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Ranging behaviour, spatial organization and activity of the Malay civet (*Viverra tangalunga*) on Buton Island, Sulawesi

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Abstract

To compare the morphometrics and ranging behaviour of the Malay civet *Viverra tangalunga* on Sulawesi with published data on Malay civets on Borneo, a trapping and a radio-telemetry study was carried out in the Kakenauwe and Lambasango Forest Reserves on Buton Island, Sulawesi. From June to September in 2001, 2002 and 2003, we obtained morphometric measurements from 32 Malay civets captured in box traps. Ten civets were radio-collared and home-range size, minimum daily distance travelled and diel activity patterns were estimated. The mean overall capture rate was one capture per 32 trap-nights. Trap capture rate varied between study sites, but there was no difference in trappability between sexes. Adult male civets were heavier, had larger neck circumferences and longer hind feet than adult females. Both sexes on Buton Island were found to have significantly smaller body sizes than their counterparts on Borneo. The mean home-range size for adult civets was 70 ha, with a mean overlap of 4.0% between ranges. The home ranges of female civets on Buton were smaller than those in logged forests on Borneo. Malay civets were most active at night from 18:00 to 07:00 h, during which the mean activity was 94%. There was no difference in the minimum distance travelled by both sexes during a 24 h period. All rest sites were situated at ground level and were associated with dense cover.

Introduction

Sulawesi has an impoverished mammalian carnivore fauna (Musser, 1987) comprising just three species of civet: the endemic Sulawesi palm civet *Macrogalidia musschenbroekii* and two introduced species – the Malay civet *Viverra tangalunga* and common palm civet *Paradoxurus hermaphroditus* (Suyanto *et al*., 1998; Veron, 2001; Lee *et al*., 2003).

The Malay civet is found on the Malay Peninsula, Sumatra, Borneo, Sulawesi, Maluku Islands and the Philippines (Corbet & Hill, 1992; Kanchanasakha, Simcharoen & Than, 1998; Suyanto *et al*., 1998) where it occurs in a wide variety of habitats including forests, secondary habitats, cultivated land and the outskirts of villages (Wemmer & Watling, 1986; Nowak, 1999). Malay civets are solitary, omnivorous and are primarily terrestrial (Kanchanasakha *et al*., 1998). The Malay civet was introduced to several islands throughout South-east Asia, including Sulawesi, to be farmed for *civetone* (a substance that was commonly used commercially in producing perfume) or to control rodent populations (Nowak, 1999). Although the Malay civet is a widespread species, little is known about its natural history and ecology in countries where it is native or has been introduced. A number of field studies have been conducted on Borneo (Macdonald & Wise, 1979; Nozaki *et al*., 1994; Heydon & Bulloh, 1996; Colon, 2002), where it comprises part of a much wider carnivore assemblage (22 species), including eight species of civets (Suyanto *et al*., 1998).

The aim of this study was to compare the morphometrics and ranging behaviour of the Malay civet on Buton Island, Sulawesi, in an area where no other mammalian carnivore species were known to exist (with the possible exception of *M. musschenbroekii*), with published data on Malay civets on Sabah, Borneo, where this species is a member of a larger carnivore guild.

Study area

Sulawesi lies in the centre of the Wallacea Biogeographical Zone, a region bounded by deep ocean trenches. It has remained isolated from the Asian and Australasian continents, even when the sea levels dropped during the last Ice Ages (Musser, 1987). This severely restricted the dispersal of animal and plant species across continents, resulting in many unique species evolving in the region, for example over 90% of the small mammal fauna is endemic to Sulawesi (Musser, 1987).

Buton Island lies off the south-east coast of Sulawesi and is *c*. 100 km long and 42 km wide at its widest point. The altitude ranges from 0 to 200 m around the coast, up to 400 m along the spine of the island, rising to 1000 m on isolated peaks. Buton has a tropical monsoon climate with a dry season from June to September (Whitten, Mustafa & Henderson, 2002).

The mean annual rainfall is 1500–2000 mm, peaking between April and June (Whitten *et al*., 2002).

Research was carried out within the Kakenauwe and Lambasango Forest Reserves, central Buton Island (5°10′S, 122°54′E) (Fig. 1). These reserves comprise lowland forest on karst coral limestone of Quaternary age. Agricultural areas outside the reserves are alluvial in nature (J. Milsom, pers. comm.). Sulawesi forests are not dominated by any one tree family (Whitten *et al*., 2002). Within these reserves there was considerable variation in the major tree species and families found at different sites (G. O'Donovan, pers. comm.), and there was some evidence of disturbance from local selective logging and rattan collection.

Within the two Forest Reserves, two study sites were selected: the Kakenauwe study area (KSA, 700 ha) and the Lambasango study area (LSA, 1000 ha) (Fig. 1). The KSA was located north of the Kaweli–Labundo road and included part of the Kakenauwe Forest Reserve and adjacent cultivated land. It also encompassed a 1 km^2 sample grid, with way-marked cross trails cut at 100 m intervals, and a number of trails that ran through the KSA to adjacent farmland areas. The major crops are rice and coconut, plus fruit and vegetables such as banana, sweet potato, cassava and papaya (N. E. C. Priston, pers. comm.). The LSA was located south of the Kaweli–Labundo road and included part of the Lambasango Forest Reserve and intervening disturbed forest. During each field season, camp Lapago was set up along a river within the LSA, *c*. 4.5 km south of the Kaweli–Labundo road.

