2016), which hunt by pursuit (Stanford, 1998; Zuberbühler et al., 1999; Mitani & Watts, 2001). Consistent results were found in playback experiments; monkeys approached the source of the noise after Leopard vocalisations but not after those of Chimpanzees (Zuberbühler et al., 1999). Thus, predator mobbing is specific to certain predator types, and alarm calling to communicate is only applicable in certain circumstances.

We define cooperation as an interaction between a group of one species and a group of another, in which both groups benefit by acting together (Noe, 2006). Interspecific communication and cooperation also occurs between species in predator defence (Eckardt & Zuberbühler, 2004). Animals adapt to and evolve in environments with other species, and therefore are likely to recognise alarm calls of other species. This may result in heightened vigilance, or alarm calling from two or more species together (Stanford, 1998; Zinner et al., 2001; Uhde & Sommer, 2002; Gil-da-Costa et al., 2003; Nijman & Nekaris, 2012). However, these same species may at other times be in competition over resources. Furthermore, interspecies cooperation may depend on the level of threat, implying some kind of a cost-benefit analysis to determine whether to cooperate or not. Researchers suggest that mixed-species groups are formed mainly for anti-predation benefits (Pook & Pook, 1982; Gautier & Gautier-Hion, 1983; Buchanan-Smith, 1990; Heymann, 1990; Peres, 1993). In some mixed-species groups the different species appear to play different roles in predator avoidance; for example one species may search for aerial predators while the other may search for terrestrial predators (Gautier & Gautier-Hion, 1983; Peres, 1993). In these situations, the anti-predator benefits presumably outweigh competition for resources, and mixed-species groups can be formed.

Langur and gibbon species inhabit similar habitats throughout Asia, and although they occupy different niches (Marshall, 2010) there is still competition between the species. Interactions between them often show gibbons to be dominant over langurs (Elder, 2013). Marshall (2010) describes the distinctions between gibbon and langur niches. The Bornean White-bearded Gibbon *Hylobates albibarbis* Lyon, 1911 is predominantly frugivorous (Marshall et al., 2009; Cheyne, 2010) and plays an important role in seed dispersal (McConkey & Chivers, 2007), whereas the Maroon Langur *Presbytis rubicunda* (Müller, 1838) (Nijman & Meijaard, 2008) eats leaves and a high proportion of unripe seeds (Ehlers Smith et al., 2013).

Predation on gibbons is rarely observed; however, known gibbon predators include leopards, eagles and snakes (Ellefson, 1974; Reichard, 1998; Uhde & Sommer, 2002; Morino, 2011). It has been suggested that gibbons have few potential predators because of their large body size, defensive territoriality, and specialised rapid locomotion (Clarke et al., 2012; Cheyne et al., 2013; however, see also Zuberbühler & Jenny, 2002). The gibbons' specialised locomotion allows them to retreat quickly from a predator, which may make them more able to mob a predator compared with terrestrial primates. Terrestrial primates are thought to be less successful at mobbing (Tórrez et al., 2012), possibly as a result of their less specialised locomotion in comparison to their predators. Arboreal primates have evolved to move quickly through the canopy, whereas predators such as leopards with their less specialised locomotion, are also able to hunt on the ground (Rabinowitz et al., 1987).

Maroon Langur and Bornean White-bearded Gibbon are present in Sabangau Tropical Peat Swamp Forest (TPSF), Central Kalimantan, Indonesia, and behavioural data is regularly collected on both species for the Orangutan Tropical Peatland Project's (OuTrop) research, a programme of the Borneo Nature Foundation (BNF).

Here we report an incident involving predator mobbing and cooperation between Bornean White-bearded Gibbons, Maroon Langurs, and a Sunda Clouded Leopard *Neofelis diardi* (G. Cuvier, 1823). This event has provoked further investigation to look at the interspecific relationships in the forest. Here we aim to explore the factors influencing prey behaviour in terms of predator mobbing and cooperation in the situation described.

METHODS

As part of BNF's ongoing conservation research on primate species, long-term data are recorded on Bornean White-bearded Gibbons (hereafter gibbons in this section) and Maroon Langurs in the Sabangau peat swamp forest, central Kalimantan, Indonesia (Fig. 1).

BNF/OuTrop has been recording behavioural data on gibbons in Sabangau since 2005, and on Maroon Langurs since 2009. Habituated groups of animals
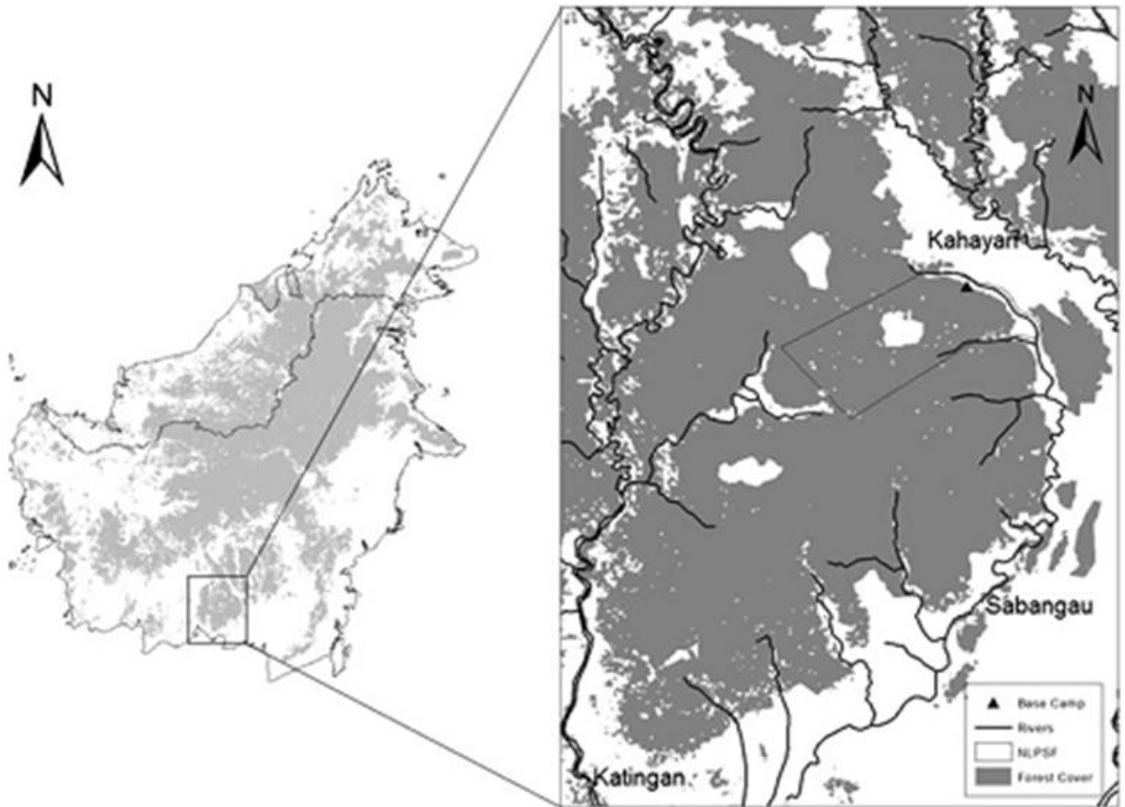
Fig. 1. Maps showing the location of Sabangau Forest, Central Kalimantan, Indonesia (BNF).

were found by searching in known home ranges and were followed from sleeping tree to sleeping tree each month for a maximum of five consecutive days. Experienced staff and researchers observed focal individuals every five minutes, recording behavioural, feeding and ranging data using a defined ethogram and a Garmin GPS (Cheyne, 2010).

The observers also recorded interactions during follows when two primate species were within 15 m of each other. The time, location, group composition, species that approached and left the area, behaviour, and circumstances of the interaction were recorded. To date we have followed gibbons for over 7,870 hours and Maroon Langurs for over 2,580 hours, and this was the first time we have witnessed an interaction like this.

