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INSIGHTS INTO THE SPATIAL AND TEMPORAL ECOLOGY OF THE SUNDA CLOUDED LEOPARD *NEOFELIS DIARDI*

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ABSTRACT. — The Sunda clouded leopard *Neofelis diardi* is an extremely challenging species to study and as such remains one of the least known of the world's larger (>10 kg) cats. We used a combination of radio-tracking and camera-trap surveys to provide some of the first insights into the spatial and temporal ecology of this elusive felid. A female clouded leopard, radio-tagged and tracked over 109 days in Sabah, Malaysian Borneo, occupied a home-range of 16.1 km^2 and a core-range of 5.4 km^2 (95% and 50% fixed-kernel estimators, respectively). Photographic records of this species from three intensive camera-trap surveys, amounting to 135 independent capture events of at least 22 individuals, were pooled and used to investigate patterns of activity. Sunda clouded leopards were found to be primarily, although not exclusively, nocturnal. We compare our results with those from two field studies of the mainland clouded leopard, *N. nebulosa*, in Thailand. Although preliminary, our data serve to underscore the need for more intensive research of this elusive wild cat.

KEY WORDS. — activity patterns, Borneo, homerange, *Neofelis diardi*

INTRODUCTION

The elusive Sunda clouded leopard *Neofelis diardi* is the largest of five wild cats, which inhabit the forests of Borneo. This felid is also found on the island of Sumatra, where it is sympatric with the tiger *Panthera tigris*, yet nowhere has it been the subject of any significant ecological research. Consequently, much of what is known of its ecology is derived from speculation, observation of captive animals (Selous & Banks, 1935), anecdotal reports (Rabinowitz et al., 1987; Santiapillai & Ashby, 1988), and chance observations of predation (Matsuda et al., 2008; Morino, 2010). Intensive camera-trap surveys are advancing knowledge of the clouded leopard's conservation status on Borneo (Brodie, 2012; Wilting et al., 2012; Hearn et al., in review). Nevertheless, the low photographic capture rates obtained during these surveys and the consequent imprecise estimates of population density are testament to just how challenging this felid is to study.

Table 1. *N. diardi* and *N. nebulosa* home ranges.

Study (location)	Sex	Age class	Study duration	Home range estimator (km²) Minimum convex polygon 100%	95%	50%	Fixed-Kernel 95%	50%
N. diardi								
This study (Borneo)	F	SA	109 days	29.9	22.6	5.2	16.1	5.4
N. nebulosa								
Grassman et al., 2005 (Thailand)	F	A	7–17 months	31	25.7	5.2	33.6	5.9
	F	SA		31.1	22.9	6.4	39.7	7.5
	M	SA		51	45.1	3.6	35.5	3.1
	M	A		34.4	29.7	8.8	43.5	4.3
Austin et al., 2007 (Thailand)	M	A	5 months	–	–	–	42.2	2.9
	F	A	5 months	–	–	–	39.4	2.9

Investigation of the spatial ecology of this felid has proved to be a particular challenge. Three intensive clouded leopard-focused live-trapping programmes, two in Borneo (Rajaratnam, pers. comm.; Hearn et al., unpublished data), one in Sumatra (J. McCarthy, pers. comm.) resulted in no captures. Thus, no data is currently available regarding the spatial ecology of *N. diardi*, yet such information is essential to help improve understanding of this felid's conservation needs and the efficacy of camera-based survey methods. Knowledge of the activity patterns of the Sunda clouded leopard is equally scant. Using camera-trap data, Cheyne & Macdonald (2011) reported that clouded leopards in the peat swamp forest of the Sabangau National Park, Central Kalimantan, were primarily nocturnal, but their small sample size permitted only preliminary conclusions.

Here we describe the movements and home-range of an individual Sunda clouded leopard, the first data of their kind. We also use camera-trap data to describe the temporal activity of this felid and we present some of the first data regarding the mass and body dimensions for this felid based on data that we collected in the field and from the literature.

