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First estimates of population ecology and threats to Sunda clouded leopards *Neofelis diardi* in a peat-swamp forest, Indonesia

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ABSTRACT: The Sunda clouded leopard *Neofelis diardi* is Borneo's largest predator. A study of the species' population ecology in 50 km^2 (effective sample area 145 km^2) of the Sabangau forest, Central Kalimantan, Indonesia, spanned May 2008 to January 2012. A total of 54 camera traps at 27 stations yielded 35 129 functional trap nights resulting in 90 photos of 6 clouded leopards: 5 males and 1 female. Using capture-recapture analysis in 3 mo blocks, we extrapolated to an estimated density range of 0.72 to 4.41 ind. per 100 km^2 across all models and all data sets. Direct hunting pressure on the cats and indirect threats through possible depletion of the prey base by humans were assessed though interview and questionnaire surveys of 68 villagers in 9 villages around the edge of the 5600 km^2 Sabangau Forest. Of the respondents, 40% hunted deer and bearded pigs, although no respondent listed hunting as their main source of income or food. The low detection rates of clouded leopards suggests that a minimum area of 100 km^2 per site, and multiple sites, should be studied to elucidate the impact of habitat disturbance and fragmentation on clouded leopard populations.

KEY WORDS: Camera trapping · Capture-recapture · Predator · Hunting

INTRODUCTION

The Bornean tropical forest contains an assemblage of 5 felid species: Sunda clouded leopard *Neofelis diardi* (Vulnerable), bay cat *Pardofelis badia* (Endangered), marbled cat *P. marmorata* (Vulnerable), flat-headed cat *Prionailurus planiceps* (Endangered) and leopard cat *Prionailurus bengalensis* (Least Concern) (IUCN 2008). Research on this assemblage in Borneo provides the chance to study clouded leopard in the absence of competitors such as tigers *Panthera tigris* and large canids (Cheyne & Macdonald 2011).

No reliable population data are available for felids in Indonesian Borneo, and the impact of human disturbance on their populations is poorly understood (Wilting et al. 2006, 2010, Povey et al. 2009, Cheyne & Macdonald 2011). Peat-swamp forests are amongst the largest contiguous forest blocks in lowland Indonesian Borneo (Page et al. 1997, Shepherd et al. 1997) and are threatened by habitat loss and conversion (Koh & Wilcove 2007). The IUCN Red List 2008 (IUCN 2008) calls for research on population size and basic ecology of the Sunda clouded leopard.

The sparse evidence available suggests that wild populations of 4 of the 5 Bornean felids are declining

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based on the assumption that they are all forest-dependent to some degree and that overall forest cover across Borneo is declining (Rautner 2005, Wilting et al. 2006, Povey et al. 2009, A. J. Hearn et al. unpubl. data, J. Ross et al. unpubl. data). Extrapolating from estimates of density and geographic range, the total effective population size (Borneo and Sumatra) of the Sunda clouded leopard has been estimated at <10 000 individuals, and no sub-population is thought to contain >1000 individuals (IUCN 2008). The clouded leopard may be a complementary flagship and umbrella species to the apes, as they may persist at lower densities, require larger areas of habitat and a sufficient prey base (Johns 1985, 1988, Burnham et al. 2013).

The perceived decline of clouded leopard populations is generally attributed to a familiar syndrome of human disturbances: habitat degradation and fragmentation and hunting (direct and indirect). Previous studies have found that clouded leopards were killed as by-catch of hunting for pigs, deer and monkeys (Rabinowitz et al. 1987, Wilting et al. 2006) or to obtain the pelts for ceremonial use (Rabinowitz et al. 1987, Nowell & Jackson 1996, Povey et al. 2009). Their teeth are also highly prized, and their bones and organs are sometimes used in traditional medicine (Shepherd & Nijman 2008). In addition, some restaurants were found to serve clouded leopard, reputedly catering to wealthy Asian tourists (Rabinowitz et al. 1987). Our aims were to identify individual clouded leopards and residence time in the study area, to investigate threats and behavioural ecology and, using rates of capture and recapture, to assess their population density in Sabangau peat forest.

