Ecology of the Malay Civet (*Viverra tangalunga*) in Lambusango forest on Buton Island Sulawesi.

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Abstract

The Malay civet (*Viverra tangalunga*) is a small to medium sized carnivore. Little is known about the demography of the species. The aim of this study was to further our understanding of morphology, abundance, home range and spatial organization. The study was performed between June-August 2008, on Buton Island in central Indonesia. In total, 28 animals were trapped and six animals were fitted with radio collars. There were no significant morphological differences or differences in home range size between sexes. Mean home range overlap was estimated to 68.1%. Comparisons with other studies revealed that Malay civet home ranges on Buton Island were smaller than on Borneo. However, no significant differences in morphology were observed between the two sites and abundance estimates were also comparable. The results indicate that Malay civets on Buton Island have not undergone any morphological changes since their introduction on the island. It also appears that Malay civets are more social than previously thought, given the high overlap in home ranges. I propose that competition is the primary cause for the differences seen in home range size between study sites.

Introduction

The Malay civet (*Viverra tangalunga*) is a small to medium sized generalist carnivore belonging to the Viverridae family. The family was previously grouped with the Herpestinae family and covered 70 species (Schreiber, 1989). However, currently the Viverridae is considered a distinct group with 35 species. These are mainly forest dwelling and occur in many parts of Africa and Asia. They are considered to be the most numerous predator group in the tropical forest they inhabit. Most of the species in this family are omnivorous and currently known to serve as predators, frugivores, pollinators and seed dispersers (Rabinowitz, 1991; Jennings *et al.* 2006).

In the Sulawesi region the Malay civet is one of only three known mammalian predators; the Sulawesi palm civet (*Macrogladia musschenbroekii*), Asian palm civet (*Paradoxurus hermaphroditus*) and the Malay civet (Musser, 1987). Both *V. tangalunga* and *P. hermaphroditus* are considered to be introduced to the chain of islands (Schreiber, 1989; Veron, 2001; Lee *et al.* 2003). The Malay civet was introduced on Buton island for civetone farming (a substance which was commercially used in perfume production) and rodent control, and is believed to be one of only two mammalian carnivores on the island (in addition to *M. musschenbroekii*).

Since the introduction, the Malay civet has become a widespread species on the island (Jennings *et al.* 2006). *V. tangalunga* appears to be an adaptable species, occupying several environments such as primary forest, secondary habitats, cultivated areas and village boarders (Nowak *et al.* 1999). They are known to feed on arthropods, small vertebrates, fruits and roots, and are also known to prey on chickens in areas close to human settlements. Scats have rarely been found on Buton Island, but on the few occasions there have been findings, they have contained considerable amounts of fur from a small murid rodent, *Bunomys andrewsii* (Seymour, A. S. unpubl.). Despite their many important ecological functions, and the potential negative impact they can have on the island as a non-native species, little is known about the behaviour, ecology and population dynamics of the species (Schreiber1989; Estes, 1996; Jennings *et al.* 2006). The lack of knowledge can be attributed to their solitary behaviour, nocturnal habits and the inaccessibility of their tropical forest habitats (Jennings *et al.* 2006; Papes and Gaubert 2007).

Buton Island provides a good opportunity to investigate the different ecological and social aspects of *V. tangalunga* due to the high species abundance and the lack of other mammalian carnivores (except *M. musschenbroekii*) on the island (Jennings *et al.* 2006). The purpose of this study was to further develop the understanding of this small to medium sized carnivore in its tropical forest habitat. More specifically, I aimed to estimate the abundance of Malay civets in the study area, compare morphology of Malay civets in this area to other areas within similar habitat and other habitat types, and to determine home range size and overlap.

Methods

Study site

The research was conducted on Buton Island. The small island (6,242 km^2) is a part of the Sulawesi region in central Indonesia (Figure 1). This region is surrounded by deep ocean trenches, which create two distinct biogeographical regions; the Asian region (east) and the Australian region (west) (Osborne 2006; Figure 1). The fact that the Sulawesi region is surrounded by ocean trenches and essentially separated from both adjacent biogeographical regions has had an important effect on species dispersal to and from the islands. Musser (1987) suggests that as much as 90% of the small mammalian fauna is endemic to the Sulawesi region.