MATERIAL AND METHODS

Estimation of home range. — In Jan.2008, researchers attempting to live-trap bearded pig (*Sus barbatus*) and sun bear (*Helarctos malayanus*) in the Ulu Segama Forest Reserve, Sabah, Malaysia, led by Siew Te Wong, inadvertently captured a female Sunda clouded leopard in a steel-wire-mesh trap. The trap (1.5 m long, 0.8 m wide, 0.8 m high) had been baited with a chicken wing and was placed approximately 3 m from an old logging road. This impromptu capture occurred at a time when our team was about to begin an intensive live-capture and tagging programme focused on Bornean felids in the same area. The animal appeared in excellent health, with no apparent trap injuries. Examination of tooth colouration and the absence of any signs of previous breeding suggested this was a sub-adult animal, although comparison of this animal's morphometric measurements with that reported for two individuals from Sarawak and six mainland clouded leopards (Table 2) suggested that this animal was at or approaching adult body size. Therefore, we took this opportunity to immobilise the animal and fit a 140 g VHF radio-collar (TW-5, Biotrack ltd, Wareham, UK), following a predetermined set of protocols developed with the Sabah Wildlife Department, and following the recommendations laid out in the UK Animals (Scientific Procedures) Act, 1986. The clouded leopard was anaesthetised with an intramuscular injection of tiletamine hydrochloride and zolazapam hydrochloride (Zoletil®, Virbac, Ltd., Carros, France) at 10.8 mg kg^{-1}.

We employed standard methods of ground-based triangulation (Kenward, 2001) to determine point locations of the clouded leopard, using R-1000 telemetry receivers (Communication Specialists, Inc, CA, USA) and hand-held, directional, three-element Yagi antennae (Biotrack Ltd., Wareham, UK). We used the Program Locate III (Nams, 2006) to estimate individual point locations and calculate 95% maximum likelihood confidence ellipses. We excluded individual locations with error ellipses larger than 10 hectares from the analysis. We calculated home-range size using 95% and 100% minimum convex polygon estimators (MCP), and the 95% fixed-kernel estimator, using Ranges VI (Anatrack Ltd., Wareham, Dorset, UK). To investigate core range we used 50% MCP and 50% fixed-kernel estimators. We calculated minimum daily movements by measuring the linear distance between consecutive daily locations.

Activity patterns. — As part of a long-term study investigating Bornean felid conservation status and responses to forest management (Hearn et al., submitted), we deployed passive-infrared digital camera traps (Snapshot Sniper LLC, OK, USA) across three contiguous lowland dipterocarp forest areas in the Malaysian state of Sabah, Borneo. Our study areas consisted of two commercial forests, Ulu Segama (2,029 km^2) and Malua (340 km^2) Forest Reserves, and an adjacent area of primary forest, Danum Valley Conservation Area (438 km^2) (see Reynolds et al., 2011 for a description of study sites). A preliminary camera survey revealed that old logging roads, established human trails, and ridgelines were favourable sites to photo-capture Sunda clouded leopards. We set the camera traps in pairs and preferentially deployed them at these habitat features. The camera traps were operational from Feb.2006 to Feb.2009, amounting to a total of 14,743 camera trap days (one camera pair operating for 24 hours). Following Azlan & Sharma (2006), we used temporal data from photographic capture events to assess Sunda clouded leopard activity patterns. We expressed clouded leopard activity as the percentage of photographs within each hour. To reduce pseudoreplication, we included only one record of each individual per hour, regardless of location. Based on the approximate times of sunset and sunrise we categorised nocturnal activity as being from 1900–0500, diurnal as 0600– 1800 hours, and we categorised activity within the intervening periods as crepuscular.

RESULTS

Estimation of home range**.** — The live-trapped individual is the first known Sunda clouded leopard to be immobilised in situ and radio-tagged. We used 37 radio-locations obtained over a 109-day period to calculate home-range size (Table 1; Fig. 1). The radio-collared female was located 22 times on consecutive days and showed movement on all days. Distances between consecutive daily locations averaged 797 m (± 667 m SD, range 97–3042 m). After 109 days the female was located in the northern part of her range; thereafter we were unable to detect the radio-signal, despite an aerial search. Table 2 presents the morphometric measurements for this female and that of an adult male from the same area, alongside measurements for two individuals from Sarawak and six mainland clouded leopards reported in the literature.