MATERIALS AND METHODS

Study site

The study was carried out in the Natural Laboratory for peat-swamp forest in the north-eastern corner of the Sabangau Forest (2° 19′ S and 113° 54′ E, Fig. 1). This area covers 50 km^2 of the total 5600 km^2 of forest.

The area is operated by the Centre for International Cooperation in Management of Tropical Peatlands (CIMTROP). Sabangau is the largest contiguous lowland rainforest remaining in Kalimantan and is recognised as one of the most important conservation areas in Borneo, for a variety of reasons including carbon storage, regulation of water supplies and

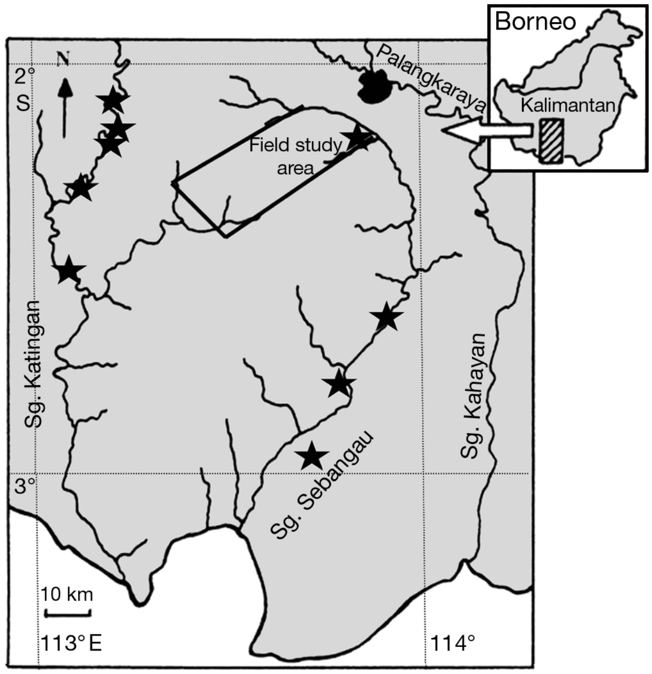

Fig. 1. Study site (black box) in the Sabangau Forest, Indonesia. Locations of villages where the questionnaire surveys were carried out are indicated by stars

conservation of flora and fauna (Aldhous 2004). The area has been subjected to long-term legal logging, illegal logging, fire and drainage from logging canals, but is now the focus of concerted protection and restoration efforts (Morrogh-Bernard et al. 2003, Cheyne 2010).

The Sabangau area is one of the deepest peat-swamp forests in the world, with peat ranging from 3 to 26 m (Page et al. 1999). Clouded leopard, leopard cat, flat-headed cat and marbled cat occur there (Cheyne & Macdonald 2011). Logging and fire have resulted in a patchwork of logged, recovering and pristine forest covering 4 habitat subtypes (mixed-swamp forest, transitional/mixed-swamp forest, low interior forest, tall interior forest; Page et al. 1999).

Cameras

From May 2008 to January 2012, 54 camera traps were set in fixed forest areas to investigate diversity, relative abundance and activity patterns of Bornean wild cats (Table 1).

In total, 20 Cuddeback Expert® and 34 Cuddeback Capture IR® (Cuddeback Digital, Non-Typical) camera traps were placed along established human-made trails (primarily >4 yr old) and, where possi-

Table 1. Characteristic sample effort for each study location within Sabangau. Trap nights exclude non-active nights. The main study site (Grid) was the focus of the work and hence has significantly more survey effort. Other areas were limited by access, size of area and number of available cameras to complete the surveys and hence were only surveyed for short periods. This allowed cameras to be used across multiple sites Dates are given as dd/mm/yy

