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COMMUNICATION

MALE RESIDENCY OF SUNDA CLOUDED LEOPARD *NEOFELIS DIARDI* (CUVIER, 1823) (MAMMALIA: CARNIVORA: FELIDAE) IN A PEAT SWAMP FOREST, INDONESIAN BORNEO

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COMMUNICATION

Male residency of Sunda Clouded Leopard *Neofelis diardi* (Cuvier, 1823) (Mammalia: Carnivora: Felidae) in a peat swamp forest, Indonesian Borneo

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Abstract: The Sunda Clouded Leopard *Neofelis diardi* is the apex predator on the island of Borneo, yet little is known of its ecology. We document the length of residency of male Sunda Clouded Leopards in Central Kalimantan, Indonesian Borneo. Over 10 years, camera trap data have been obtained in the Sebangau peat swamp forest in a study area of ~ 105km^2. We identified 11 individuals (eight males, one female, and two with unknown sex), from 152 notionally independent photographs. On average, males remained in the study area for 39.3 months (SE 8.3), or 3.3 years (SE 0.7), ranging from less than a month of residency up to 71 months. Females were infrequently recorded, possibly as a result of human disturbance and/or high male densities. Our results reveal that even a 10-year dataset is inadequate to answer some basic ecological questions, emphasising the importance of long-term monitoring of this species.

Keywords: Camera trap, Kalimantan, male sex-bias, social organisation.

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INTRODUCTION

The rainforests of Sumatra and Borneo harbour one of the least known cat species (Allen et al. 2016): the Sunda Clouded Leopard *Neofelis diardi* (Wilting et al. 2006). This medium-sized cat weighs 11–25 kg and is thought to be adept to climbing because of its broad paws and long tail (Wilting et al. 2006). On Borneo, it occupies the role of the apex predator, being the largest of five cat species on the island (Cheyne & Macdonald 2011).

The Sunda Clouded Leopard inhabits primary and selectively logged dipterocarp forest, peat swamp forest, and mangroves (Hearn et al. 2016). Borneo's forests have been heavily affected by logging, conversion to plantations and fire since the early 1970s (Gaveau et al. 2014). This habitat loss coupled with illegal hunting of wild prey is considered a serious threat to the Sunda Clouded Leopard (Wilting et al. 2006), resulting in a decreasing population (Hearn et al. 2015). Since 2015, the Sunda Clouded Leopard is listed as Vulnerable on the IUCN Red List (Hearn et al. 2015), and rapid and efficient conservation measures are necessary.

Research effort has already increased, but studying the Sunda Clouded Leopard remains a challenge (Hearn et al. 2013). It is rare, elusive, and predominantly nocturnal (Adul et al. 2015). The increase in camera trapping for ecological studies, however, has somewhat alleviated this problem.

The Sunda Clouded Leopard is solitary, and assumed to be territorial (Allen et al. 2016), however, this assumption is based on little empirical evidence, and results of recent research indicate that home ranges of males overlap (Allen et al. 2016; Pallemaerts et al. 2019). A similar social organisation was identified in some other felid species such as Leopard Cat *Prionailurus bengalensis* (Grassman et al. 2005), Leopard *Panthera pardus* (Odden & Wegge 2005), Jaguar *P. onca* (Harmsen et al. 2009; Guilder et al. 2015), and Tiger *P. tigris* (Goodrich et al. 2010). This spatial organisation involves a combination of temporal avoidance and tolerance towards conspecifics (Grassman et al. 2005; Harmsen et al. 2009; Núñez-Pérez 2011).

We describe the residency of male Sunda Clouded Leopards that were recorded on camera trap between 2008 and 2018 in a peat swamp forest in Kalimantan, Indonesia.