The study areas had an elevation range between 40 and 360 m. To the east of the study areas was the village of Labundo Bundo, and along the western and eastern edges of the Kakenauwe Forest Reserve were agricultural/open field areas.

Methods

This study was carried out during the dry season months of June–September, in 2001, 2002 and 2003. In 2001 and 2002, two small (76 × 27 × 25 cm) and five large (140 × 40 × 40 cm) wire-box traps were opportunistically set at 42

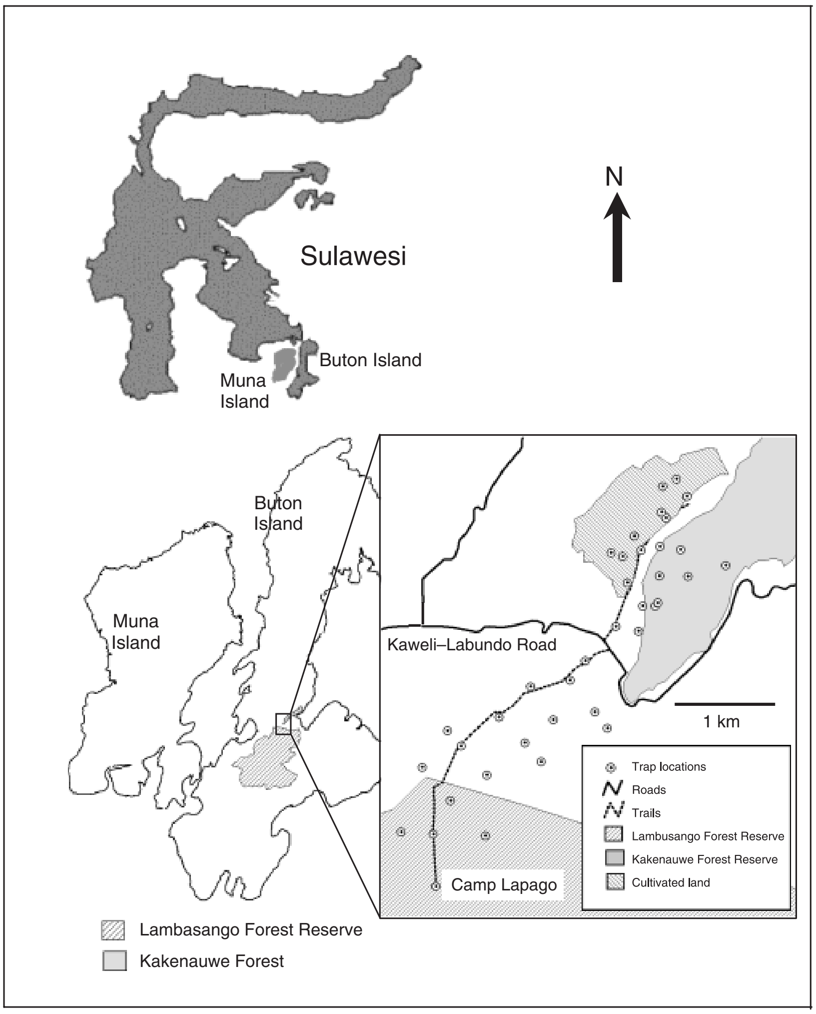

Figure 1 Map showing the location of the study sites in Buton Island, south-east Sulawesi. The Kakenauwe study area is located north of the Kaweli–Labundo road, and the Lambusango study area is located south of the Kaweli–Labundo road.

locations in the forest throughout the KSA. In 2003, an intensive trapping programme was undertaken using 34 large-sized traps. Fifteen traps were set in 20 locations in the KSA, including six in cultivated land, four on the forest boundary and 10 in the forest (Fig. 2). Nineteen traps were also set on a trapping grid in the LSA, with trap sites spaced at *c.* 500 m intervals. The shape and size of this grid were limited by steep terrain.

Traps were positioned on level, dry ground at the base of large trees and alongside fallen trees. They were completely covered by woody debris and the trap floor was covered with soil and leaf litter to maintain substrate continuity with the surrounding ground. Domestic cat food or salted fish was used as bait and placed at the back of the trap. In 2001 and 2002, civet oil and fish oil (Minnesota Trapline Products, Pennock, MN, USA) were placed high up on prominent tree branches around the trap site to act as scent lures. Traps were checked twice a day (in the morning and afternoon).