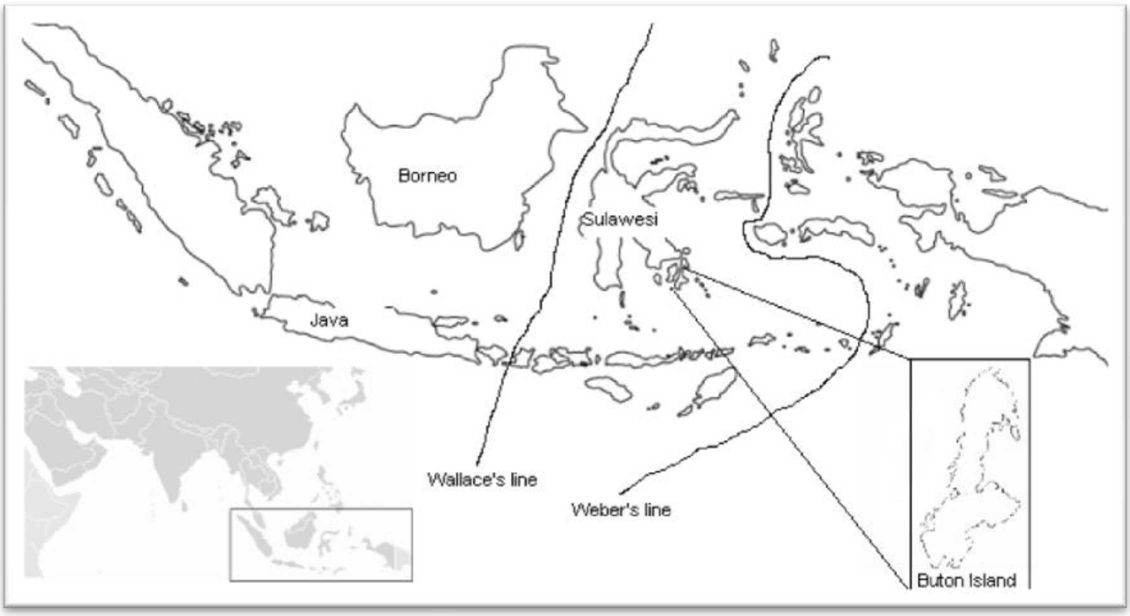

Figure 1. Map of Indonesia with Wallace's and Weber's lines separating the two biogeographic zones in the area.

Research was carried out from June – August 2008, near the northern border of the Lambusango forest reserve, in the central part of Buton Island (5 10'S 122 54'E). The island is 100 km long and 42 km wide. Elevation of the study area ranged from 40 to 360 meters above sea level (masl) and lay approximately two km from the eastern coastline. The habitat is comprised of lowland forest with a high diversity of tree species without any single dominant tree family (Figure 2). The soil type in the area is of karst coral limestone and originates from the Quaternary age (Winarni and Jones 2006). The study area shows different levels of human disturbance including hunting, agriculture, mining, and illegal logging (Winarni and Jones 2006). Buton Island has a typical monsoon climate with annual rainfall of 1500-2000 mm. The typical wet season occur between April – June (Whitten *et al.* 2002). The main camp (Lapago) used during the fieldwork was situated approximately 4.5 kilometers from the Labundo Bundo road with the Jalan and Kodoc trail connecting the camp and the road (Figure 3).

Figure 2. Typical forest area where the current study was performed.