STUDY AREA

We conducted this study in a portion of the 550km^2 Natural Laboratory for Peat Swamp Forest (NLPSF), nested within the tropical peat swamp forest of Sebangau in Central Kalimantan, Indonesia (Fig. 1). This area of approx. 5,600km^2 is the largest area of contiguous forest remaining in Kalimantan (Cheyne et al. 2013). The NLPSF is seasonally flooded from October to June, and is one of the deepest peat swamp forests in the world with a peat depth of 3–26 m (Page et al. 1999). The forest has a history of logging concessions, illegal logging, drainage and wildfire (Cheyne 2010; Cheyne & Macdonald 2011), but has been protected as a national park since 2004 (Cheyne 2010). Due to past exploitation and disturbance, it is a patchwork of pristine and recovering forest (Page et al. 1999).

MATERIAL AND METHODS

In May 2008, an extensive and continuous camera trap survey was started within the NLPSF. It is still running and is, therefore, the longest-running camera trap survey on Borneo. Over the years, we used six camera trap models including Cuddeback Expert, Cuddeback IR, Cuddeback Ambush IR, Maginon WK 3 HD, Crenova RD100, and Bushnell NatureView HD.

For this study, only data between May 2008 and February 2018 were used. At the start of the survey, we planned to place camera traps in a systematic grid in the study area, and this was achieved in the forest immediately surrounding the base camp (Fig. 1). Due to the difficult terrain, however, such a grid was not practical in the areas further away from base camp, and so, over the years, short expeditions were undertaken to set up several camera trap stations in areas of interest within the NLPSF, resulting in a clumped trapping grid (Fig. 1). As a result, we placed camera traps at 94 different locations between 2008 and 2018 and sampled an area of 104.8km^2 (i.e. 19.1%) of the NLPSF, as determined by the polygon formed by the outermost locations (Fig. 1). Most locations were sampled for two or three months, but sometimes 1–2 years, within this 10-year period, while other locations have been sampled almost continuously since 2008, with an average sampling duration of approximately 21 months for a single location. On average, the cameras were located at a distance of 2.7 ± 0.6 km from each other. Because of the close proximity between stations, the clumped array of cameras, and uneven distribution of sampling across our study area, we checked the independent photographs for spatial autocorrelation using Moran's index I (Sokal & Oden 1978) in ArcMap 10.3 with weights for pairs of neighbouring stations computed using the inverse distance between the respective camera trap stations. Camera trap photographs were spatially independent at all stations, with Moran's index over the entire survey period (2008–2018) being non-significant ($I = 0.043$, $p = 0.87$).

Where possible, we placed the camera traps in pairs at a distance of 7–10 m from each other, henceforth termed station, to allow for simultaneous photographs of both sides of Sunda Clouded Leopards. We installed the stations along transects, animal trails, boardwalks, natural bridges, or watering holes to maximize photographic rates. If insufficient cameras were available, they were placed singly. We deployed each camera at about 50cm above ground and protected them with a simple plastic box from rainfall and potential destruction by wildlife. In the early years of the camera trap survey, the stations were checked every two weeks to change batteries and retrieve memory cards; later, due to improvements in battery life, they were checked every 40 days.

We identified individual Sunda Clouded Leopards based on their unique coat patterns and, when possible, sexed them based on secondary sexual traits. For each individual, a capture history was made based on the number of notionally independent photographs each year (Fig. 2), where a photograph was considered notionally independent if it was taken at a different station than the previous one, or if there was at least a 10-minute interval between two photographs at the same station. We defined the residency of individual Sunda Clouded Leopards as the number of continuous months and years each individual was recorded during the entire study period and estimated it using the dates of first and last detection within the study area. We categorised an individual as resident if it was recorded for at least six continuous months, a length of time that was judged to reflect site attachment by Hemker et al. (1984) and Zimmermann et al. (2005). We categorised individuals present in the area for less than this period as transient individuals.