In order to reduce trauma during immobilization, a 'squeeze panel' was used to restrict the civet's movements inside the cage. When the animal was pressing against the cage, it was injected intramuscularly with a mixture of Ketaset (Ketamine HCl, Parke, Davis & Co., Detroit, MI, USA) and Rompum (Xylazine HCl, Bayer). Most civets were ataxic within 5 min and remained so for at least 20 min. While under anaesthetic the civets were weighed, measured and radio-collared. The sex and age of each animal was determined based on the body size and the condition of the teeth. The age categories were: juvenile (not full size and milk teeth present), young adult (almost full size but not sexually mature), adult (full size and showing signs of reproductive activity) and old adult (full size and pronounced tooth wear). Reproductive status was determined by checking the condition of the nipples in females and testes in males. The following body measurements were taken (Wilson *et al.*, 1996): head and body length, tail length, neck circumference, right ear length, hind foot length (excluding claws), fore-footpads (length and width), and right canine length (upper and lower). Coloured plastic tags (Rototags, Dalton, Henley-on-Thames, Oxfordshire, UK) were clipped onto both ears. Selected individuals were fitted with transmitters (MOD-80, Telonics, Mesa, AZ, USA) on a butyl collar incorporating a whip-antenna (mean total weight 58 g). Each transmitter had an operational life of 6 months and was fitted with activity sensors (S6B) that caused a reduction in pulse frequency when the animal was inactive. All animals were placed back into the trap and allowed to recover fully for 2–3 h before being released.

Radio-collared civets were tracked each day using TR-4 receivers and two-element RA-14 antennas (Telonics). During the initial trapping phase, transmitters were used to assess the accuracy of radio fixes in the study area. These were placed in various known locations within the study area and compass bearings were taken on them from different places along the grid/trail network. This enabled us to determine the maximum acceptable level for error ellipses around location fixes.

At least three bearings from known positions along the grid/trail network were taken from each tagged animal, using a sighting compass. A maximum of 5 min between

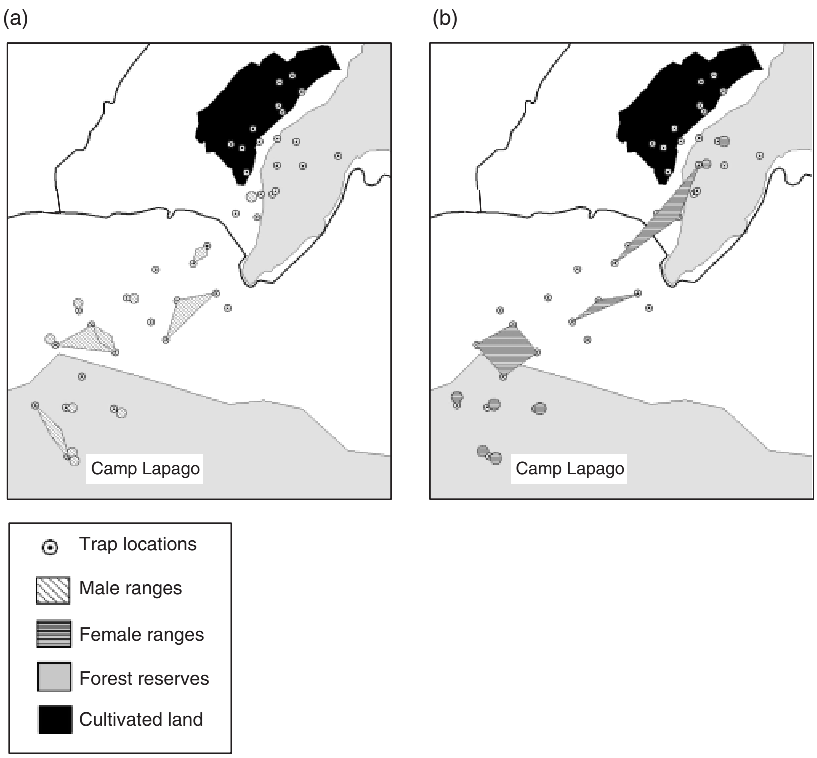

Figure 2 Trap ranges of Malay civets *Viverra tangalunga* captured in 2003 in the Kakenauwe and Lambasango study areas: (a) males and (b) females. The trap range of individuals caught in only one trap location is represented by a circle next to the trap site. The trap range of individuals caught in more than one trap is represented by a polygon between capture locations.

successive bearings was allowed in order to minimize location errors because of an animal's movement. These bearings were first plotted onto field maps to check for signal bounce. Bearings that appeared erroneous were eliminated from the data set.

Activity was determined based upon signal integrity and pulse frequency. An animal was recorded as 'active' if the signal rate was 75 pulses per minute (ppm) and there was fluctuation in the signal strength. An animal was recorded as 'inactive' if the pulse frequency was 45 ppm and the signal strength was steady. Continuous monitoring of each animal's activity over 8–12 h periods was also undertaken whenever possible. During this period, an animal's activity was recorded every 15 min (Colon, 1999). A few 'walk-ins' were attempted on inactive animals to investigate rest sites.

At the end of each study period, traps were deployed to recapture and remove radio-collars from tagged civets (ear tags were not removed). All animals were in good health and showed no sign of injury or irritation from the radio-collar.