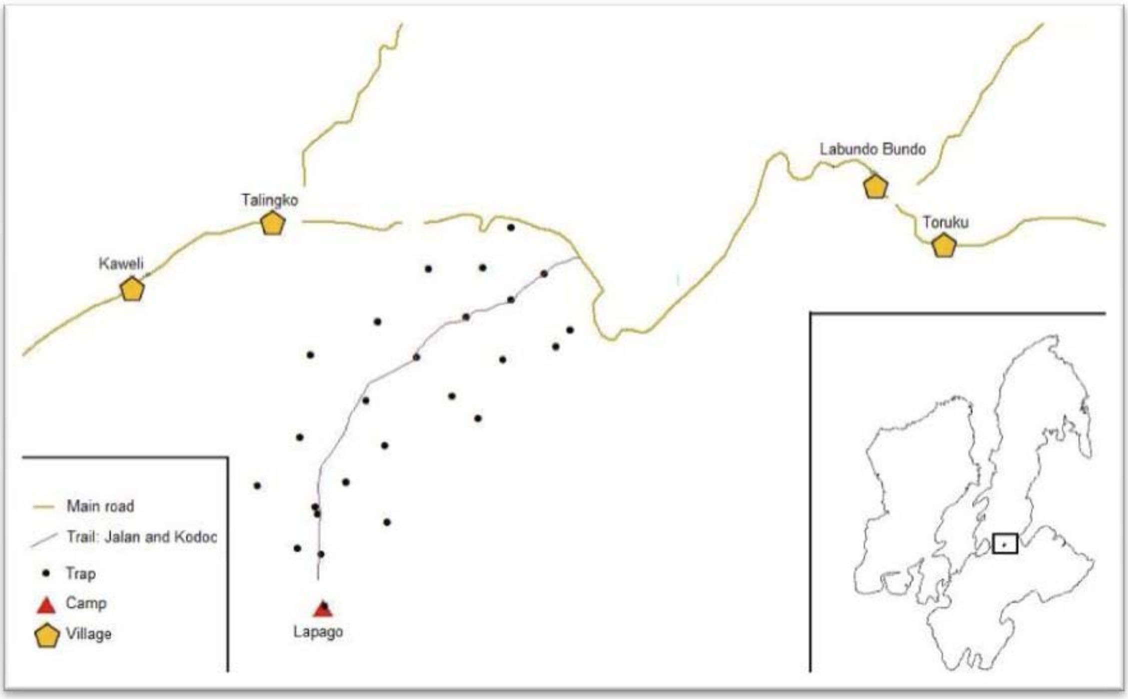

Figure 3. Map of the study site with the camp, traps, nearby villages and roads illustrated.

Trapping

During the fieldwork, 25 wire box traps (140x40x40cm) were used to capture the animals. The traps were placed every 500 meters along three transects throughout a 2.4 km² study area. The middle transect was set up along a forest path leading down to the Lapago campsite. This path was frequently used by people. The two additional transects were set up parallel with the path, one to the south-west and the other to the north-east, approximately 350m to each side of the path. Traps were positioned on dry and level ground. Traps were covered with vegetation and fallen organic debris. Since the traps had been placed at the same location for several years, tarpaulins were occasionally used as an alternative to organic debris, thus minimizing disturbance. Bait consisted of either salted fish or a mixture of oats, peanut butter and strawberry flavouring. The bait used depended on availability and price.

Figure 4. Trap with anaesthetised Malay civet.

Traps were checked once every day (Figure 4). During the sedation of a captured animal a "squeeze panel" was used to restrict movement within the trap. Once the animal was confined, a mixture of Ketaset (Ketamin HCL, Parke, Davis &Co., Detroit, MI, USA) and Rompum (Xylazine HCL, Bayer) was injected intramuscularly to immobilise the individual. The sedative became effective on most animals between five to ten minutes after injection and the animal remained immobilised for approximately 20-30 minutes. All civets were tagged in both ears with coloured plastic tags (Rototag, Dalton, Henley-on-Thames, Oxfordshire, UK) and were kept in the trap to recover for 2-3 hours before being released. Seven civets were also fitted with a radio transmitter, which enabled tracking. Although seven animals were fitted with transmitters, only six were used in the current study. Individual M43 (Dan), a sub-adult caught at the far north-eastern end of the study area, was fitted with a transmitter to determine whether he would migrate or remain in the area. Due to his location (opposite side of the study grid) and the fact that he was not an adult (and thus not a focal animal), he was only occasionally tracked.