RESULTS

On 7 March 2016, three researchers followed a habituated Maroon Langur group (group BD, nine individuals). The observers began recording data from 05:18 h of a focal individual's first movement from its

sleeping tree. At 06:40 h the Maroon Langur group moved towards the direction of the gibbon alarm calls, and at 06:50 h they joined a known gibbon group, Group C. At the last count, on 14 February 2016, Group C comprised an adult pair, a juvenile, and an infant. Both species were alarm-calling constantly; a juvenile Maroon Langur and a juvenile gibbon were observed sitting in the same tree, and no agonistic interaction was observed between the two species. The team noticed that the c. six-month-old gibbon infant was no longer present.

Both groups alarm-called continuously, and at 07:57 h the male gibbon's behaviour was directed at a tangle of lianas c. 14 m up in the canopy. The male gibbon grabbed something in the lianas, shook the lianas and branches, retreated to 4-5 m and vocalised, waited for c. 20 seconds, and then continuously repeated the action. At 08:38 h the team could see there was a Sunda Clouded Leopard among the lianas, while the male gibbon continued with the same behaviour, getting within 2 m of the clouded leopard (Fig. 2). The male Maroon Langur was within 10 m of the clouded leopard and gave alarm calls more frequently than the

other Maroon Langurs. The other gibbons and Maroon Langurs also vocalised throughout this encounter.

At 09:06 h the male gibbon grabbed and released the clouded leopard's tail, which was hanging in the lianas. The leopard responded by drawing its tail towards its body. At this point the leopard was identified as a male, and the team could see its face which was quite alert, looking in the direction of the male gibbon. At 09:34 h the gibbon group moved away from the area, leaving the Maroon Langur group and the clouded leopard. The Maroon Langurs continued to vocalise sporadically. The research team left the Maroon Langurs to follow the gibbon group to see if the infant would appear. The gibbon group split at this time, and the male was recorded travelling in the forest and vocalising (hooting) sporadically. The female and juvenile could not be seen or heard, and the infant was not seen again.

Out of 27 clearly recorded instances of relatively close proximity between gibbons and Maroon Langurs in Sabangau forest from 2005-2014, 55.5% (n=15) resulted in chasing; 29.7% (n=8) when individuals or groups of one species travel through the area in the presence of the other species, but did not exhibit any observable interaction; and 14.8% (n=4) when individuals or groups of both species were observed in the same area, but did not exhibit any observable interaction.

Out of 14 known outcomes of interactions between gibbons and Maroon Langurs in the study area, the gibbons appeared dominant in 12 (86%) and Maroon Langurs were dominant in only two (14%). Dominance is when one or more adults from one group chase another from a different group, usually with alarm calls from one or both groups. Dominance was only recorded during interactions which were clearly described, and when there was displacement with one species successfully chasing away another.

DISCUSSION

During this event, the Bornean White-bearded Gibbons and Maroon Langurs appeared to be cooperating by mobbing the predator. From previous interactions between Bornean White-bearded Gibbons and Maroon Langurs, we saw that most interactions resulted in one species chasing the other away, predominantly the Bornean White-bearded Gibbons chasing Maroon Langurs. Bornean White-bearded Gibbon and Maroon Langur's home ranges in Sabangau overlap, and although they have different ecological niches (Marshall, 2010) they still frequently encounter each other (CW, S, & AK, pers. obs.). A high degree of overlap of ecological niches is likely to result in a higher frequency and intensity of aggressive interactions (Elder, 2013). Sabangau is a non-masting forest, which may mean relatively low competition between

Fig. 2. Adult male gibbon (*Hylobates albibarbis*) mobbing a Sunda Clouded Leopard (*Neofelis diardi*). Photo by Supiansyah and Eko/ BNF.

species, as there is generally a steady availability of food resources such as fruit and leaves (Harrison et al., 2010). At Sabangau and at other field sites, the Bornean White-bearded Gibbon has been recorded to displace the Maroon Langur (Tilson & Tenaza, 1982; Marshall et al., 2009); however, to the authors' knowledge, there are no reports, of cooperation between Maroon Langur and Bornean White-bearded Gibbon. That both species stayed in the same area for over two and a half hours, in the same and adjacent trees is an unusual event in Sabangau (CW, S, & AK, pers. obs.).

Clouded Leopards are a predator of both gibbons (Reichard, 1998; Morino, 2011; Clarke et al., 2012) and Maroon Langur (Nijman & Nekaris, 2012), therefore it is mutually beneficial to address this threat. Mobbing is likely to be more effective with more individuals; thus, predator mobbing may be a unique situation where these species are likely to cooperate.

Gibbon infants usually cling to their mothers for six to eight months, and only begin to make exploratory movements away from the mother after this. Infants will begin to travel fully independently after around two years of age (Treesucon, 1984; Reichard, 2003; Cheyne, 2009; Lappan, 2009). Therefore, it was unusual that the six-month old gibbon infant was no longer observed with the group during this interaction, suggesting a possible predation by the clouded leopard. However, the infant could have disappeared at any point after the group was previously observed (on 14 February 2016), and its disappearance might not necessarily be due to predation by the clouded leopard. The clouded leopard might have happened to be sleeping in the lianas when the gibbons encountered it. However, there is a possibility that the infant gibbon was predated upon by the clouded leopard, and this may have led to the mobbing bout described. Although Sunda Clouded Leopards in Sabangau are predominantly active from 17:00-07:00 h, they are occasionally active during the day (Cheyne & Macdonald, 2011; Cheyne et al., 2013; Adul et al., 2015).

The Maroon Langurs could have moved towards the direction of the gibbons' alarm calls simply to investigate the threat, or possibly they could distinguish the type and nature of the calls. In either case, it appears that these two primate species recognised the threat, and thus by cooperating could be more successful at deterring predation.

CONCLUSION

This rare event is an example of two primate species cooperating to deter a predator, and provides further insight into the dynamics of inter-species associations of the primate community at Sabangau. It is evident that both gibbons and langurs consider the clouded leopard a threat that resulted in these two occasionally competing species to cooperate.

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OBSERVATIONS ON THE BENGAL SLOW LORIS *Nycticebus bengalensis* in PAKKE TIGER RESERVE, ARUNACHAL PRADESH, INDIA

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INTRODUCTION

The Bengal or Northern Slow Loris, *Nycticebus bengalensis* (Lacépède), ranges widely from northeast India to east Bangladesh, south China, Myanmar, north and central Vietnam, Laos, Cambodia, Thailand, and possibly north of peninsular Malaysia (Roos et al., 2014). Currently, nine species of slow lorises are recognized, with most living allopatrically (Nijman & Nekaris, 2010). Previously, the Bengal Slow Loris was considered a subspecies of the Greater Slow Loris *N. coucang* (Boddaert), but later taxonomic studies (Groves, 1998) and molecular work (Roos, 2003) demonstrated it to be a distinct species. An understanding of the extent of its range and abundance is essential for conservation, especially considering the possibility of further taxonomic revision in the future.

For many years the Bengal Slow Loris was listed on the IUCN Red List as Data Deficient, but it was updated to Vulnerable in 2008 (Nekaris et al., 2008; Streicher et al., 2008). A Red List re-assessment in December 2015 elevated the threat status to Endangered (K.A.I. Nekaris, unpublished data). The increasing number of slow lorises in illegal international wildlife trade led to all species of *Nycticebus* being transferred from Appendix II to Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 2007 (Nekaris & Nijman, 2007). Slow lorises are well protected by legislation in all range countries, categorized under Schedule I of the Wildlife Protection Act 1972 in India (amended in 2006), which prohibits domestic trade of slow lorises and their products (Nekaris & Starr, 2015). Yet slow lorises remain among the most commonly observed primates for sale in markets across their distribution range (Nekaris & Nijman, 2007). They are most often sold for use as pets as well as for the production of traditional medicines. This over-exploitation for illegal trade combined with rampant habitat loss are the main threats to *Nycticebus* spp. (Nekaris & Nijman, 2007; Thorn et al., 2009; Starr et al., 2011; Nekaris et al., 2013).

In India, the distribution of *N. bengalensis* is confined to only seven North-eastern states (Assam, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Nagaland, and Tripura), within a wide variety of habitats: tropical evergreen, semi-evergreen, tropical mixed deciduous and sub-tropical broadleaf forests (Choudhury, 1992; 2001). Several surveys of this nocturnal primate have been conducted to determine the extent of its distribution (Choudhury, 1992; Radhakrishna et al., 2006, 2010; Swapna et al., 2008; Das et al., 2009, 2014). From these results, it appears that the species is rare, found only in some isolated pockets of northeast India. Here we build upon the current knowledge of Bengal Slow Loris distribution by reporting on surveys carried out in Pakke Tiger Reserve, Arunachal Pradesh, India.