Compass bearings were entered into the computer program LOAS (Version 2.06, Ecological Software Solutions, www.ecostats.com) to generate location fixes and error ellipses. Fixes with error ellipses greater than 1 ha were rejected. Location fixes were then imported into RANGES V computer software (Kenward & Hodder, 1996) for home-range analysis. Home-range sizes were calculated using the minimum convex polygon method (MCP) using 100 and 95% of all fixes. This method was chosen to allow for comparisons with other field studies. Activity data were grouped into 1 h blocks over a 24 h time period and expressed as the proportion of active fixes. Animal daily displacements were estimated by measuring the linear distance between consecutive 24 h radio locations. Because of the non-linear route followed by collared animals, the actual distances covered between consecutive days were greater than expected. The 2003 data were analysed to determine trap ranges and spatial and temporal patterns of civet capture. The trap range of an individual was defined as the area between capture locations for multiple captures or the immediate vicinity of a trap for single captures. For all parametric tests, the assumptions of normality and homoscedasticity were tested prior to the analysis. A significance level of ≤ 0.05 was used. Comparisons between means were made using independent *t*-tests or Mann–Whitney *U*-tests with SPSS for Windows (Version 11.0). All means are presented with $\pm$ standard deviation.

Results

Morphometrics

Thirty-two Malay civets were captured, examined and measured (Table 1). The mean weight of adult civets was 3.78 ± 0.36 kg (males $= 3.98 \pm 0.36$ kg, $n = 10$; females $= 3.57 \pm 0.22$ kg, $n = 9$). Adult males were significantly heavier than adult females ($t = 2.9$, d.f. $= 17$, $P < 0.05$). Adult males also had significantly larger neck circumferences ($t = 4.6$, d.f. $= 17$, $P < 0.005$) and longer hind foot lengths than adult females ($t = 2.4$, d.f. $= 17$, $P < 0.05$).

The morphometrics of adult Malay civets in Buton were compared with those recorded for captured civets in Sabah, Borneo (Colon, 2002). Table 2 provides a summary of the morphometrics recorded for adult Malay civets in Borneo. Males in Buton had significantly shorter head and body lengths ($t = 3.3$, d.f. $= 17$, $P < 0.05$), tail lengths ($t = 2.5$, d.f. $= 17$, $P < 0.05$), and hind foot lengths ($t = 2.6$, d.f. $= 17$, $P < 0.05$) than males in Borneo. Females on Buton had significantly shorter head and body lengths ($t = 4.2$, d.f. $= 15$, $P < 0.005$) and tail lengths ($t = 2.4$, d.f. $= 15$, $P < 0.05$) than females in Borneo. However, there was no difference in weight within sexes among civets from Borneo and Buton (males: $t = 1.8$, d.f. $= 17$, $P = 0.1$; females: $t = 0.1$, d.f. $= 15$, $P = 0.9$).

Capture rates

The overall mean capture rate was one civet per 32 ± 16 trap-nights (Table 3). The overall trap capture rate in the KSA averaged one capture per 35 ± 12 trap-nights and one capture per 27 ± 27 trap-nights in the LSA (Table 3). In 2003 civets were caught in the KSA forest at a rate of one capture per 24 trap-nights (six captures in 143 trap-nights), whereas the trap rate in the LSA forest was one capture every eight trap-nights (48 captures in 397 trap-nights). This difference in capture rate was significant (Mann–Whitney test, $U = 46$, $n = 39$, $P < 0.001$).

Spatial patterns of civet capture

In 2003, none of the 10 traps set in the cultivated land of KSA caught any civets, even after 110 trap-nights (Fig. 2). Five civets were caught in four of the 10 traps located in the adjacent forest. In the LSA all but two of the 19 traps caught at least one civet. Both of the unsuccessful traps were located in particularly steep terrain. Among traps that caught adult civets, 87% captured one individual of either sex and 13% captured more than one individual of either sex. Recaptures were highly clustered and usually occurred in a trap adjacent to the initial capture location. Only one civet (F08) was recaptured in a non-neighbouring trap.

The trap ranges of two adult male civets (M10 and M12) and two adult females (F06 and F07) overlapped at camp Lapago (see Fig. 2). The trap ranges of two adult females (F08 and F10) overlapped in the KSA. There were insufficient capture data to determine whether the occurrence of same-sex adult civets in traps was dependent on one another. However, the distributions of males and females in traps were independent (Fisher exact test: $P = 0.7$).