Radio tracking

Radio tracking was carried out from June – August, 2008. Civets trapped in the more accessible part of the study area (south-west) and in close proximity to each other were equipped with radio transmitters. The transmitters used (MOD-80, Telonics, Mesa, AZ, USA) were fitted with a motion sensor and a whip- antenna. Animals were tracked using three TRX-1000 receivers (Wildlife Materials Inc., USA) with collapsible 3-element Yagi antennae (Figure 5). Three tracking teams were used to enable triangulation of the animals. Communication between the teams occurred mostly through radio contact to enable quick and accurate movement. This was especially important when adjusting position due to animal movement. On some occasions, faulty receivers limited tracking exercises to only two TRX-1000 receivers. In these cases, only biangulation was achieved. In situations where only one tracking team could locate an individual, a fix were recorded and labelled as a monoangulation.

Figure 5. Tracking antenna and receiver.

Both continuous and discontinuous radio tracking was performed during the field study. However, the current study design focussed on continuous tracking. The day was divided into four tracking periods; morning (06-12), afternoon (12-18), evening (18-00) and night (00-06) to allow 24 hour coverage of animal movements. Each fix was triangulated on a 20-minute cycle. If several individuals were present, a five-minute gap was placed between each individual scanning. Within every cycle, all animal transmitter frequencies were scanned to detect individuals entering the radio-tracked area. When a new individual was detected, a fix was taken at the end of the cycle. Only once were there more than four individuals tracked at one time. During this period, five animals were tracked, forcing the tracking cycle to be extended to 25 minute.

Disturbance of the radio signal was low due to the lack of electronic equipment in the immediate area. Signal bounce was present, however, as a result of the local topography and vegetation. The signal from the individual civets radio transmitter was categorized in three different strengths; 1) a signal without a signal bounce (i.e. weak), 2) a signal bounce that was audible 180 degrees (medium strength), and 3) a signal audible 360 degrees around the receiver (strong) and with the receiver's attenuator option switched on (a function that drastically lowers the sensitivity of the receiver). An estimate of the distance between the receiver and the transmitter based on the different signal strengths was established through tests within the study area. The tests were carried out by placing a transmitter at known distances from the receiver and estimating the strength of the signal (Figure 6; Seymour, A. S. unpubl.). Information gathered from these tests allowed us an additional variable during the analysis of triangulation and biangulation data.

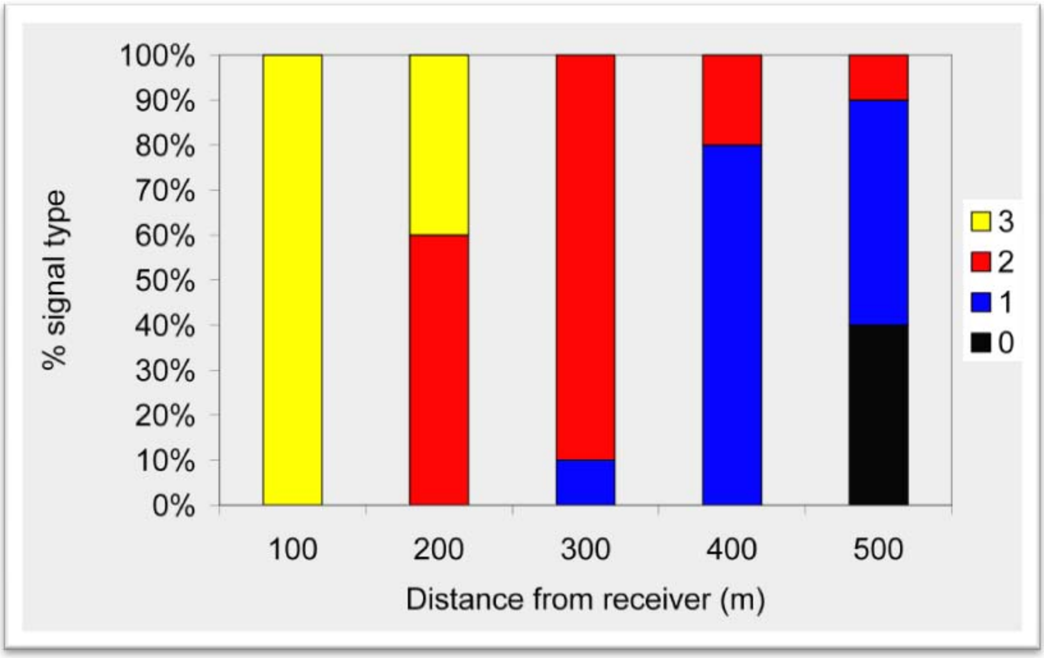

Figure 6. Different signal strengths for various distances between transmitter and receiver (Seymour A. S. unpubl.).