METHODS

Study area

The survey site, Pakke Tiger Reserve (PTR) (26°54'–27°16' N and 92°36'–93°09'E), is situated in the foothill forests of East Kameng district of western Arunachal Pradesh, India, and spread over 862 km² (Fig. 1). The north and west sides are bounded by the Bhareli River, the east side by the Pakke River and the southern edge has a common boundary with the state border of Assam. The area is characterized by undulating and hilly terrain with altitudes ranging from 200 m to about 2000 m above sea level (Kumar & Solanki, 2008). This area was declared as the 'Pakhui Wildlife Sanctuary'

in 1977 which was changed to 'Pakke Tiger Reserve' in 2002 due to the large tiger population within the protected area. For the period 2001 to 2003, PTR has a tropical and subtropical climate with an average annual rainfall of 2,545 mm, with the annual mean maximum temperature at 31°C and the annual mean minimum temperature at 18°C (Kumar & Solanki, 2014). The forest type of PTR is Assam Valley tropical semi-evergreen forest 2B/C1 (Champion & Seth, 1968) and vegetation is composed of several canopy layers with high density and tree diversity, woody lianas, epiphytic flora, and climbers. The lower plains and foothills are dominated by tropical semi-evergreen forests while at the elevations of 900 to 1800 m, subtropical broadleaf evergreen dense forests occur.

Survey method

We surveyed for *N. bengalensis* within the study area for four nights from 20 February 2015 to 23 February 2015 on foot. We consulted with local people and forest guards regarding the best potential locations, using photographs. Reconnaissance survey techniques (White & Edwards, 2000) were adopted for spotlighting surveys of lorises using pre-cut paths

to maximize access to forested areas (Burnham et al., 1980; Hedges & Lawson, 2006). Each night we selected two transects (at 18:00–21:30 h & 22:00–01:00 h), a minimum of 1 km apart to reduce (though not eliminate) the risk of counting the same individual more than once. Slow lorises generally move at a rate of c. 1 km/h (Nekaris, 2003), therefore the chances of re-counting a slow loris were very low. Our previous studies in this area showed that *N. bengalensis* generally rest between 21:00 h and 24:00 h, and would therefore move at a slower rate, if at all, during the period of our second transect walk for that night. Each night, new transects were surveyed (Peres, 1999), and four surveyors walked a 2 km-long transect marked with flagging tape at every 50 m. We maintained a pace of no more than 1 km/h, observing both sides of the transect (Nekaris et al., 2014). We used Petzl 4.5 headlamps (with xenon micro halogen bulb), searching all types of vegetation and different levels of the canopy for the loris's characteristic orange eye shine. A red filter was mounted on each headlamp to minimize disturbance (Nekaris et al., 2008). To facilitate comparisons with other nocturnal primate studies (Singh et al., 2000; Nekaris et al., 2008), we used the
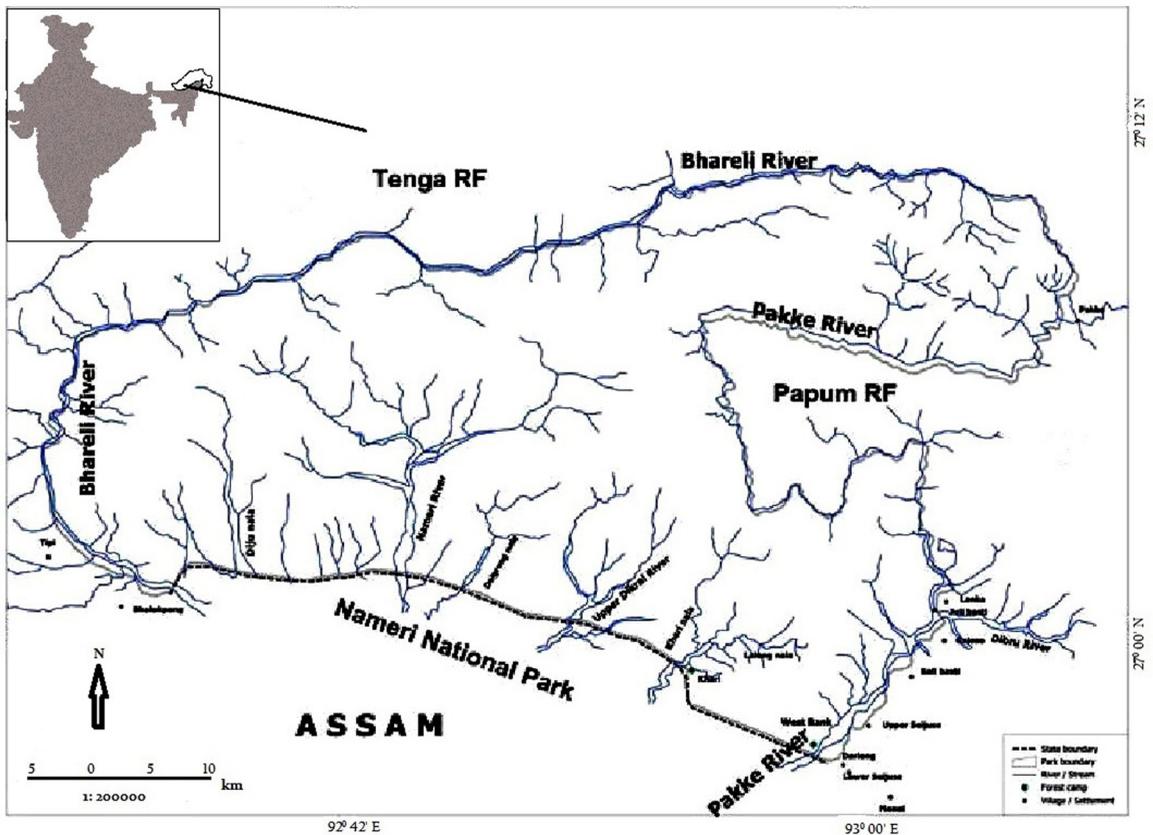

Fig. 1. Pakke Tiger Reserve, Arunachal Pradesh, India.

linear encounter rate as an index of relative abundance: the number of sightings per km (Sutherland, 2002).

Whenever a loris was encountered, the following data was recorded: the loris's distance from the start of the transect; GPS location, distance (m) from observer to loris, perpendicular distance from loris to transect, height of loris in the tree, activity, habitat type, number of individuals, ages of individuals observed (adult, infant, other immature following Rode-Margono et al., 2014), sex, time, and tree species where the loris was encountered. Tree species identification was made on the spot by a trained local forest guide, and unidentified trees were marked and re-visited the following day for identification. Photographs of the encountered lorises were taken when possible.

RESULTS
Field observations

We encountered four *N. bengalensis* over 7 transects, during 4 survey nights covering a total of 15.3 km in PTR. The mean transect length was 3.83±1.10 km. The encounter rate of Bengal Slow Lorises was calculated as 0.26 lorises /km. The mean sighting distance from the transect was 12.25±2.06 m and mean perching height of lorises was11.25±2.75 m (Table 1).

We encountered a single *N. bengalensis* on 20 February 2015 at 22:20 h in *Duabanga grandiflora* (DC) Walp. in Khare area of the PTR, an area characterized by undulating hills with woody forests. We observed the loris travelling rapidly in the mid to upper level of the canopy and observed the animal clearly at a distance of 10 m for approximately 10 minutes. Based on body size and testes, the individual was identified as an adult male. The next encounter was a sub-adult of unknown sex at 21:45 h, on *Gmelina arborea* Roxb. We observed the individual moving rapidly downwards (hilly terrain) for 2.5 minutes. We encountered the third individual at 22:05 h on another *Duabanga grandiflora*

plant, approximately 50 m from the previous one, at 10 m from the transect. We identified the animal as an adult pregnant female based on her distinct swollen abdomen above the rib cage. We spotted the fourth loris at 20:30 h, on *Garcinia xanthochymus* Hook.f. ex T.Anderson, 12 m from the transect line. We saw the animal clearly for 2.5 minutes, confirming it to be a sub-adult of unknown sex.