Temporal patterns of civet capture

In 2003, the average time from trap placement to first capture was 5.9 ± 5.0 nights (range = 0–21 nights). There was no significant difference in time to first capture for males (mean $= 7.7 \pm 6.9$ nights) and females (mean-4.9 ± 3.8 nights) ($t = 1.7$, d.f. $= 14$, $P = 0.3$). The quickest

Table 1 Morphometric data collected from captured Malay civets *Viverra tangalunga* in the Kakenauwe and Lambasango study areas, Buton Island, Sulawesi

Civet	Sex	Age	Weight (kg)	Head-body length	Tail length	Neck circumference	Right hind foot length	Right ear length	Right forepaw length	Right forepaw width	Upper right canine length
M01	M	Adult	3.75	60.0	31.0	20.8	10.0	4.8	3.8	3.0	1.1
M02	M	Old adult	4.25	61.0	30.5	21.5	10.5	3.7	3.0	3.7	0.3
M03	M	Adult	3.75	57.5	29.5	21.0	10.0	4.5	3.3	3.8	0.8
M04	M	Adult	3.75	62.0	31.5	20.0	9.8	4.2	3.0	3.5	0.9
M05	M	Adult	4.50	65.5	32.0	22.5	10.4	4.1	3.5	4.0	1.3
M08	M	Adult	4.25	61.0	35.0	22.0	10.0	4.3	3.5	3.3	0.6
M09	M	Adult	3.75	61.0	29.5	19.5	10.2	2.5	3.1	2.9	0.9
M10	M	Adult	4.50	60.0	31.0	22.0	10.5	3.7	3.4	3.3	0.8
M12	M	Adult	3.75	55.0	31.0	21.0	9.5	3.0	3.0	3.4	0.7
M18	M	Adult	3.50	60.0	29.0	20.0	10.0	3.5	3.6	3.1	1.0
Mean			3.98	60.3	31.0	21.0	10.1	3.8	3.3	3.4	0.8
F02	F	Adult	3.75	64.0	30.2	19.0	9.7	4.4	4.0	3.5	1.0
F03	F	Adult	3.50	63.0	30.5	18.0	9.8	4.4	3.5	3.8	0.9
F04	F	Old adult	3.50	58.7	27.3	18.8	8.2	4.2	3.0	3.5	0.4
F06	F	Adult	3.50	58.0	30.0	19.2	10.0	3.5	3.1	3.2	1.0
F07	F	Adult	3.75	59.0	32.0	19.0	9.6	3.2	3.5	3.5	0.6
F08	F	Adult	3.50	54.0	31.0	20.0	10.0	3.8	3.0	3.4	0.9
F10	F	Adult	3.75	58.0	32.0	20.6	10.0	3.8	3.7	4.2	1.1
F12	F	Adult	3.75	61.0	30.0	19.0	9.6	3.5	3.0	3.4	1.0
F14	F	Old adult	3.10	56.0	26.0	19.0	9.6	3.9	3.3	3.4	0.3
Mean			3.57	59.1	29.9	19.2	9.6	3.9	3.3	3.5	0.8
M07	M	Young adult	3.50	58.0	28.0	19.0	9.5	3.5	3.0	2.7	1.0
M11	M	Young adult	3.25	57.0	30.0	20.0	9.6	3.8	2.9	2.9	0.6
M13	M	Young adult	3.25	60.0	30.0	19.6	9.7	4.1	2.5	2.5	0.7
Mean			3.33	58.3	29.3	19.5	9.6	3.8	2.8	2.7	0.8
F05	F	Young adult	3.00	53.0	30.0	17.0	10.0	4.0	3.1	2.4	Missing
F11	F	Young adult	3.25	60.0	28.5	18.0	10.0	4.0	3.0	3.1	Missing
Mean			3.13	56.5	29.3	17.5	10.0	4.0	3.1	2.8	–
M06	M	Juvenile	1.50	48.5	12.2	14.3	8.8	4.0	2.5	2.5	0.4
M14	M	Juvenile	1.50	44.0	–	–	8.0	–	–	–	–
M15	M	Juvenile	0.30	35.0	19.0	8.0	7.5	3.8	2.1	2.4	0.4
M16	M	Juvenile	1.00	42.0	23.0	12.0	8.0	3.3	2.4	2.6	0.5
M17	M	Juvenile	1.00	40.0	18.0	–	–	–	–	–	–
Mean			1.06	41.9	18.1	11.4	8.1	3.7	2.3	2.5	0.4
F01	F	Juvenile	2.30	51.0	26.5	14.0	9.2	4.3	3.0	2.7	0.5
F09	F	Juvenile	2.75	57.0	29.0	19.0	9.8	4.0	3.1	3.2	0.7
F13	F	Juvenile	2.70	58.0	30.0	19.0	10.0	4.0	2.6	3.4	0.8
Mean			2.73	57.5	29.5	19.0	9.9	4.0	2.9	3.3	0.8

All measurements are in centimetres.

captures occurred in the traps set in the vicinity of camp Lapago in the LSA.

Individual civets were trapped up to seven times (mean- 2.0 ± 1.4 captures). There was no significant difference between the mean number of times captured for males (mean $= 1.7 \pm 0.8$ captures) or females (mean $= 2.5 \pm 1.9$ captures) ($t = -1.5$, d.f. = 24, $P = 0.2$). The mean time between subsequent recaptures was 9.1 ± 6.7 nights. The mean time to recapture was less for females (mean- 8.5 ± 8.1 nights) than males (mean $= 10.2 \pm 3.0$ nights), but this difference was not significant ($t = 0.7$, d.f. = 18, $P = 0.5$). Seventy per cent of adult females ($n = 10$) and 87% of adult males ($n = 8$) were caught more than once in the same or neighbouring traps, or re-sighted, or radio-tracked in the vicinity of the capture site. Although the 2003 trapping season started on 5 July, the first juvenile civet was not caught until 11 August. Juveniles were observed in the vicinity of camp Lapago throughout mid and late August.