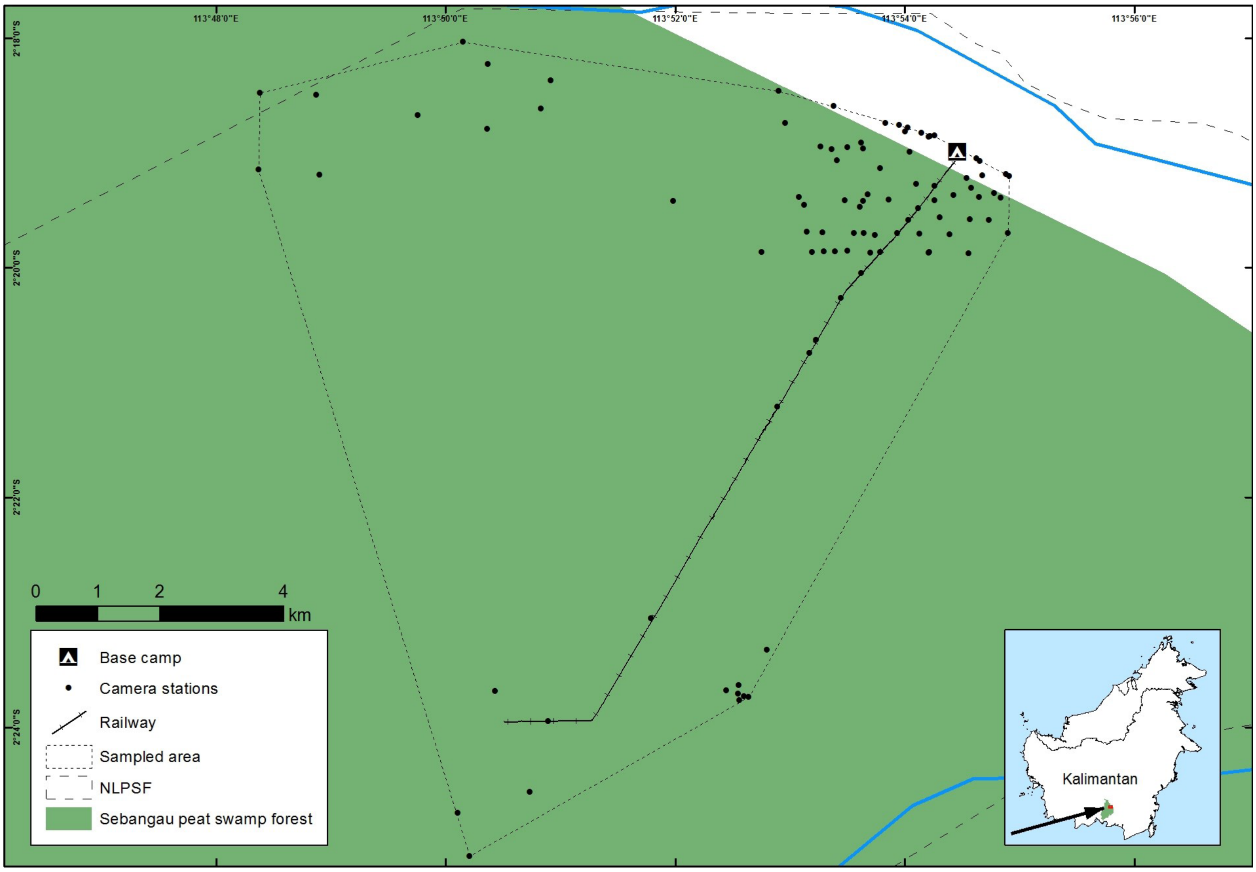

Figure 1. Study area within the NLPSF in Central Kalimantan, Indonesian Borneo.

RESULTS

During the entire study period, we obtained 152 notionally independent photographs of Sunda Clouded Leopards in more than 55,075 traps nights. Eight of these photographs were not clear enough to be attributed to any known individual, and were excluded from further analyses. From the remaining 144 independent photographs, we were able to identify 11 individuals (Table 1). Eight were male, one was female, and two could not be sexed. The number of individual photographs for individuals ranged from one to 32, with a mean at 13.1 (SE 3.7) records per individual.