DISCUSSION

Our study provides an important new distribution record for Bengal Slow Lorises in Northeast India. Our encounter rate falls among the average of rates from previous studies (Table 2). Both the speed of walking (Nekaris et al., 2014) and the number of surveyors have a significant effect on the detectability of this shy animal (Nekaris et al., 2008), with smaller teams recommended. PTR may hold substantial populations of Bengal Slow Lorises and should be targeted as a key site for conservation efforts.

Bengal Slow Lorises have been found in a wide variety of habitats across their distribution range in Southeast Asia. Our study supports previous work on this species within India, providing further confirmed sightings in subtropical and tropical semi-evergreen forests (Swapna et al., 2008; Das et al., 2014). Similarly, Bengal Slow Lorises are known to occur in semi-evergreen and evergreen forests within their range in Laos (Duckworth, 1994; Evans et al., 2000). In Thailand, they have also been observed in old plantations (Pilosungnoen et al., 2010); and in Cambodia, they are found in dry dipterocarp forest (Starr et al., 2010). The species can, however, also occur in heavily disturbed areas, including home gardens. In India, many slow lorises found in such conditions are translocated to semi-evergreen forests such as the PTR (Kumar et al., 2014). An understanding of the ecology and behaviour of Bengal Slow Lorises in these very different habitats is necessary to know if such translocations are beneficial or detrimental to the species' conservation.

Table 1. Ecological characteristics and localities of four Bengal Slow Lorises encountered in Pakke Tiger Reserve, Arunachal Pradesh, India.

Tree species where loris encountered	Tree family	GPS location	Perching height (m)	Distance from transect (m)
Duabanga grandiflora	Lythraceae	N27°00'29", E92°53'06"	13	12
Gmelina arborea	Lamiaceae	N26°58'31", E92°54'54"	14	10
Duabanga grandiflora	Lythraceae	N26°58'45", E92°55'07"	10	15
Garcinia xanthochymus	Clusiaceae	N27°02'44", E92°46'45"	8	12

Table 2. A summary of encounter rates for the Bengal Slow Loris in India and Southeast Asia based on 18 studies.

Study site	Encounter rate (Loris/km)	Reference
Pakke Tiger Reserve, Arunachal Pradesh, India	0.26	This survey
Protected areas in Assam, India	0.06–0.18	Das et al., 2014
Namdapha NP, Arunachal Pradesh, India	0.2	Das et al., 2014
Samkos WLS, Cambodia	0.38–0.50	Coudrat et al., 2011
Meghalaya, India	0.04–0.10	Radhakrishna et al., 2010
KhaoAng Rue Nai WLS, Thailand	0.34–1.02	Pliosungnoen et al., 2010
Phnom Kulen NP, Cambodia	0.50	Starr et al.,2010
Gibbon WLS, Assam, India	0.18	Das et al., 2009
Trishna & Sepahijala WLS, Tripura, India	0.22	Swapna et al., 2008
Assam, India	0.03–0.33	Radhakrishna et al., 2006
Muang Hom, Central Lao PDR	0.10–0.21	Evans et al., 2000
Nam Kading, Central Lao PDR	0.10–0.22	Evans et al., 2000
Nam Ao, Central Lao PDR	0.14–0.30	Evans et al., 2000
Bang Navang, Central Lao PDR	0.09–0.20	Evans et al., 2000
Xe Namoy, Southern Lao PDR	0.40–0.87	Evans et al., 2000
Nakay-Nam Theun, Central Lao PDR	0.04–0.08	Duckworth,1998
Phou Xang He, Central Lao PDR	0.30–0.65	Duckworth, 1994
Xe Pian, Central Lao PDR	0.13–0.27	Duckworth et al.,1994

NP=National Park; WLS=Wildlife Sanctuary

Only a handful of surveys have been conducted on the distribution and population density of the Bengal Slow Loris in Northeast India (Radhakrishna et al., 2006, 2010 in Assam and Meghalaya; Swapna et al., 2008 in Tripura; Das et al., 2009, 2014 in Assam and Arunachal Pradesh). This species is threatened by a number of factors including habitat destruction through selective logging, encroachment, *'jhum'* or shifting cultivation (by the hill tribes) and monoculture forest plantations, resulting in habitat fragmentation. Hunting for meat and medicinal purposes as well as the pet trade are also serious threats in central and eastern Arunachal Pradesh. Remoteness and insurgencies affect all states in Northeast India, making conducting field research a security concern, especially at night. Hence, monitoring slow loris populations and their threats is a challenge.

The core area of the PTR is nearly free from anthropogenic pressure, apart from the occasional organized hunting and poaching trips, although severe habitat destruction, hunting and poaching are very frequent in the adjacent forest areas of PTR (Kumar & Solanki, 2004; Kushwaha & Hazarika, 2004). Since the mid-1990s, an unprecedented number of encroachments by ethnic-minority tribes have converted mature forests to agricultural land and permanent settlements in bordering areas of Nameri National Park (Assam) and PTR, and pose a major threat to this protected-area complex. Still, we feel that PTR is a relatively safe area to begin a long-term study of this species.

In this report we confirm a new distribution area for Bengal Slow Loris and show densities largely similar to the mid to lower estimates of other studies. A comprehensive survey of Bengal Slow Lorises and other threatened primates is essential to assess their status effectively in this important forest complex that encompasses PTR. In addition, a primate monitoring program is crucial to understand how populations of this species are changing.

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A MARK-RECAPTURE POPULATION SIZE ESTIMATION OF SOUTHERN YELLOW-CHEEKED CRESTED GIBBON *Nomascus gabriellae* (Thomas, 1909) IN CHU YANG SIN NATIONAL PARK, VIETNAM

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ABSTRACT

The Southern Yellow-cheeked Crested Gibbon *Nomascus gabriellae* occurs in southern Vietnam and southeastern Cambodia and is an IUCN Red List Endangered species. The species occurs in Chu Yang Sin National Park (CYSNP), Vietnam, but quantitative data were lacking. We conducted an auditory point count survey in 2012 to estimate the number of gibbon groups. We analyzed the data using a mark-recapture framework in program MARK to adjust for variation in the gibbon daily calling probability. Twenty-eight gibbon groups were detected during the survey. The species inhabited only broadleaf evergreen forest, mixed forest with broadleaf and bamboo, mixed broadleaf and coniferous forest. On average, 87.5% of the gibbon groups were detected in the three survey days at each listening post. We estimated the number of gibbon groups in the surveyed area to be 32.25 (CI: 25.26–39.24) and the total number of gibbon groups in CYSNP to be 166 (CI: 135.04–203.84). Thus the estimated Southern Yellow-cheeked Crested Gibbon population of CYSNP is the largest known gibbon population in Vietnam and CYSNP is an important conservation area for the species.

Keywords: Chu Yang Sin, gibbon, mark-recapture, *Nomascus gabriellae*

INTRODUCTION

The Southern Yellow-cheeked Crested Gibbon *Nomascus gabriellae* (Thomas) occurs in southern Vietnam and southeastern Cambodia (Geissmann et al., 2000, Van et al., 2010). The species is threatened by habitat destruction, hunting, and wildlife trade (Geissmann et al., 2000) and is listed as Endangered on the IUCN Red List (Geissmann et al., 2008). The population sizes of the Southern Yellow-cheeked Crested Gibbon in Vietnam are relatively unknown. Although common in the central highlands of Vietnam, only a few rapid surveys have been conducted, with a focus on the status and distribution of the species (Geissmann et al., 2000). Additional, detailed surveys are needed for long-term gibbon-conservation planning.

Chu Yang Sin National Park (CYSNP) is located in the central highlands of Vietnam (12°52′37″N 108°26′17″E). It is one of the least disturbed and largest protected areas in Vietnam, covering an area of 59,531 ha (BirdLife International & FIPI, 2001). The forest in CYSNP is mostly intact, only slightly disturbed by humans, and is considered suitable gibbon habitat. Gibbons have been recorded in CYSNP (Le Trong Trai et al., 2008), and a brief survey recorded eight groups in a 2,500 ha area (BirdLife International, 2010), but few intensive surveys or recorded conservation actions had taken place. CYSNP is thus a potential site for conserving a viable population of the species.