Survey area	No. paired stations	Area (km^2) (no buffer)	Days active	Trap nights	Date set	Date removed	Clouded leopards detected
Canal I	6	3	50	300	04/06/09	23/07/09	N
Grid	31	9	1014	31434	15/05/08	21/01/12	Y
Jelutong	6	3	50	300	04/08/09	22/09/09	N
Koran	5	3	499	2495	09/11/10	14/04/11	N
Grid and Tall Pole	6	50	100	600	10/10/11	31/01/12	Y
Total	54			35129			

ble, watering areas, located so as to maximise the success rate of photographic 'detections' (Wilting et al. 2006, Gordon & Stewart 2007). Two cameras were placed opposite each other, 7 to 10 m apart to create a paired station at each location with the aim of photographing each flank of the animal simultaneously. The passive infrared sensor was set at about 50 cm height. The Expert cameras have a pre-set minimum of 60 s delay between triggers, and used a white flash, whereas the Captures use an infrared flash. The infrared cameras have no white-light flash, and this was deemed better for long-term use to avoid potential trap shyness from flash photography (Rowcliffe & Carbone 2008, Rowcliffe et al. 2008). There are no logging roads in the study area, and all cameras were placed along established trails at cross-roads and near fallen logs or man-made boardwalks, which may facilitate felid movements during the flooded wet season. Only 2 of 22 stations were on newly cut trails, the remainder being sited on established trails 0.5 to 1.0 km apart. No bait or lure was used, and batteries were changed every 14 d. All cameras were placed 0.5 to 5 km from the forest edge in previously logged mixed-swamp forest with 1 pair in the mixed-swamp/transitional forest 5 km from the forest edge (farthest accessible point). Cameras were not placed in the deforested areas, which had been burnt, lacked canopy cover and were inaccessible. To prevent damage by sun bears *Helarctos malayanus* and by pig-tailed macaques *Macaca nemestrina*, and to enable more precise placement of cameras, all cameras were placed in protective boxes supported by a single wooden leg. No differences were found between the infrared and white flash cameras, and these were also never paired together.

Analysis of CAPTURE data

We followed the example of Lynam et al. (2009) and used a capture-recapture approach (White et al. 1982); a web-based version of Program CAPTURE (Otis et al. 1978, White et al. 1982) was employed to estimate numbers of clouded leopards present at each site. In Program CAPTURE we ran 2 population models: the first assumes equal probabilities of capture for individuals (known as the null population model, M_0) and the second assumes heterogeneous probability of detection of individuals (known as the jack-knife population model, M_h; White et al. 1982). Due to the very small sample sizes, we followed the recommendations of White et al. (1982) and Lynam et al. (2009) and estimated a 95% CI as $\widehat{N} \pm 1.96$ SE (where $\widehat{N}$ is estimated abundance) and then rounded up to the nearest whole integer to get the upper limit, and rounded down to the nearest whole integer to get the lower limit. If the lower limit was less than the number of individuals caught (N_{CI+1}), we then used N_{CI+1} as the lower 95% CI (White et al. 1982).

No distinction was made between males and females. To avoid violating the assumptions of closed populations, the data were split into blocks of 3 mo (Table 2). Only the locations where clouded leopards were detected on the cameras were used for this analysis, i.e. Grid and Grid + Tall Pole (Table 1). Based on the total number of cats detected and the maximum number of recaptures, 3 blocks were selected for analysis. Block 6 represents the block with the highest number of individual cats, Block 9 the block with the lowest number of individual cats, and Block 15 the block with the largest continuous survey area. These blocks represent (1) the minimum number of cats and recaptures in the core study area, (2) the maximum number of cats and recaptures in the core study area and (3) the largest continuous area surveyed.

Estimating density from CAPTURE data

In the absence of telemetry data, various ad hoc approaches can be used to estimate animal range sizes and hence to estimate the area trapped. The effective trapping area is a combination of the total trapping area with a buffer to estimate the area sur-

Table 2. *Neofelis diardi.* Each closed-population survey block is shown with the ID of each individual captured in this period (Males M1–5 and Female F1), the total individuals detected, total photo detections (dtns) of all individuals and the number of re-detections