Activity patterns**.** — A total of 135 independent photo-captures of Sunda clouded leopards was used to investigate activity patterns (Fig. 2). Sunda clouded leopard activity appears to be primarily nocturnal (81% of records), although there was also a small increase in activity around dawn. Activity peaked between 2000–0059 hours and activity was at its lowest during the diurnal period, with no evidence of activity from 1100–1559 hours.

DISCUSSION

The clouded leopard home-range and core-range estimates are similar to those calculated for female mainland clouded leopards in Thailand by Austin et al. (2007) and Grassman et al. (2005) (Table 2), although the latter were obtained over a much longer period. Owing to the dense vegetation and rugged topography of our study area we were frequently unable to locate our study animal. Therefore, it is quite likely that the range size for this female is an underestimate.

We characterised Sunda clouded leopard activity as primarily, although not exclusively, nocturnal, supporting Cheyne & Macdonald's (2011) preliminary findings from the peat swamp forests of southern Borneo. Nevertheless, although mainly nocturnal in their habits, we did record several instances of diurnal activity, and there are accounts of Sunda clouded leopards hunting primates during the day (Davis, 1962; Matsuda et al., 2008; Morino, 2010). Radio-telemetry studies of *N. nebulosa* in Thailand revealed that this felid's activity patterns were largely arrhythmic with increased activity during crepuscular and nocturnal periods