Morphology and age

Measurements of animal morphology were taken while animals were anaesthetised during the trapping process. Data on reproductive status, age, sex and morphological measurements were collected. The age was determined based on body size and the condition of the teeth. Individual civets were categorised as: juveniles (< 2 kg, milk teeth present), sub adults (usually < 3 kg and no signs of sexual maturity), young adults (sexually mature and teeth in very good condition), adults (sexually mature and teeth in fair condition) and old adults (showing signs of decline in weight and health, and pronounced tooth wear). The morphological measurements included, head and body length, neck circumference, right ear length, right hind foot length, length and width of right front footpads, right canine length and width (upper) and tail length. Reproductive status was determined by inspecting nipple condition on females and testicle condition on males (Figure 7). During the analysis of morphological data, all non-adult individuals (juvenile, young adult, sub-adult and old adult) were excluded to allow comparisons with previous studies (Colón 2002, Jennings *et al.* 2006). For this study comparison, right fore foot length and right fore foot width, were excluded due to a lack of data. The current study and Jennings *et al.* (2006) used an additional age group (sub-adult). This had no effect on the results as either all animals or exclusively adults were used in the analysis.

Figure 7. Morphological measurements being collected of a Malay civet (*V. tangalunga*).

Abundance, home range and spatial organisation

Abundance calculation was performed using two methods. Dividing the total home range area for all radio tracked animals using the Minimum Convex Polygon (MCP) method. The second method divided the effective trapping area with the total number of trapped animals (MacDonald *et al.* 1980; Colón, 1999). In the,between-study comparison, Jennings *et al.* (2006) was excluded due to a lack of comparable data. Density is presented as civet/ha.

Home range estimation was based on, the data acquired from the radio tracking. Triangulations larger than 10 000m^2 (1 ha) were discarded along with any obvious erroneous fixes (e. g. fixes under 1 ha but the distance between receiver and transmitter were too large to be registered). Biangulations were chosen based on signal strength and location compared to the previous fix. No monoangulations were used. The radio tracking data was entered in to LOAS (Version 4.0, Ecological Software Solutions, www.ecostats.com) and then inserted into ArcView GIS 3.2 (ESRI, Redlands, California) where the Home Range Extension (HRE) for ArcView (Ministry of Natural Resources, Ontario, Canada) was used to calculate home ranges. The Minimum Convex Polygon method (MCP) was used to analyse home range areas. The MCP method was chosen to facilitate comparisons between studies. The current study presents two different MCP calculations; MCP 100% and MCP 95%. The former uses all available tracking data while the latter only uses 95% of available data. In this study, I use MCP 95% in calculations and comparisons to provide conservative estimates of home range sizes. When statistically analysing differences in home range size between sexes, data from Jennings *et al.* (2006) was pooled with data from this study to increase sample sizes. No animals were represented twice in the pooled data set.

Overlap calculations were performed in ArcView 3.2 using the HRE following the method in MacDonald *et al.* (1980). Overlap was estimated based on the home range size calculated from MCP 95%. The amount of overlap estimates represents the area of home range that two or more animals share.

Study comparison

The results from this study are compared to two studies; Colón (2002) and Jennings *et al.* (2006). The study by Colón (2002) was performed in Danum Valley, Sabah, on Borneo. The study encompassed a total of 20 captured animals at two different locations: one logged and one unlogged site. Each site had six radio-tracked civets.

The comparisons made herein were only performed using the unlogged study area as this closely resembles the circumstances in this study. Jennings *et al.* (2006) performed their study at the same study location as the current study and is based on a total of 32 captured animals, 8 of which were radio-tracked.

While discussing the Island rule later in the paper, the study performed by Colón (2002) is related to as the main land. Although this is not the case, as Borneo is a 743,330 km^2 large Island (roughly 120 times Buton Island), similar assumptions are made in Jennings *et al.* (2006).