Block	Survey area	Start date	End date	M1	M2	M3	M4	M5	F1	No. ind.	Total dtns	Total re-dtns
1	Grid	May 2008	Jul 2008	1	0	0	0	0	0	1	1	0
2	Grid	Aug 2008	Oct 2008	3	6	0	0	0	0	2	9	7
3	Grid	Nov 2008	Jan 2009	0	3	0	0	0	0	1	3	2
4	Grid	Feb 2009	Apr 2009	2	0	0	0	0	0	1	2	0
5	Grid + Canal I	May 2009	Jul 2009	0	1	0	0	0	0	1	1	0
6[a]	Grid + Jelutong	Aug 2009	Oct 2009	1	6	0	0	1	2	4	10	6
7	Grid	Nov 2009	Jan 2010	0	2	1	0	2	0	3	5	2
8	Grid	Feb 2010	Apr 2010	1	0	0	0	0	0	1	1	0
9[a]	Grid	May 2010	Jul 2010	0	5	0	0	0	0	1	5	4
10	Grid	Aug 2010	Oct 2010	0	0	2	3	0	0	2	5	3
11	Grid + Koran	Nov 2010	Jan 2011	0	1	2	2	1	0	4	6	2
12	Grid + Koran	Feb 2011	Apr 2011	0	0	1	2	1	0	3	4	1
13	Grid	May 2011	Jul 2011	0	1	1	1	0	0	3	3	0
14	Grid	Aug 2011	Oct 2011	0	0	1	0	0	0	1	1	0
15[a]	Grid and Tall Pole	Nov 2011	Jan 2012	0	3	0	0	5	0	2	8	6

[a]Locations used for analysis

veyed as accurately as possible (Karanth & Nichols 1998). Previous studies calculating the buffer width based on distance moved by the animals have resulted in an over-estimation of the density due to incomplete data about distance moved (Silver et al. 2004, Soisalo & Cavalcanti 2006). Following Wilting et al. (2006), we used a modified equation to calculate the buffer width:

$$W = \frac{\frac{\sqrt{C}}{2} + \bar{\alpha}(M)}{2} \quad (1)$$

where C is the core area of home range sizes and M is the average daily movement. The value for C (= 6 km^2) was obtained from Grassman et al. (2005) in Phu Khieo Wildlife Sanctury, Thailand, which is similar to the recent data from Hearn et al (2013) of 50% MCP of 5.2 km^2 and 50% fixed kernel of 5.4 km^2 from Sabah. Data for M were obtained from the movement of the clouded leopards in this study (M for Blocks 6 and 9 = 1.74 km and for Block 15 = 3.35 km). A strip of width W was added to the convex hull (minimum convex polygon) of the trap sites (i.e. the polygon which bounds the outer traps). Following Maffei et al. (2005), it is preferable to add a circle of radius W around each camera trap and then calculate the area bounded by the merged perimeter. This 'concave' approach reveals whether there are any 'unsampled' areas between cameras, which would result in a 0 probability of capture. The abundance estimates were then used to estimate the clouded leopard densities, defined as $\hat{D} = N/A$, where N is animal abundance and A is the effective surveyed area sampled.

Hunting surveys

Questionnaire-based surveys were carried out in 9 villages on the Sabangau River (eastern side of the research site) to investigate the extent of direct removal of clouded leopards and/or the indirect impact on the species' abundance of humans hunting clouded leopards' prey. Data were compiled from 37 families and a total of 68 respondents from different households between May 2009 and July 2010. The research samples were derived using non-probability quota sampling (Kerlinger 1986). The method was chosen to obtain an equally distributed sample over 5 different categories which were divided by age class (20–39 yr, >40 yr) and gender, and 1 category was for local 'governmental employees' such as the village head. Age classes were established after consulting with several community members how the age-line (i.e. at what point people are considered 'young adult', 'middle-aged' or 'elderly') was defined within the villages, and the 'young adult' and 'middle-aged' classes were combined.

Questionnaires represented individual opinions and were adapted to local conditions by using information gained from informal and semi-structured interviews. Before starting the sampling process in the villages, successive refinements of the questionnaire were tested 3 times on Indonesian students to identify any questions which could bias the responses. To avoid bias, respondents were selected to come from different households, i.e. although some members of the same extended family were interviewed, they represented independent economic households. Furthermore, different households were selected to cover a wide range of different social levels. The questionnaires contained open as well as closed questions. For some issues, the contingent ranking method (Chambers 1994) was applied (e.g. to determine the relative importance of different forest resources for people's livelihood). Thus, each respondent was asked, for example, to choose the 5 most important aspects for their personal life. Afterwards the aspects were written on small cards and the respondent was asked to arrange them in ascending order of importance. Respondents were asked about all hunting activities to determine their impact on the natural community of which clouded leopards and their prey were part. Respondents were asked to rate their perception of availability of animals hunted by humans over a period of 10 yr to account for possible depletion of prey in any given area. All data were collected by Indonesian researchers without foreign presence. Previous studies on which the questionnaire was based (Harrison et al. 2011) found a good correlation between reported hunting numbers and numbers of flying foxes in markets; thus we have no reason to suspect that answers were untruthful.