As gibbon groups do not call daily, several survey days are needed to detect almost all gibbon groups (Brockelman & Ali, 1987). A recent advance to estimate gibbon density and population size is the application of a correction factor (Jiang et al., 2006), which requires estimating the daily calling probability. The calling probability can be estimated using two methods (Vu & Rawson, 2011). The first method uses long-term observations of calling behaviour of known groups. This method can lead to biased estimates of calling probability, because only a small number of gibbon groups can be followed, and how well this small number represents the entire population is uncertain. The second method relies upon data collected over multiple visits to listening posts (Jiang et al., 2006; Vu & Rawson, 2011). The calling probability estimated using this method is more representative of the entire population and does not require following known gibbon groups. This method assumes homogeneity in the calling probability among gibbon groups and occasions (days). Variation among groups (heterogeneity in calling probability), across occasions (time variation in calling probability), or due to the behaviour of surveyors (behavioural variation in detection probabilities) might occur for a number of reasons. Individual group heterogeneity in calling probability can be created by competition among groups (Raemaekers & Raemaekers, 1985). Variation in gibbon density within surveyed areas can also lead to variation in stimuli for gibbons to call (Vu & Dong, 2015) and group size can affect the calling probability (Phanchana & Gray, 2009; Vu & Dong, 2015). Additionally, variation in weather and spatial microclimate variation can lead to temporal variation in the calling probability; e.g., vocalizations of Southern Yellow-cheeked Crested Gibbon in Cambodia are less frequent in the rainy season (Rawson, 2004). Finally, surveyors are more likely to detect groups that have been detected before, resulting in a behavioural variability in detection probability. These sources of variation in detection of gibbon groups can lead to biased estimates, and should be accounted for when estimating the size of gibbon populations (Otis et al., 1978).

Our objective was to assess the population status and distribution of Southern Yellow-cheeked Crested Gibbon in CYSNP. This is one of the few studies (see also Kidney et al. 2016) in which data from auditory point counts has been analyzed in a mark-recapture framework to estimate gibbon daily calling probability and gibbon population size.

METHODS
Field surveys

We relied upon a forest cover map of CYSNP (Vietnam Administration of Forestry, 2010) to conduct the field survey and data analysis. CYSNP has five main forest types: broadleaf evergreen, mixed broadleaf and bamboo, mixed broadleaf and coniferous, coniferous, and shrub (Vietnam Administration of Forestry, 2010). Broadleaf evergreen forest, the dominant habitat type in CYSNP, was further classified into rich forest (standing tree volume = >200m³/ha), medium forest (standing tree volume = 100-200 m³/ha), poor forest (standing tree volume = 10-100 m³/ha, after selective logging), and regrowth forest (standing tree volume = 10-100 m³/ha with regenerating trees; Fig. 1).

Gibbons usually live in the upper forest canopy and are sensitive to human presence. Therefore, seeing gibbons is difficult in the field, especially during short surveys. Gibbons can be detected by their loud and long song bouts (Geissmann, 1993; Geissmann & Orgelginger, 2000). Thus, an auditory point count method was used to assess gibbon population size and density (Brockelman & Ali, 1987). A total of 26 listening posts were selected randomly (Fig. 1). Each group of three posts was surveyed simultaneously (Fig. 2) for three consecutive mornings (05:00–09:00 h) from April to July 2012. Surveyors recorded compass bearing and estimated distance to the calling group, start and end time of song bouts, and song type (duet or solo). Gibbon groups were differentiated by their locations and were considered to be separate if more than >500m apart (Brockelman & Ali, 1987). Gibbon calls can be heard at a maximum of 2 km in this mountainous region of the Central Highlands of Vietnam (Vu & Dong, 2015) and we restricted our detections to a radius of 2 km around each listening post (Fig. 1 and 2).

Data analysis

The overlap of listening posts allowed us to use MapInfo 10.0 (Pitney Bowes Business Insight, New York, US) to triangulate gibbon groups using the angle and distance data recorded by surveyors (Fig. 2). We used the Pledger models (Pledger, 2000) in MARK (White & Burnham, 1999) to estimate the number of gibbon groups in the sampled area (the area within which a gibbon could be heard) while also correcting for variation in calling probability of gibbon groups as well as time and behavioural variation. Since detection probability of a gibbon group was a combination of daily calling probability of a group (group heterogeneity), weather (time variation) and listening ability of the
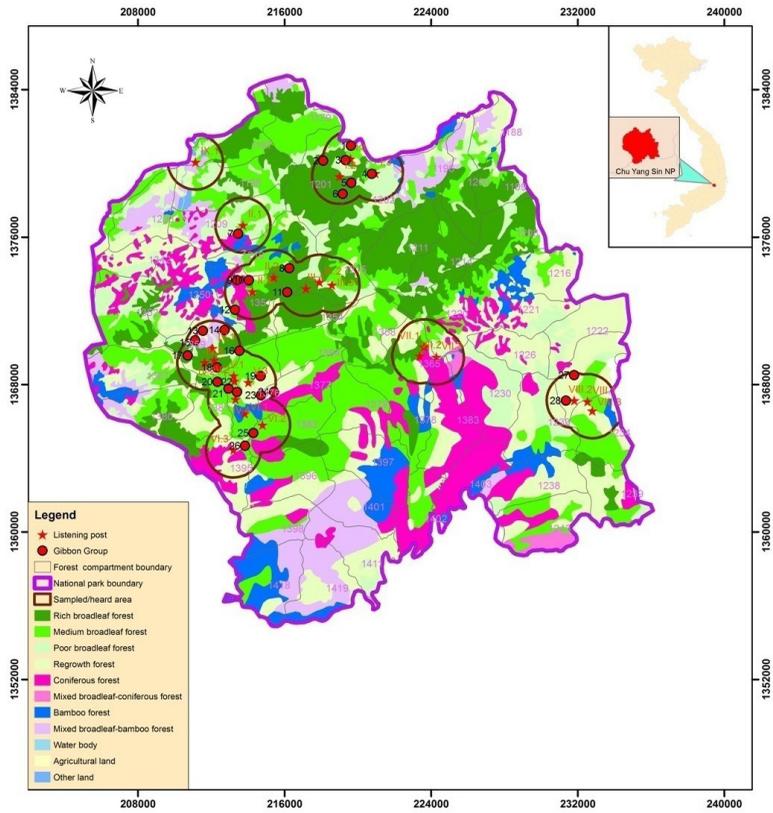
**Fig. 1.** Listening posts, gibbon groups, and sampling areas in Chu Yang Sin National Park in 2012.
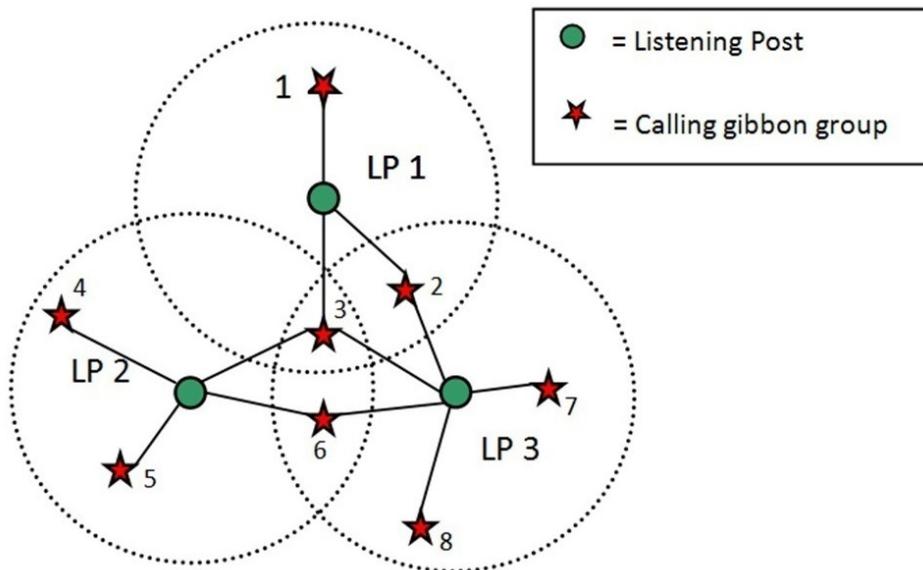
Fig. 2. Arrangement of listening posts for gibbon surveys in Chu Yang Sin National Park in 2012.