Time spent living in the study area ranged from less than a month up to 71 months. We identified eight individuals that were present for at least six months in the study area, and three transient individuals. The mean residency of the eight resident individuals was 39.3 months (SE 8.3 months) or 3.3 years (SE 0.7 years) with a range of nine to 71 months. All but one residents were males.

The number of individuals present within the study area each year varied from one to five, and averaged 2.8 (SE 0.5). During one year, individuals were recorded between once and 19 times across the study area (Fig. 2). Several camera traps were visited by different males, with an average of 1.5 (SE 0.1) males visiting the same location in a six-month period.

DISCUSSION

On average, resident males seem to remain in our study area for approximately three years, before ceasing to be detected by camera traps. Short gaps in an individual's detection record may indicate that it evaded camera traps (M1 and M4), whereas longer gaps (M3 and M5) could indicate genuine periods of absence (Fig. 2). The reason for these absences are unknown. As our study area is located close to a hard border of the overall habitat, the Sebangau River, it may be possible that our camera traps were positioned at the edge of the individuals' home ranges, and short gaps in detection could indicate that the individuals spent some time in their core range.

In our study area, four males appeared to overlap (M2, M3, M4, and M5 all overlap amongst themselves; Pallemaerts et al. 2019). This suggests some combination of temporal partitioning and tolerance, as also reported for the Leopard Cat (Grassman et al. 2005) and Jaguar (Harmsen et al. 2009; Guilder et al. 2015). We did not record any instance of wounds that indicate fighting. Several photographs revealed instances of olfactory communication like urine spraying, cheek rubbing and tree scratching, all of which have been interpreted as territorial behaviour by Allen et al. (2016). They could equally function in the maintenance of temporal avoidance.

Another, more striking, result of our camera trap survey was the low detection rate of female Sunda Clouded Leopards. Over the course of 10 years, we

Table 1. Summary of all adult Sunda Clouded Leopard detections within the study area from May 2008 until February 2018. Individuals were classified as residents if they were recorded in the study area for longer than six months. One captive-born individual released in the study area was excluded from this analysis.

ID	Sex	No. of notionally independent photographs	First detection	Last detection	Residence (months)	Status
M1	M	9	3.vii.2008	28.vii.2011	36	Resident
M2	M	29	14.viii.2008	25.xii.2011	40	Resident
M3	M	20	4.xi.2009	29.x.2015	71	Resident
M4	M	32	3.xi.2009	20.viii.2015	69	Resident
M5	M	29	26.x.2013	25.i.2018	51	Resident
M6	M	3	14.ii.2014	14.ii.2014	0	Transient
M8	M	11	6.xi.2014	5.xi.2016	24	Resident
M9	M	3	9.x.2016	8.xii.2017	14	Resident
F1	F	2	8.x.2009	9.x.2009	0	Transient
ID1	?	1	5.x.2014	5.x.2014	0	Transient
ID2	?	5	25.xii.2013	8.ix.2014	9	Resident

M—male | F—female | ?—unknown sex.

Image 1. Cumulus (M3), the longest resident male Sunda Clouded Leopard in our study area. He stayed in the NLPSF for 71 months. © Susan M. Cheyne

Image 2. Nimbus (F1), the only female photographed by camera traps in the NLPSF between 2008 and 2018. © Susan M. Cheyne