Home ranges

Eight civets (four adult males, three adult females and one young adult female) were radio-collared in the KSA and two civets (one adult male, one adult female) were radio-collared in the LSA. Sufficient data to calculate home ranges were collected for the eight radio-tracked civets in the KSA

Table 2 Mean body measurements of adult Malay civets *Viverra tangalunga* captured in a logged forest in Sabah, Borneo (taken from Colon, 2002)

Sex	*n*	Weight (kg)	Head- body length	Tail length	Neck circumference	Right hind foot length	Right ear length	Upper right canine length
Males	9	3.73	66.6	32.8	20.4	10.5	3.6	0.9
Females	8	3.55	64.2	31.9	18.9	10.0	3.6	1.0

All measurements are in centimetres.

Table 3 Trapping effort and capture rates (average number of trap-nights to catch one animal) of Malay civets *Viverra tangalunga* in the Kakenauwe and Lambasango study areas in 2001, 2002 and 2003

		Trap effort (trap-nights)		Captures		Capture rate	
Year	Number of traps	KSA	LSA	KSA	LSA	KSA	LSA
2001	7	193	–	9	–	21	–
2002	7	160	92	4	2	40	46
2003	34	258	397	6	48	43	8

KSA, Kakenauwe study area; LSA, Lambasango study area.

Table 4 Home-range sizes (100 and 95% MCP) of eight Malay civets *Viverra tangalunga* radio-tracked in the Kakenauwe study area in 2001, 2002 and 2003

Civet	Sex	Age	100% MCP (ha)	95% MCP (ha)	Locations
F01	Female	Young adult	18	13	35
F02	Female	Adult	71	60	30
F03	Female	Adult	28	24	27
F10	Female	Adult	109	66	34
M01	Male	Adult	39	37	34
M03	Male	Adult	197	189	28
M04	Male	Adult	49	43	59
M05	Male	Adult	84	76	31

MCP, minimum convex polygon method.

(Table 4). All home-range sizes reached an asymptote after 27 fixes. Figure 3 shows the home-range polygons (95% MCP) for the eight Malay civets within the KSA. The mean home-range size (95% MCP) was 86 ± 71 ha for adult males ($n = 4$) and 50 ± 23 ha for adult females ($n = 3$). There was no significant difference between male and female home-range sizes ($t = -0.8$, d.f. = 5, $P = 0.4$), and the mean home-range size for all adult civets was 70 ± 55 ha. In a logged forest in Borneo, the mean home-range size (95% MCP) was 159 ± 111 ha for adult males ($n = 3$) and 105 ± 20 ha for adult females ($n = 3$) (Colon, 2002). The home-range sizes of male civets within the KSA were not significantly different from the home-range sizes of male civets in logged forests in Borneo ($t = -1.1$, d.f. = 5, $P = 0.3$). However, the home-range sizes of adult female civets within the KSA were significantly smaller than those of female civets in logged forests in Borneo ($t = -3.2$, d.f. = 4, $P < 0.05$).

The mean overlap of contemporary home ranges was 0.0 ± 0.0% among females and 7.9 ± 5.1% among males. The female range overlap was significantly smaller than the male range overlap ($t = 3.1$, d.f. = 6, $P < 0.05$). The mean home-range overlap for all tagged civets was 4.0 ± 5.4%.

Activity, movement and rest sites

A total of 1701 activity readings was recorded from 10 civets (five males, five females). Figure 4 shows the activity data for all civets grouped into 1 h blocks over a 24 h time period. Malay civets were significantly more active from 18:00 to 06:59 h (mean = 94.0 ± 9.6% of active fixes) compared with 07:00–17:59 h (mean = 57.7 ± 9.1%) ($t = -9.5$, d.f. = 22, $P < 0.0001$). During the night, there was a noticeable drop in activity from 02:00 to 03:59 h and in the daytime there was a peak in activity from 12:00 to 13:59 h (Fig. 4). The mean overall activity for males (77.5 ± 20.9%) was not significantly different from that of females (78.4 ± 26.2%) ($t = -0.1$, d.f. = 44, $P = 0.9$).

The mean minimum distance covered during a 24 h period was 415 ± 99 m for males ($n = 4$) and 286 ± 157 m for females ($n = 4$). There was no significant difference in the minimum movement distances between males and females ($t = -1.4$, d.f. = 6, $P = 0.2$).

Six rest sites were found for three individual civets (one male, two females). All were situated at ground level and were associated with some form of cover such as logs, dense brush pile, or thick herbaceous vegetation. Each rest site was accessible from all directions and none were communal.