surveyors (behaviour variation), we estimated detection probability p, and redetection probability (c) of gibbon groups from the daily calling surveys by developing the following five models that incorporated these three variabilities in detection probabilities (detection probability can be considered capture probability under a mark-recapture framework):

a) *p = c* where detection probability on day one for a group, *p*, is equal to the redetection probability (*c*) on subsequent days. Gibbon groups were not partitioned into mixtures (groups of animal with relatively homogeneous capture probabilities). This model assumes no variation in heterogeneity, time, or behaviour i.e., probability of calling is constant across gibbon groups, days, and surveyor.

b) *p # c*: This model considers detection affecting the probability of subsequent detection. Gibbon groups were not partitioned into mixtures. This model allows variation due to observer behaviour only.

c) *p = c*, mixture: Same as (a), but gibbon groups were partitioned into two mixtures that have homogeneous calling probabilities. This model allows variation due to heterogeneity between gibbon groups only.

d) *p # c*, mixture: Same as (b), but gibbon groups were partitioned into two mixtures that have homogeneous calling probabilities. This model allows variation due to heterogeneity between gibbon groups and surveyor behaviour.

e) *p = c*, time: Same as (a) with time variation; gibbon groups were not partitioned into mixtures. The model allows for variation in detection probability by survey occasion (day) only.

We evaluated and ranked the models using AICc (Akaike's information criterion adjusted for small samples), ΔAICc, AICc weight (*w_i*), and cumulative AICc weights (Σ*w_i*) (Burnham & Anderson, 2002). Parameters of interest were model-averaged across the entire model set. The number of gibbon groups in CYSNP was then extrapolated based on density and the amount of suitable habitat.

RESULTS
Gibbon groups detected

Twenty-eight gibbon groups were detected during the survey: 16 groups were detected on the first day, 17 groups on the second day, and 13 on the third day (Table 1). Gibbons were only detected at 16 of 26 listening posts (61%). The areas where gibbons were detected are dominated by rich or medium broadleaf forests. Only Groups 11, 15, 22, and 24 were detected on all three days (Table 1). Ten groups were detected calling on two days and 14 groups were detected on only one day.

Distribution of gibbons

Distribution in relation to habitat

Gibbons were only detected in broadleaf evergreen forest, mixed broadleaf and bamboo forest, mixed broadleaf and coniferous forest, which are considered suitable habitat types (total suitable habitat in CYSNP = 48,535 ha; Table 2). The 26 listening posts were within these five habitat types (Fig. 1, Table 3). The total area sampled/heard around all listening posts was 10,634.8 ha, including 9,422.4 ha of suitable habitat for gibbons. Twenty-six of the 28 gibbon groups surveyed inhabited evergreen broadleaf forest, with only two groups detected in mixed broadleaf and coniferous forests (Fig. 3). Sixteen groups (57.2%) were detected in the most suitable habitat types, the closed canopies of the rich and medium broadleaf forest (eight groups in each).

Spatial distribution

The survey recorded six gibbon groups in the northern part of CYSNP, in Forest Compartments 1201 and 1202 (Vietnam Administration of Forestry, 2010). Twenty gibbon groups were detected in the centre of CYSNP in Forest Compartments 1209, 1351, 1259, 1376, 1381 and 1382. In addition, two groups were recorded in the southeast of CYSNP in Forest Compartments 1227 and 1233 (Fig. 1).

Population size estimation

The model with no variation in gibbon daily calling probability (Model a) ranked highest and suggested a detection probability of 0.48. Models that considered no difference in detection (p) vs redetection (c) probability (Models a, b, c) had more AICc weight (0.91) than models (d and e) that coded for a difference in detection and redetection probability (Table 4). We found little evidence for mixture or time effects. The estimates of the number of groups, N, in the listening area from the five models were similar and ranged from 31.02 to 33.19 groups (Table 4). Our best estimate of N, based on model-averaging and accounting for model uncertainty, was 32.25 (CI: 25.26–39.24). The estimated area of suitable habitat in the listening area was 9,422.4 ha (Fig. 1), and in CYSNP was 48,535.3 ha (19.41% of suitable habitat in the CYSNP

Table 1. Yellow-cheeked Crested Gibbon (*Nomascus gabriellae*) groups detected during the survey in Chu Yang Sin National Park in 2012.

Group ID	Order of day at LP			Forest compartment	Listening post
	First day	Second day	Third day		
1	0	0	1	1209	II.1
2	1	1	0	1351	II.3
3	1	0	0	1351	II.3
4	1	0	0	1210	II.2
5	0	0	1	1351, 1354	II.2
6	1	1	0	1351	II.3
7	1	0	0	1359	IV.2
8	0	1	1	1359	IV.2
9	1	0	0	1359	IV.2
10	0	0	1	1359	IV.1
11	1	1	1	1376	IV.2
12	1	0	0	1376	V.2
13	0	1	0	1376	VI.1
14	0	0	1	1381	VI.2
15	1	1	1	1381	IV.2
16	1	1	0	1376	VI.3
17	0	0	1	1376	VI.3, VI.2, V.1
18	0	1	1	1376	VI.3, VI.2
19	0	1	0	1382	VI.3
20	0	1	0	1382	VI.3
21	1	1	0	1201	I.2
22	1	1	1	1201	I.2
23	0	1	1	1201	I.1
24	1	1	1	1202	I.1
25	1	1	0	1201	I.2
26	1	1	0	1201	I.2, I.3
27	1	0	1	1227	VIII.2, VIII.3
28	0	1	0	1233	VIII.2, VIII.3
Total	16	17	13	12	16

1: Detected during the survey day
0: Not detected during the survey day

Table 2. Main habitat types in Chu Yang Sin National Park (2012).

No	Habitat	Area (ha)
I	Broadleaf evergreen forest	43,499
1.1	Rich forest	10,679
1.2	Medium forest	12,603
1.3	Poor forest	7,034
1.4	Regrowth forest	13,183
II	Mixed broadleaf and bamboo forest	4,470
III	Mixed broadleaf and coniferous forest	565
IV	Coniferous, shrub land and others (non-suitable habitat for gibbon)	10,996
Total		**59,531**

Table 3. Coverage of Yellow-cheeked Crested Gibbon call records by habitat type in Chu Yang Sin National Park in 2012.

Habitat type	Survey Area (ha)	Total Area in CYSNP (ha)	% Area Surveyed
Rich broadleaf forest	2,368.3	10,679.2	22.2
Medium broadleaf forest	3,192.1	12,602.9	25.3
Poor broadleaf forest	1,471	7,034.4	20.9
Regrowth broadleaf forest	2,090.7	13,182.9	15.9
Mixed broadleaf and bamboo forest	1,96.6	4,470.1	4.4
Mixed broadleaf and coniferous forest	1,03.7	565.8	18.3
Total	**9,422.4**	**48,535.3**	
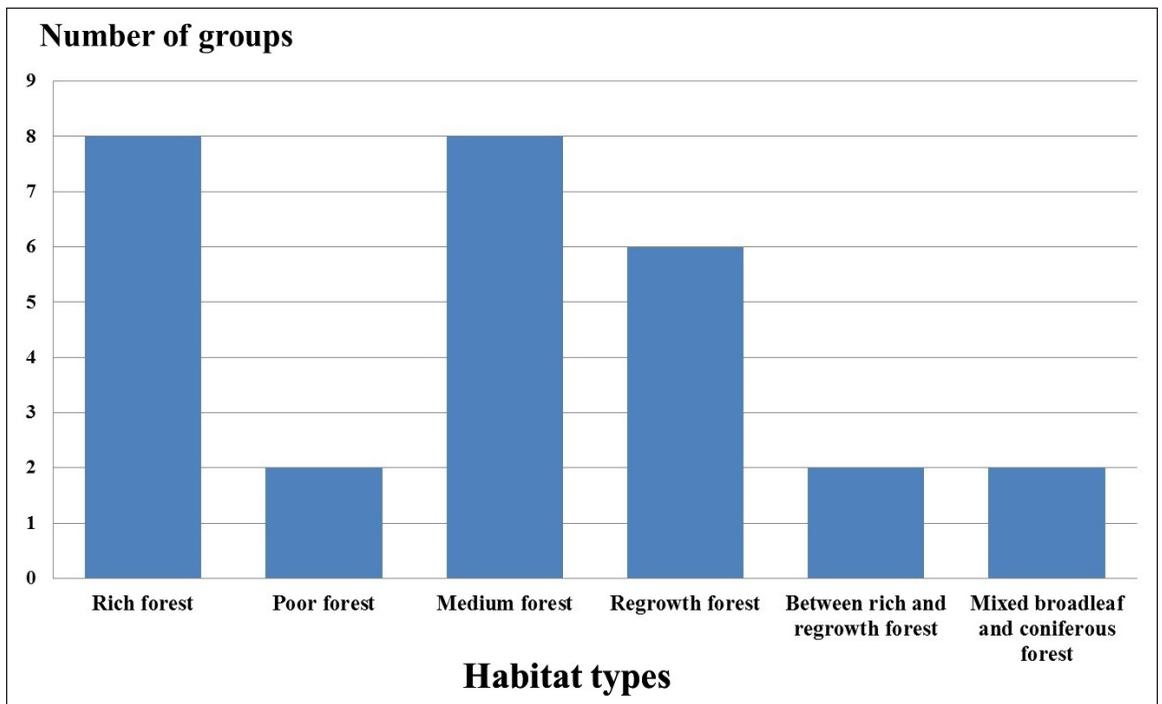
Fig. 3. Distribution of gibbon groups detected in relation to habitat types in Chu Yang Sin National Park in 2012.