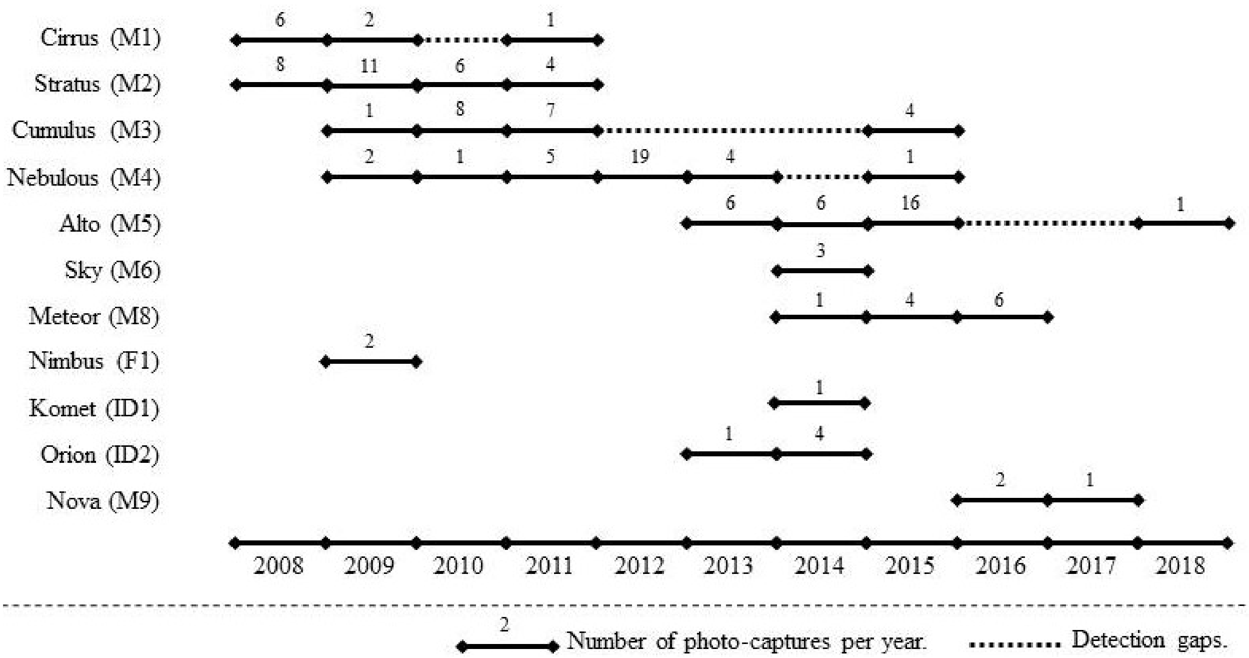

Figure 2. Residency of all Sunda Clouded Leopards identified within the NLPSF. The numbers above each line indicate the number of independent captures during the respective year. Dotted lines indicate gaps in the captures of individuals.

were able to identify only one female, namely F1 (Image 2). This male-biased detection is recurrent in studies on both Sunda Clouded Leopard and mainland Clouded Leopard *Neofelis nebulosa* (Cheyne & Macdonald 2011; Wilting et al. 2012; Cheyne et al. 2013; Sollmann et al. 2014; Mohamad et al. 2015; Hearn et al. 2017), and has been noted for the Jaguar (Harmsen et al. 2009) and the Leopard (Gray & Prum 2012) as well. To date, only Borah et al. (2014) reported a more balanced detection of both Leopard and mainland Clouded Leopard females and males, based on a camera trapping design that covered the 300km^2 large study area homogeneously. The lack of photographs of females may be due to their spending more time in trees (Wilting et al. 2012) and avoiding trails and forest edges, which may affect their detectability (Cheyne et al. 2013). Adult female Sunda Clouded Leopards weigh only half as much as adult males (Nájera et al. 2017), adding to the likelihood of niche separation (Quentin Phillipps pers. comm. 10 September 2018). While there is no evidence to date that Sunda Clouded Leopards move in the canopy, there have been reports of them hunting in trees (Matsuda et al. 2008; Wilcox et al. 2016). We recommend to place camera traps in a systematic grid to enhance the chances for a more balanced representation of both sexes of the Sunda Clouded Leopard in future studies. The possibility of spatial segregation between females and males, and their different exposure and reactions to disturbance, are all factors relevant for planning adequate conservation measures, and thus merit further investigation.

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