Discussion

Morphology

Male and female Malay civets in Buton Island were found to have significantly smaller body sizes than their counterparts in Borneo. In addition, we found evidence of increased sexual dimorphism in civets on Buton Island: there was a significant difference in weight between adult males and females that was not found on Sabah. On the Sabah study site, there are eight species of sympatric civet (Heydon & Bulloh, 1996). Two of these species, the common palm civet and the banded palm civet *Hemigalus derbyanus*, are at least

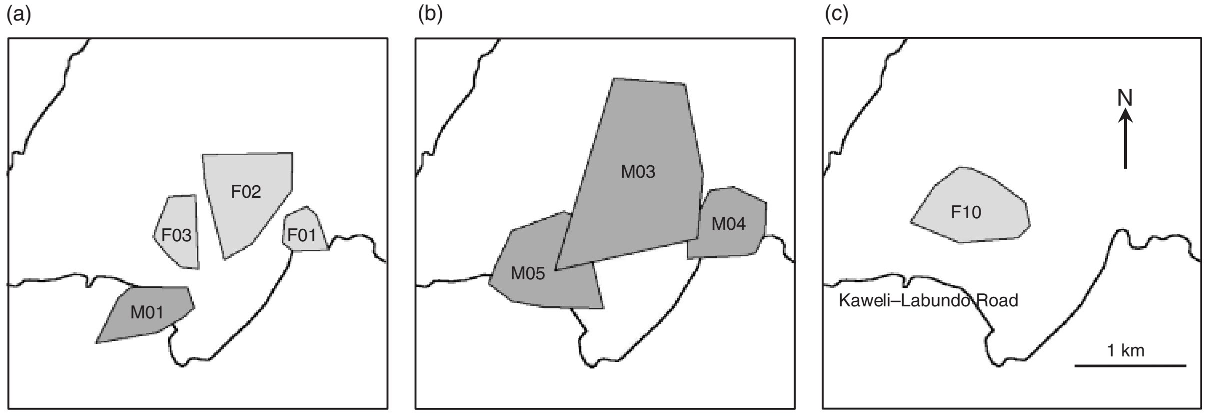

Figure 3 Home-range polygons (95% minimum convex polygon method) of eight Malay civets *Viverra tangalunga* (four adult males, three adult females and one young adult female) radio-tracked in the Kakenauwe study area in (a) 2001, (b) 2002 and (c) 2003.

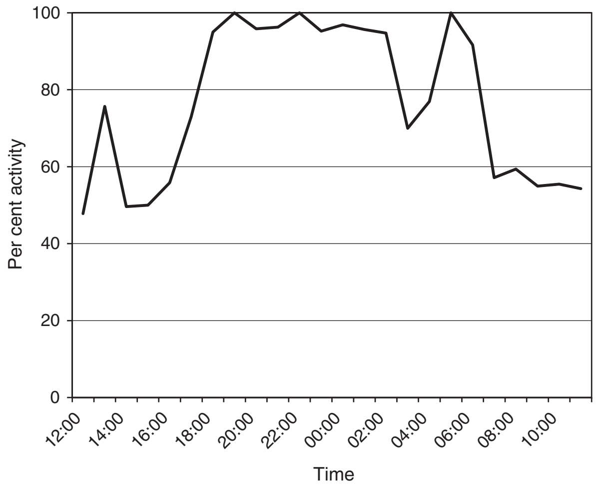

Figure 4 Mean per cent activity levels of 10 Malay civets *Viverra tangalunga* radio-tracked in Kakenauwe and Lambasango Forest study areas in 2001, 2002 and 2003. Dawn occurred at around 06:00 h and dusk at around 18:00 h.

partially terrestrial like the Malay civet, hunt similar types of prey (Nowak, 1999), and occur in fairly high densities (Heydon & Bulloh, 1996). In Buton, there are no such competitors, with the possible exception of *M. musschenbroekii*, which, if present, exists at low densities. These observed morphological differences may be explained in terms of competitive release (e.g. Dayan & Simberloff, 1994). Competitive release has been used to explain morphological differences in the small Indian mongoose *Herpestes javanicus* in areas of allopatry (including islands where introduced) and sympatry with congeneric species (Simberloff *et al*., 2000). However, there are at least six criteria for demonstrating competitive release (Schluter & McPhail, 1992), and we have insufficient data to support many of these. In particular, we cannot demonstrate that the observed morphological differences are related to differences in food acquisition, or that there is a genetic basis for the observed morphological differences. Many explanations for size differences between populations on islands and mainlands have been proposed (e.g. Lomolino, 1985; Dayan & Simberloff, 1998), and further data are required to evaluate these competing hypotheses.

Home ranges and spatial organization

Male spatial organization in solitary carnivores is influenced by two factors: the dispersion of food and/or females (Sandell, 1989). If feeding ranges are minimized and mating ranges are maximized in males, it follows that male ranges should be larger than predicted by energy requirements (Sandell, 1989). In this study, the home ranges of males were not significantly larger than those of females even though males were heavier than females and presumably had higher energy demands (McNab, 1989). However, if females were providing for dependent young during the period of June–September, their energy requirements and hence home ranges would be greater than expected from their body size (Oftedal & Gittleman, 1989; Sandell, 1989). The capture of post-lactating adult females and several juvenile civets during June–September suggested that female civets may have had dependent young during the study periods.