Table 4. Model selection results.

Model	AICc	ΔAICc	AICc Weights	Model Likelihood	Num. Par	N* (group)	Standard Error
a) p = c	-19.70	0.00	0.58	1.00	2	32.18	3.20
b) p=c, mixture	-17.74	1.96	0.22	0.38	3	33.11	4.31
c) p=c, time	-16.43	3.27	0.11	0.19	4	32.03	3.14
d) p#c	-15.47	4.22	0.07	0.12	4	31.02	3.73
e) p#c, mixture	-13.46	6.24	0.02	0.04	5	31.06	3.92

*Estimated number of groups

was surveyed). Thus, our extrapolated estimate of the number of gibbon groups in CYSNP is 166 (CI: 135.04–203.84).

DISCUSSION
Detection

We found little evidence for variation in detection probability (Table 4) with an average probability of 0.48, leading to a correction factor of approximately 0.875 (correction factor = 1- $[1-p]^3$) which is similar to results from other studies (Hoang et al., 2010; Ha et al., 2011; Luu & Rawson, 2011). Greater variability in detection might be expected over larger spatial and temporal scales; e.g. weather alone would be more variable across longer time scales. With the exception of mixed broadleaf and bamboo forest, and regrowth broadleaf forest, the proportion of habitat areas we surveyed is uniform among habitat types (Table 3). We surveyed a higher proportion of mixed broadleaf and bamboo forest, and regrowth broadleaf because these types represent a small portion of the national park. Future surveys could stratify based on area of forest type, but this might be risky because of small areas for some forest types.

Population size

We estimated 166 gibbon groups inhabiting CYSNP, with gibbon density being highest in the mixed broadleaf and coniferous forest (two gibbon groups detected in 104 ha). However, this habitat type might not be the most suitable habitat for gibbons. The area of this type of forest is very small and forest units of different types border each other. Therefore some error might have occurred in determining the habitat where gibbon groups were detected. Evergreen broadleaf forest provides abundant and year-round food resources because of its high diversity in tree species. Additionally, broadleaf forest, especially with high canopy closure, is suitable for gibbon movement (Pham, 2002). Forest Compartments 1201, 1202, 1209, 1351, 1259, 1376, 1381, 1382, 1227 and 1233 are dominated mainly by rich and medium broadleaf forest and we believe they should be a high priority for patrolling and monitoring efforts. CYSNP is large with steep terrain. Hence, patrolling efforts should focus on the more accessible areas with high biodiversity.

With an estimated total of 166 gibbon groups, CYSNP apparently supports the largest number of Southern Yellow-cheeked Crested Gibbon in Vietnam. Populations of the species in Bu Gia Map National Park and Nam Cat Tien National Park were previously considered the largest in Vietnam (Rawson et al., 2011), but are apparently smaller than CYSNP (Table 5). The Southern Yellow-cheeked Crested Gibbon population of CYSNP is comparable to the populations of the protected areas in Cambodia (Channa & Gray, 2009) and our results suggest the global importance of CYSNP in the conservation of the Southern Yellow-cheeked Crested Gibbon across its range.

There are six gibbon species in the genus *Nomascus* in Vietnam, and a comparison across the genus shows that the number of *Nomascus* gibbon groups is also highest at CYSNP (Table 6). CYSNP appears to hold the largest *Nomascus* gibbon population in Vietnam. This is likely because of its large area (59,531 ha, of which 81.5% is considered suitable habitat). Additionally, the difficult terrain and the lack of human inhabitants limit the anthropogenic pressures on the species survival, and underline the importance of CYSNP to the conservation and survival of the Southern Yellow-cheeked Crested Gibbon.

Table 5. Population size of *N. gabriellae* in Vietnam.

Protected area	Area (ha)	Number of groups	Source
Bu Gia Map National Park	25,926	124	Rawson et al., 2011
Cat Tien National Park	73,878	149	Rawson et al., 2011
Chu Yang Sin National Park	59,531	166	This study
Bi Dup-Nui Ba National Park	63,938	≥25	Rawson et al., 2011
Phuoc Binh Nature Reserve	19,814	≥4	Rawson et al., 2011
Ninh Son Protected Forest	30,332	≥6	Rawson et al., 2011
Nam Nung Nature Reserve	10,499	30	Rawson et al., 2011
Ta Dung Nature Reserve	18,893	12-18	Hoang et al., 2010
Vinh Cuu Protected Forest	100,303	15	Rawson et al., 2011

Table 6. Population size of *Nomascus* species in Vietnam.

No	Species	Scientific name	Protected area	Area (ha)	Number of groups	Source
1	Western Black Gibbon	*N. concolor*	Mu Cang Chai Nature Reserve	20,293	> 14	Le & Le, 2010
2	Eastern Black Gibbon	*N. nasutus*	Trung Khanh Nature Reserve	1,656	18	Rawson et al., 2011
3	White-cheeked Gibbon	*N. leucogenys*	Pu Mat National Park	91,113	130	Luu & Rawson, 2011
4	Siki Gibbon	*N. siki*	Phong Nha - Ke Bang National Park	85,754	37	Le et al., 2009
5	Northern Yellow-cheeked Crested Gibbon	*N. annamensis*	Dak Rong Nature Reserve	37,640	56	Rawson et al., 2011
6	Southern Yellow-cheeked Crested Gibbon	*N. gabriellae*	Chu Yang Sin National Park	59,531	166	This study

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BOOK REVIEW

Primates of the World: An Illustrated Guide

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The *Primates of the World: An Illustrated Guide,* first published in French in 2010 and later translated into English by Robert Martin in 2013, is reminiscent of the early books on natural history. The book's introductory chapters discuss primate origins and evolution, ecology and adaptations, social organization and behavior; and the rest of the book, about 75% of it, features 76 colour plates of non-human primates and 86 colour distribution maps, organized by Madagascar, South America, Asia and Africa, covering nearly 300 primate species.