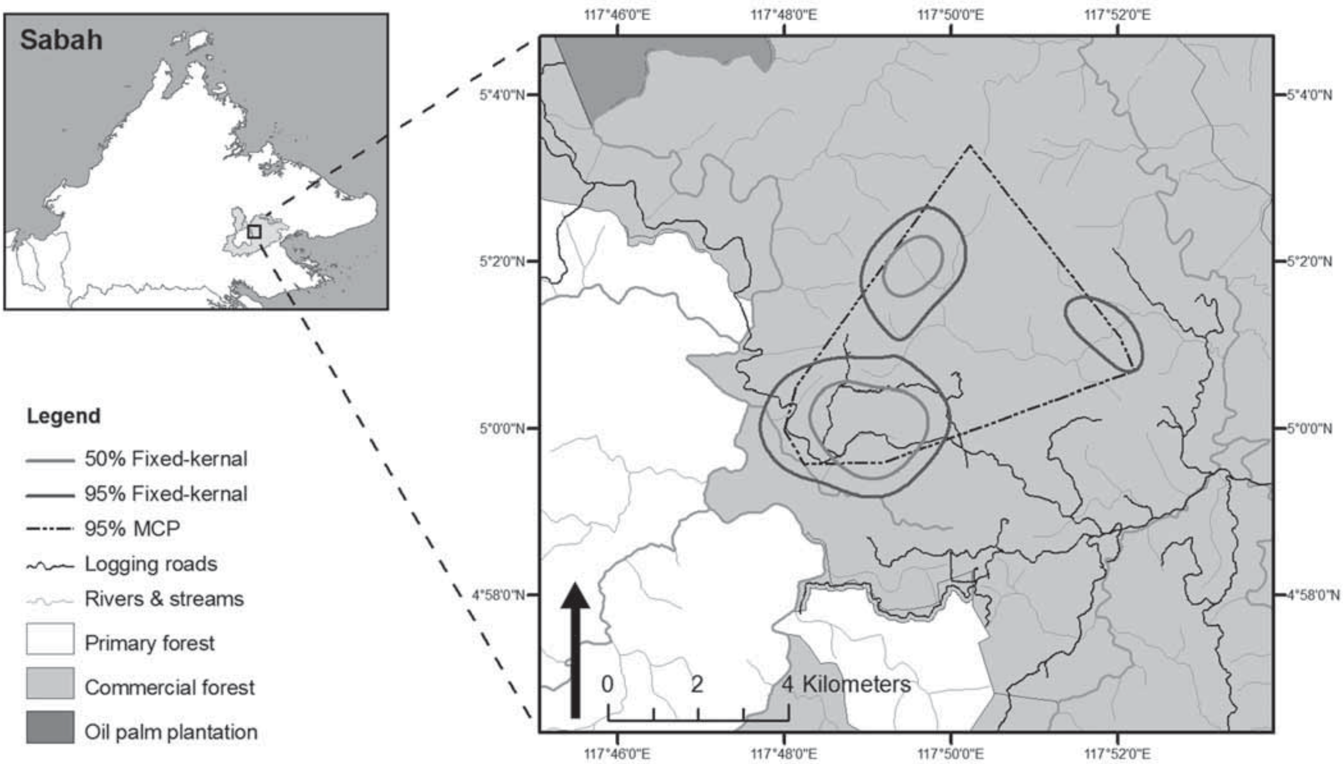

Fig. 1. Study site, showing the home-range of the Sunda clouded leopard derived from radio telemetry.

Table 2. Morphometric measurements for two wild Sunda clouded leopards from the Ulu Segama Forest Reserve in comparison with measurements for this species and *N. nebulosa* reported in the literature. SA: subadult; A: adult; F: female; M: male; HB: head-body length; T: tail length; HF: hind-foot length; HS: height at shoulder. * Discovered recently killed, as a result of a shotgun wound, along a logging road in the Ulu Segama in Nov.2007. [a] converted from the imperial measurements provided.

Specimen	Sex	Age class	Weight (kg)	HB (cm)	T (cm)	HF (cm)	HS (mm)
N. diardi							
Radio-tagged female	F	SA	12.0	87	77	14.5	380
Dead male*	M	A	23.3	104	79	20.0	510
Sealous & Banks, 1935 (Borneo)	F	A	16.8[a]	–	–	–	–
	M	SA	10.9	83	76	–	–
N. nebulosa	F	SA	10.5	86	71	15.5	–
Grassman et al., 2005 (Thailand)	F	A	13.5	82	74	15.5	–
	M	SA	12.0	99	72	18	–
	M	A	16.0	98	67	18.5	–
Austin & Tewes, 1999 (Thailand)	F	A	11.5	94	82	17.0	–
	M	A	18	108	87	18.5	–

(Grassman et al., 2005; Austin et al., 2007), whereas a camera trap study in Peninsular Malaysia found this felid to be almost exclusively nocturnal (Gumal et al., in prep). The Sunda clouded leopard, at around 11–23 kg, is significantly larger than any other sympatric predator on Borneo, and thus intraguild predation and competition are unlikely to influence their activity patterns. Instead, their activity is most likely influenced by the activity cycles of their preferred prey, as shown in other Pantherine felids (e.g., Jenny & Zuberbuhler, 2005; Harmsen et al., 2011) or otherwise reflect mechanisms to maximise hunting success. Conversely, on Sumatra the Sunda clouded leopard is sympatric with the tiger, and so we might expect the significantly smaller and thus potentially competitively subordinate, clouded leopard to minimise overlap with this felid in both space and time.

We provide some of the first data regarding the mass and body dimensions for wild Sunda clouded leopards and, in so doing, highlight the paucity of information of this kind. Further samples are required to establish the range in