A wide range of home-range sizes for Malay civets has now been documented in both Buton (24–189 ha) and Borneo (27–283 ha) (Macdonald & Wise, 1979; Nozaki *et al*., 1994; Colon, 2002). This perhaps reflected a difference in habitat quality and food availability across and between the different study areas. Colon (2002) found that the population density of Malay civets in a logged forest was lower than that in an unlogged forest and suggested that this may be because of lower fruit availability in the logged forest. A wide range of home-range sizes has been found for common palm civets at different study sites in Nepal and Thailand (Dhungel & Edge, 1985; Rabinowitz, 1991; Joshi, Smith & Cuthbert, 1995; Grassman, 1998), and this was thought to be because of differences in habitat productivity (Joshi *et al*., 1995; Grassman, 1998).

The home-range sizes of adult female civets within the KSA were significantly smaller than those of female civets in logged forests in Borneo. This suggests that female civets were more sensitive to any difference in food resources between these two sites. The lack of interspecific interference and/or competition for food from other mammalian carnivore species on Buton may result in an increased prey base available for Malay civets in Buton, allowing females to meet their daily energy requirements within smaller home ranges. However, other animal species present in Buton may be potential competitors for food such as the Buton macaque *Macaca ochreata*, reticulated python *Python reticulates*, monitor lizard *Varanus salvator* or Sulawesi serpent-eagle *Spilornis rufipectus*. The lack of significant difference in home-range size between males on Buton may be a result of small sample sizes. Also, these are only dry season ranges and do not necessarily reflect year-round ranges, which may be very different because of seasonal changes or food availability, although Colon (1999) found that Malay civet home ranges were not affected by rainfall in her study area.

There was a high turnover of adult civets within the study areas in Buton (only 36% of adult civets tagged in 2003 were recaptured in 2004; A. S. Seymour, unpubl. data). This is strong evidence that adult civets present in one year are not likely to be present in the next, and means that we should only consider range overlap within study years. The radio-tracking data then suggest that there was a low overlap of intra-sexual home ranges. However, several adult male and female civets were trapped and observed at camp Lapago, but scavenging on food waste probably accounted for the high degree of range overlap within this area. Colon (2002) found considerable home-range overlap of both sexes in Borneo and concluded that the Malay civet was not territorial. A similar pattern was observed among common palm civets in Nepal (Joshi *et al*., 1995) and Thailand (Rabinowitz, 1991). Among solitary carnivores, exclusive home ranges are expected only when food resources are stable and evenly distributed (Sandell, 1989). Joshi *et al*. (1995) found that home-range overlap in common palm civets was minimal when food was abundant and uniform and increased when food was most clumped. Colon (2002) expected food abundance and distribution in rainforests to vary in space and time and suggested that this accounted for the overlapping home ranges of Malay civets in Borneo. Colon (2002) also considered that trails and roads were an important resource for this species and may have contributed to the high overlap observed within her study areas. There was one road and several trails throughout the KSA and the LSA, and Malay civets were often observed crossing roads and travelling along trails.

Activity

The activity pattern of Malay civets in this study showed that they were most active during the night from 18:00 to 07:00 h, although civets were also quite active throughout the day. Colon (2002) found a similar pattern for Malay civets in Borneo, although the activity levels of civets on her study sites were considerably lower during the day. Studies of other civet species have revealed nocturnal activity patterns (Macdonald & Wise, 1979; Dhungel & Edge, 1985; Rabinowitz, 1991; Joshi *et al*., 1995; Grassman, 1998). Activity is often associated with foraging, whose timing and duration are usually a function of resource availability (Gittleman, 1989). Nocturnal activity in Malay civets in Buton would increase encounter rates with prey such as rodents, which were found to be strictly nocturnal within the KSA and the LSA (N. Grimwood, unpubl. data). Since there were no other mammalian carnivores within the study areas, other animal species may influence the activity patterns of Malay civets.

Small carnivore species may also adjust their activity patterns to reduce encounters with larger mammalian carnivores that may kill them (Palomares & Caro, 1999). Interspecific killing among mammalian carnivores may account for up to 68% of known mortalities in some species (Palomares & Caro, 1999). Two of five radio-tracked common palm civets were killed by undetermined carnivores in Nepal (Joshi *et al*., 1995). The absence of large nocturnal predators such as tigers *Panthera tigris* or leopards *Panthera pardus* in our study areas may have contributed to the high frequency of nocturnal activity observed among the Malay civet in Buton Island. The Sulawesi palm civet is the largest, native mammalian carnivore on Sulawesi. However, it is not known what competitive interaction may occur between Malay and Sulawesi palm civets in areas where both species are present. Since no Sulawesi palm civets were found in the study areas, adult Malay civets may have no carnivore predators to avoid.

Conclusions

The Malay civet is an adaptable species that seems to thrive under a variety of environmental conditions including habitat disturbance arising from human activities (such as selective logging). This study indicates that the Malay civet also shows morphological and behavioural plasticity in different areas of its range in response to local factors, including habitat quality, food availability, and interspecific competition.

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