However, with recent releases of the two must-have publications of "all" of the world's extant primates, namely the *Handbook of the Mammals of the World, Vol. 3: Primates* (Mittermeier et al., 2013) and *All the World's Primates* (Rowe & Myers, 2016), one cannot help but wonder what more can *Primates of the World: An Illustrated Guide* offer. By "all" here it means that despite how recent these publications are, yet there have been some new primate taxa described since the release of these publications – primarily due to taxonomic revisions based on the advances in our genetic studies. As of August 2016, the IUCN SSC Primate Specialist Group recognizes 502 species and 694 taxa (species and subspecies), and a few more have been recently described e.g. the Skywalker Hoolock Gibbon *Hoolock tianxing* (Fan et al., 2017). The *Primates of the World: An Illustrated Guide* covers nearly 300 species

So, what can a somewhat "outdated" *Primates of the World: An Illustrated Guide* offer?
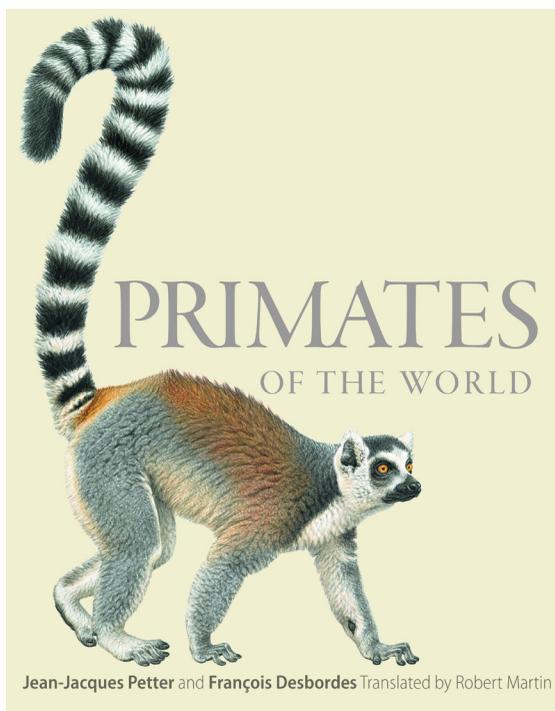
The publication excels with its rich, stunningly impressive and detailed drawings and watercolor paintings of the non-human primates – images, postures, and expressions that cannot be simply captured by camera. It provides readers a visual appreciation of the diverse array of one the more fascinating and magnificent groups of animals – primates – the very order by which we, the human species, belongs to. The *Primates of the World: An Illustrated Guide* also covers topics that include *In Search of Our Origins, The Precursors of Mammals,*

Evolution of Madagascar's Lemurs, The Role of the Forest and Primate Adaptation, Predators, Primate Territories and Social Organization, Primate Sociability and Recognition Signals, and *Classification of Primates.*

Although lacking detailed scientific information on members of the Order Primates, such as that provided in the *Handbook of the Mammals of the World, Vol. 3: Primates* (Mittermeier et al., 2013) and *All the World's Primates* (Rowe & Myers, 2016), yet the *Primates of the World: An Illustrated Guide* provides sufficient text to entice the layperson or amateur naturalists to learn, understand and appreciate our closest and remarkable living relatives better. In fact, the illustrations in *Primates of the World: An Illustrated Guide* more than compensate for the lack of detailed scientific information. The *Primates of the World: An Illustrated Guide* also provides brief descriptions of the key features for each genus, in the facing-pages, to accompany the full-page descriptions.

Moreover, despite the shortcomings, it can still serve as a beautiful, yet reasonably priced, resource on the Order Primates even to undergraduates and graduates, and definitely a must-have for all those who appreciate the diversity of primates and beauty of the natural world.

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Gorillas. Illustration by Francois Desbordes.
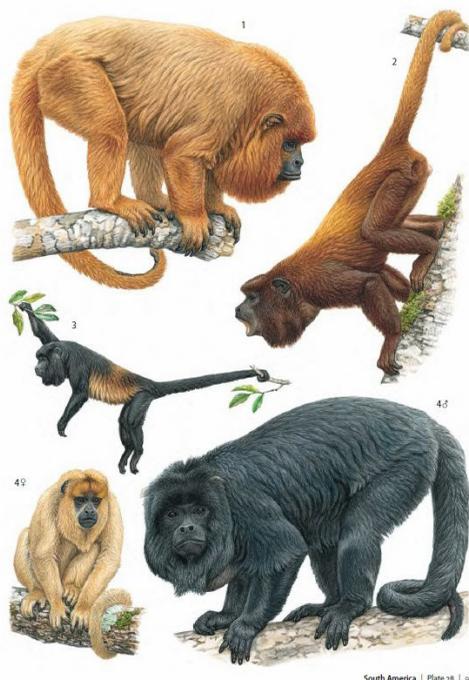
Howler Monkeys. Illustration by Francois Desbordes.

Instructions to Contributors

Scope
This journal aims to provide information relating to conservation of the primates of Asia. We welcome manuscripts on any relevant subject, including taxonomy and genetics, biogeography and distribution, ecology and behaviour, active threats and primate-human interactions. Submissions may include full articles, short articles and book reviews.

Submissions
Manuscripts and all editorial correspondence should be directed to Dr Ramesh Boonratana (ramesh.boo@mahidol.ac.th or ramesh. boo@mahidol.edu or rboonratana@gmail.com). Manuscripts are to be submitted to the journal on the understanding that they have not been published previously and are not being considered for publication elsewhere. The corresponding author is responsible for ensuring that the submitted manuscript has been seen and approved by all co-contributors, and the covering letter accompanying it should be signed to this effect. It is also the responsibility of the contributor to ensure that manuscripts emanating from a particular institution are submitted with the approval of the necessary authority. The editors retain the right to modify the style and the length of a contribution and to decide the time of publication; they will endeavour to communicate any changes to the contributors. The full name and address of each contributor should be included. Please avoid the use of unexplained abbreviations and acronyms.

Contributions
Manuscripts should be submitted in UK English. Manuscripts must be in electronic format in MS-Word or a compatible program, double- spaced and left-justified. The first page should include a concise title, up to seven keywords not found in the title, full names and addresses of all authors, current addresses if different, email addresses, and indication to whom queries and proofs should be sent. In-text citations should use comma and ampersand and follow first chronological, then alphabetical, sequence: (Matsuzawa & MacKinnon, 1980; Marsh, 1998; Matsuzawa, 1998a, 1998b). All pages including tables should be numbered. Footnotes should be avoided.

Full articles will be sent out for peer-review and should contain significant new findings. They should not exceed about 20 pages in length (double-spaced), including references. Please include an abstract of no more than 200 words, placing the work in conservation context and summarising what it has contributed, and subheadings (e.g. Introduction, Methods, Results, Discussion, Acknowledgements, References) as appropriate.

Taxonomy
Scientific nomenclature should be used at first mention of any species or subspecies. Nomenclature should include taxonomic authority (at first mention) as currently recognised by IUCN (or more recent/authoritative sources), e.g. Northern Pigtailed Macaque Macaca leonina (Blyth) (see www.iucnredlist.org). Authors are referred to The Plant List (www.theplantlist.org) for up-to-date plant nomenclature.

Numbers
Measurements should always be metric, or where this is inappropriate, the metric equivalents given in parentheses. Time should be designated in the 24-hour system (as e.g. 17:30 h) and date in the European system (e.g. 7 December 2011). Summary statistics should include measures of both central tendency and dispersion where appropriate, e.g. means and standard deviations (SD). Reports of all statistical tests should include the name of the statistical test, the name and value of the test statistic, the degrees of freedom, the probability value used to determine significance and the authors' interpretation. Probabilities should be reported as exact values if not significant, otherwise rounded off to either $p < 0.05$, 0.01 or 0.001.

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Acknowledgements
Remember to thank those who have contributed substantially to your paper, not forgetting (in the final submission) the reviewers.

References
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Journal article
Bynum, E.L., Kohlhaas, A.K. and Pramono, A.H. 1999. Conservation status of Sulawesi macaques. *Tropical Biodiversity* **6**: 123–144.

Chapter in book
Hohmann, G.M. and Fruth, B. 1995. Loud calls in great apes: sex differences and social correlates. **In**: *Current Topics in Primate Vocal Communication*, E. Zimmerman, J.D. Newman and U. Juergens (eds.), pp. 161–184. Plenum Press, New York, USA.

Book
Niemitz, C. 1984. *The Biology of Tarsiers*. Gustav Fischer, Stuttgart, Germany.

Thesis/Dissertation
Barrett, E. 1984. *The Ecology of some Nocturnal, Arboreal Mammals in the Rainforests of Peninsular Malaysia.* PhD dissertation, Cambridge University, UK.

Report
Eudey, A.A. 1987. *Action Plan for Asian Primate Conservation: 1987–1991.* IUCN/SSC (Species Survival Commission) Primate Specialist Group, Gland, Switzerland.

Electronic reference
Nadler, T., Timmins, R.J. and Richardson, M. 2008. *Trachypithecus germaini.* **In**: The IUCN Red List of Threatened Species 2008: e.T39874A10278272. http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T39874A10278272.en. Accessed on 18 February 2016.

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