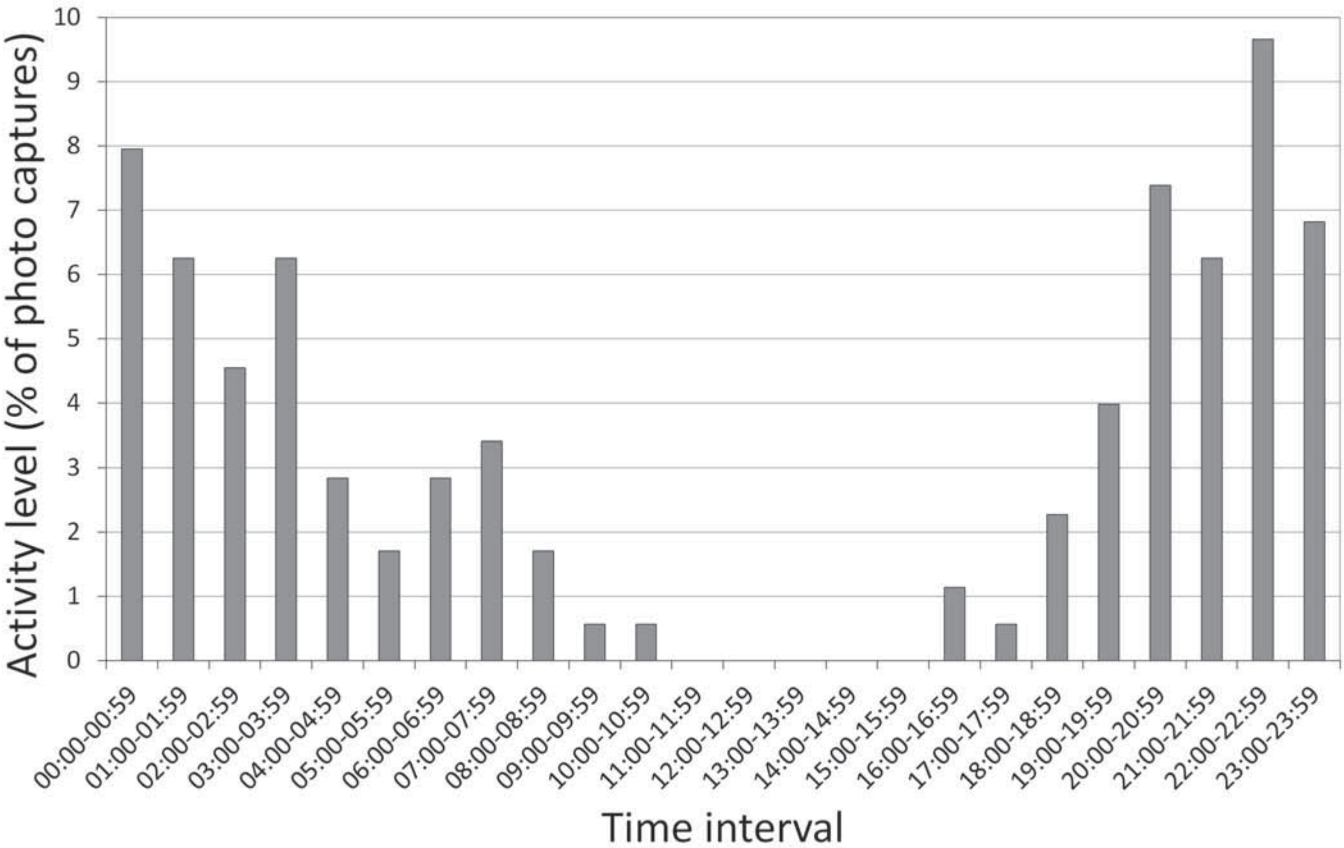

Fig. 2. Frequency distribution of hourly activity for Sunda clouded leopard based on 135 independent photo-captures.

mass and body size of both species of clouded leopard, but although speculative, these data hint at the notion that Sunda clouded leopard, or at least the Bornean sub species, *N. diardi borneensis*, may be somewhat heavier than its mainland cousin, possibly reflecting the absence of larger sympatric felids. It should be noted, however, that a comparison of 50 skulls failed to find any significant differences in size between the species (Per Christiansen, in litt).

Together these data, although preliminary, provide some of the first insights into the spatial and temporal ecology of the Sunda clouded leopard and serve to underscore the need for more intensive research of this most elusive of wild cats. A priority for future research is to investigate more fully the Sunda clouded leopard's spatial ecology and ecological needs, and to gain an insight into this felid's responses to habitat loss and disturbance and factors that influence their dispersal abilities in the increasingly fragmented forests of contemporary Borneo and Sumatra.

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LITERATURE CITED

Austin, S. C. & M. E. Tewes, 1999. Ecology of the clouded leopard in Khao Yai National Park, Thailand. *Cat News*, **31**: 17–18.