Table 3. *Neofelis diardi.* Summary data of all detections and length of time present in the study area. Multiple encounters on a single short occasion are not likely to be independent; i.e. while an animal may pass in front of a camera several times in a five minute period and produce many photos, this is possibly the same animal so cannot be counted multiple times. Independent stations are geographically separate camera pairs; number of redetection stations refers to the number of camera stations to which the individual clouded leopard returned

ID	No. of independent photos	No. of independent stations	No. of redetection stations	First detection	Last detection	Months active in camera area
F1	3	2	2	Oct 2009	Oct 2009	1
M1	8	6	6	Jul 2008	Aug 2009	14
M2	28	18	14	Aug 2008	Jan 2012	42
M3	8	8	0	Aug 2010	May 2011	10
M4	7	4	2	Sep 2010	May 2011	10
M5	10	8	2	Nov 2010	Nov 2011	13

RESULTS

Population analysis

A summary of the 6 clouded leopards is presented in Table 3. All individuals were captured on camera more than once, but the female was detected at 2 stations and was only present in October 2009. This location was visited by only 1 of the males (M2) on 1 occasion, so despite 4 yr of data, the movements of female clouded leopards in this site remain unknown. Ten of the 27 stations yielded photos of clouded leopards. The maximum distance moved (i.e. farthest distance between cameras on which the individuals were caught) by a single individual was 10.8 km; this distance was covered by 2 males (M2 and M5).

CAPTURE analysis

Analysing the data under both heterogenous (M_h) and homogenous (M_0) capture probability produces different estimates of the number of individuals present in each study area. M_0 calculates a range of 0.63 to 2.64 individual clouded leopards in the study area, and M_h calculates a range of

Table 4. *Neofelis diardi.* Parameter estimates (with SE) from CAPTURE models of camera trapping data of Sunda clouded leopards in Sabangau Forest. Number of occasions refers to the number of times any clouded leopard was captured during this sample period. M_h: jack-knife population model; M_0: null population model

Parameter	Abbreviation	Block 6	Block 9	Block 15
Effective area surveyed (incl. buffer; km^2)	A	80	80	145
Probability of capture under M_h	p	0.33	0.33	0.23
Closure test	P	0.4	0.4	0.5
Selection criteria	M_o	1	1	1
Selection criteria	M_h	0.89	0.89	0.89
No. occasions	T	5	10	8
No. individuals caught	M_{t+1}	1	4	2
Total captures–recaptures	n	8	5	8
Probability of ≥1 detection	p1	0.11	0.11	0.11
Estimated no. leopards by M_0	$\widehat{N}$ (95% CI)	1.00 ± 0.37 (1–2)	2.00 ± 0.64 (2–5)	2.00 ± 0.15 (2–2)
Estimated no. leopards by M_h	$\widehat{N}$ (95% CI)	2.00 ± 0.44 (2–5)	3.00 ± 0.53 (2–6)	2.00 ± 0.95 (2–4)

1.05 to 3.53 individuals (Table 4). The CAPTURE analysis estimated that clouded leopard densities fall within the range 0.72 to 4.41 individuals 100 km^{-2} (Table 5).