Austin, S. C., M. E. Tewes, L. I. Grassman & N. J. Silvy, 2007. Ecology and conservation of the leopard cat *Prionailurus bengalensis* and clouded leopard *Neofelis nebulosa* in Khao Yai National Park, Thailand. *Acta Zoologica Sinica*, **53**: 1–14.

Azlan, J. M. & D. S. K. Sharma, 2006. The diversity and activity patterns of wild felids in a secondary forest in Peninsular Malaysia. *Oryx*, **40**: 1–6.

Brodie, J. & A. J. Giordano, 2012. Density of the Vulnerable Sunda clouded leopard *Neofelis diardi* in a protected area in Sabah, Malaysian Borneo. *Oryx*, **46**: 427–430.

Cheyne, S. M. & D. W. Macdonald, 2011. Wild felid diversity and activity patterns in Sabangau peat-swamp forest, Indonesian Borneo. *Oryx*, **45**: 119–124.

Davis, D. D., 1962. Mammals of the lowland rainforest of North Borneo. *Bulletin of the National Museum of Singapore*, **31**: 1–29.

Grassman, L. I. Jr, M. E. Tewes, N. J. Silvy & K. Kreetiyutanont, 2005. Ecology of three sympatric felids in a mixed evergreen forest in North-Central Thailand. *Journal of Mammalogy*, **86**: 29–38.

Gumal, M., A. B. B. M. Salleh, M. N. Yasak, L. S. Horng, B. P. Y-H. Lee, L. C. Pheng, H. Hamzah, D. Kong, D. Magintan, D. T. C. Yung, A. Z. B. Zalaluddin, A. B. Azmi, N. B. Khalid, T. P. Yen, V. Mufeng, F. C. F. Meng & S. Ng, in prep. Small-medium wild cats of Endau Rompin Landscape in Johor, Peninsular Malaysia.

Harmsen, B. J., R. J. Foster, S. C. Silver, L. E. T. Ostro & C. P. Doncaster, 2011. Jaguar and puma activity patterns in relation to their main prey. *Mammalian Biology*, **76**: 320–324.

Hearn, A. J., J. Ross, R. Sollmann, H. Bernard, L. Hunter & D. W. Macdonald, in review. Can rehabilitated forest restore Sunda clouded leopards?

Jenny, D. & K. Zuberbuhler, 2005. Hunting behaviour in West African forest leopards. *African Journal of Ecology*, **43**: 197–200.

Kenward, R. E., 2001. *A Manual for Wildlife Radio Tagging*. Academic Press, London, United Kingdom.

Matsuda, I., A. Tuuga & S. Higashi, 2008. Clouded leopard (*Neofelis diardi*) predation on proboscis monkeys (*Nasalis larvatus*) in Sabah, Malaysia. *Primates*, **49**: 227–231.

Morino, L., 2010. Clouded leopard predation on a wild juvenile siamang. *Folia Primatologica*, **81**: 362–368

Nams, V. O., 2006. Locate III User's Guide. Pacer Computer Software, Tatamagouche, Nova Scotia, Canada.

Rabinowitz, A., P. Andau & P. P. K. Chai, 1987. The clouded leopard in Malaysian Borneo. *Oryx*, **21**: 107–111.

Reynolds, G., J. Payne, W. Sinun, G. Mosigil & R. P. D. Walsh, 2011. Changes in forest land use and management in Sabah, Malaysian Borneo, 1990–2010, with a focus on the Danum Valley region. *Philosophical Transactions of The Royal Society, Series B*, **366**: 3168–3176.

Santiapillai, C. & K. R. Ashby, 1988. The clouded leopard in Sumatra. *Oryx*, **22**: 44–45.

Selous, E. M. & E. Banks, 1935. The clouded leopard in Sarawak. *Journal of the Sarawak Museum*, **4**: 263–266.

Wilting, A., A. Mohamed, L. N. Ambu, P. Lagan, S. Mannan, H. Hofer & R. Sollmann, 2012. Sunda clouded leopard *Neofelis diardi* density in two used forests in Sabah, Malaysian Borneo. *Oryx*, **46**: 423–426.