Hunting (direct and indirect)

A total of 68 respondents from 9 villages ranged in age from 23 to 52 yr. All respondents were male, as hunting is a male-dominated activity. The main sources of income were farming (15% of respondents), fishing (50%) and private (35%). No one listed hunting as their main source of income. Despite this, 10 to 20% of the population of each village engaged in hunting in any one month: the main method used was dogs and spear, with snares being the next most common. Animals targeted were: deer (Sambar deer *Rusa unicolor* and greater and lesser mouse deer, *Tragulus napu* and *T. kanchil*, which corresponds to 20% of respondents catching an average of 1 to 2 animals per hunting trip; bearded pig *Sus barbatus* corresponding to 20% of respondents catching an average of 1 animal trip^{-1}; fish (blackwater species) corresponding to 40% of respondents catching an average of 1 to 20 animals trip^{-1}, and flying fox *Pteropus vampyrus natunae* corresponding to 20% of respondents catching an average of 1 to 40 animals trip^{-1}. The perceived availability of animals for hunting over the last 10 yr varied: bearded pigs and deer were deemed to be stable, while fish and flying fox catches were listed as declining.

The interviews revealed that all 68 individuals engaged in hunting, on average about once a month. Availability of deer species and bearded pigs was not deemed to have declined or increased, but the availability of fish and, especially, flying foxes was perceived to have declined. Flying foxes especially have suffered a marked (and documented) decline (Struebig et al. 2007, Harrison et al. 2011). The majority of hunting was either for bush meat or for the pet trade. Song birds and owls (e.g. Malay fish owl *Ketupa ketupu* and brown wood owl *Strix leptogrammica*) were targeted for sale as pets. Of species hunted for bush meat, fish were hunted by 40% of respondents, deer (Sambar deer and greater and lesser mouse deer *Tragulus napu* and *T.kanchil*) and bearded pig were hunted by 40% of respondents, and flying fox was hunted by 20% of respondents. No mention was made of the pangolin *Manis javanica*, which is hunted in the region for its scales, which are used in traditional Chinese medicine (Pantel & Yun 2009). In addition, hunting did not occur every month but rather seasonally, and most frequently in the dry season months (June to September) when access to the forest is easier. Respondents were asked to list all species which were hunted for any purpose, and no mention of felids was made, either as targeted species, opportunistically hunted species or species which may be killed as competitors for the deer and bearded pigs. The vast majority of local people are not aware of the protected status of all felids in Borneo and so would have few reservations about being truthful. Similar questionnaires used in the highlands of Indonesian Borneo have elicited responses that felids (clouded leopards and leopard cats) are hunted for their pelts and because the cats attack chickens (Cheyne et al. 2012), so we have no reason to suspect that respondents in this study were deliberately not mentioning the hunting of felids.

DISCUSSION

Density

Sabangau is a peat swamp forest, a habitat in which Sunda clouded leopards have not previously been studied, and which it was predicted that they would inhabit at low density, if at all, in accordance with the low productivity of this type of ecosystem (Page et al. 1997, Cheyne et al. 2008). We found an estimated density range of 0.72 to 4.41 individuals per 100 km^2 using data from Blocks 6, 9 and 15 and from the M_0 and M_h models. Other studies using different modelling approaches to generate their estimates (and often different field methods as well) have obtained different estimates (Table 6).

Table 5. *Neofelis diardi.* Spatial parameters and clouded leopard density estimates during 3 survey periods using buffer widths calculated following Wilting et al. (2006) and based on M_0: null population model, M_h: jack-knife population model

Site (no. leopards)	Buffer distance (km)	Effective sample area (km^2)	Density (ind. 100 km^{-2}) M_0	M_h
Block 6 (1)	1.74	80	0.84–1.71	2.08–3.05
Block 9 (4)	1.74	80	1.70–3.30	3.09–4.41
Block 15 (2)	3.35	145	1.28–1.48	0.72–2.03

Table 6. *Neofelis diardi.* Comparison of Sunda clouded leopard population densities (ind. 100 km^{-2}) from Borneo. 'Whole area' includes logged forest. SECR: spatially explicit capture-recapture

Site	Density	Range	Method	Source
Tabin Wildlife Reserve, Malaysia	8	8–17	Capture-recapture	Wilting et al. (2006)
Danum Valley, Malaysia	4.8–7.3	4.8–7.3	Capture-recapture	A. J. Hearn et al. (unpubl.)
Tangkulap-Pinangah Forest Reserve, Segaliud Lokan Forest Reserve, Malaysia	1	0.84 ± 0.42 and 1.04 ± 0.58 (SE)	SECR	Wilting et al. (2012)
Sabangau Peat-swamp Forest, Indonesia	0.72–4.41	0.72–4.41	Capture-recapture	This study
Malinau Basin Conservation Area, Sabah, Malaysia	1.9 (primary forest) 0.8 (whole area)	0.7–5.4 0.2–2.6	SECR	Brodie & Giordano (2012)

Population and activity

One male (M2) was resident throughout this study, with the other males apparently having shorter residency. It is possible that the core study area is an important part of the territory of M2. The males came within 700 m of the base camp and within 500 m of the forest edge, whereas the female was 1.5 to 2.76 km from the forest edge. The presence of humans in this area may have an impact on the presence of females, but even when the cameras were placed 12 km from camp, no females were detected. Males clearly did not occupy exclusive ranges, as we had photographs of multiple different males at the same location, indicating overlapping home ranges and that males clearly tolerate each other; only 1 male was shown to overlap with a female. We have detected males moving across 10.8 km with 8 d between detections; thus this probably cannot be interpreted as a range or seasonal shift.

There are several hypotheses for the small number of female clouded leopards detected during the 3 mo survey windows. Females are smaller than males and have sole responsibility for raising cubs; therefore, our current hypotheses as to the lack of photo detections of females are as follows. (1) We strongly suspect that the females are staying well away from any human disturbance, as all cameras are on trails and within the research areas/areas where humans are encroaching. (2) Females are perhaps staying away from high concentrations of males, as males may pose a threat to newborn cubs e.g. due to either the risk of infanticide or to avoid inter-sexual competition. (3) Females are staying away from high concentrations of males as they cannot compete for prey with so many larger males present. (4) The selectively logged/disturbed nature of the study locations renders them unsuitable for denning cubs so the females do not come there.

Limitations of this study include the small size of the core survey area (due to the inaccessibility of the study site) and low recapture rates (due to the likelihood that the clouded leopards' home ranges are large relative to the grid). Additionally, given the small survey area, different individual cats were resident in the study area at different times, making the data analysis for density in 3 mo blocks problematic; in no block were all 6 identified individuals detected on the cameras (see Table 2). Despite these limitations, the results (especially the lower end) are more or less in line with previous estimates. Sample sizes of ~10 to 20 individuals, probably all that is it practicable to achieve for an elusive carnivore in a remote, impenetrable environment, are problematic using capture-recapture closed population models (Otis et al. 1978, White et al. 1982).

Hunting

In neither the semi-formal interviews and questionnaires nor in general conversation with local people (S. M. Cheyne pers. obs.) was there any mention of clouded leopard skins being used in ceremonies, as has been reported in Malaysian Borneo (Rabinowitz et al. 1987). We conclude that, in this area, direct hunting and/or persecution is not a substantial threat to clouded leopards (Wilting et al. 2006). However, the interviews confirmed that hunters target potential clouded leopard prey (mouse deer, Sambar deer and bearded pigs). Although hunting was not the main source of income for any respondents, 10 to 20% of each village are engaged in hunting in any given month, with an increase in hunting activity over the dry season. People included fishing as hunting as this is removal of wild animals for human use/consumption. Population estimates for the villages around the study area are not available and thus more information is needed to elucidate the hunting intensity. The interviewees did not mention muntjac (*Muntiacus* spp.) and greater mouse deer, but the local people do not distinguish between species of mouse deer and may have subsumed muntjac with them.

CONCLUSIONS

This is the first population study for this threatened felid in any peat-swamp forest, although we have been at pains to emphasise the methodological caveats. We conclude that even with preliminary density range estimates of only 0.72 to 4.41 ind. per 100 km^2, peat forest (of which there are an estimated 68 000 km^2 in Indonesian Borneo; Page et al. 1997, 1999, Cheyne & Macdonald 2011), may be more important to clouded leopard conservation than previously supposed. If our evidence is typical, then by extrapolation, the totality of peat forest in Indonesian Borneo might harbour a significant population of clouded leopards. Local surveys suggest that hunting pressure is relatively low, and thus habitat loss and fragmentation are likely to be the greatest threats.

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