Data analysis

All statistical analysis in this study was performed using Minitab version 15 (Minitab Inc. USA). A 2-Sample t-test was used in all inter-sexual statistical analysis. Equal variance was assumed for all 2-Sample t-tests. A One-Way Anova with Fishers individual error test (Dytham, 2003) was used in the between-study comparison, where three studies were compared. However, in some cases, morphological data were compared between two studies only. In these cases, a 2-Sample t-test was performed. Normal distribution was tested prior to statistical analysis. All statistical tests use a 5% level of significance.

Results

During a total of 35 trapping days there were 102 capture events in a total of 26 traps. A minimum of 28 individuals was captured. One captured individual was not adequately identified and could therefore be represented twice in the total number of captured animals. Minimum trap capture rate was calculated to 3.9 ± 3.0 animals per trap.

Morphology

A summary of morphological data is provided in Table 1. There were significant size difference in neck circumference (t = -4.36, d.f. = 7, P= 0.003), right hind foot length (t = -2.94, d.f. = 7, P= 0.022) and right canine width (t = -3.93 d.f. = 7, P= 0.006) between sexes. Other morphological variables did not portray any significant differences between sexes.

Table 1. Summary of morphological data from captured Malay civets (*V. tangalunga*) in the Lambusango forest, Buton Island, Indonesia.

Id	**Name**	**Sex**	**Age**	**Weight (g)**	**Hb length (cm)**	**Tail length (cm)**	**Neck circ. (cm)**	**Re. ear length (mm)**	**Rt. hind foot (cm)**	**Rt. fore-foot pad length (mm)**	**Rt. fore-foot pad width (mm)**	**Rt. canine length (mm)**	**Rt. canine width (mm)**
M42	Sudi	M	Young Adult	3.3	57.3	29.2	20.3	44	9.9	28.9	32.2	11.53	5.39
M34	Angur	M	Adult	3.52	60.5	35.8	20.4	41	10.3	33	36	14	6
M43	Dan	M	Sub-adult	2.925	56.1	30.6	17.8	32	9.8	28.2	32.3	6.3	4.1
M40	Itchy	M	Adult	3.775	66.4	35.2	19.5	35	10.6	30.2	36.2	1.6	6
M45	Harry	M	Sub-adult	2.87	60.5	31.2	18.8	44	10.3	30.5	32	8	2.6
M46	Daddy	M	Adult	4.2	63.5	34	20.8	42	10.4	32	31.1	11	6.1
M30	Elvis	M	Adult	*	*	*	*	*	*	*	*	*	*
M47	Colin	M	Adult	3.9	64.2	30	19.4	40	10.2	31.7	36	11	5.8
M48	Storm	M	Young Adult	3.15	58	29.5	18	40	10.2	28.2	31	11	4.8

M2	Beng-Beng	M	Adult	*	*	*	*	*	*	*	*	*	*
M49	Bob Marley	M	Adult	3.65	62	33	20	40	10	29	31.3	13.2	4.8
M50	Baz	M	Adult	3.8	64	32	20.6	42	10.5	32.3	36	14.5	6
M51	James	M	Sub-adult	2.75	57	31.5	18	34	9.8	30	31.8	8	3.6
M52	LaIra	M	Sub-adult	2.7	54	33.6	16.5	40	9.6	27	30	8	4.5
M39	Scott	M	Adult	*	*	*	*	*	*	*	*	*	*
F5	Nina	F	Old Adult	3.275	62.8	32.1	17.8	43	10.2	28.7	32.2	8.75	5.1
F30	Maria	F	Adult	3.375	61	33	18	36	10	30	32	12	5
F16	SJ	F	Sub-adult	2.8	59	31	17.4	48	9.8	27	36	8	4
F31	Kit	F	Young Adult	3.3	61	32	17.6	36	10	29	36	10	4
F29	Claudia	F	Adult	3.9	63.6	32.2	19	38	10	31	35	10	4

F26	Aisla	F	Young Adult	3.1	64.3	30.8	18.7	36	9.8	30	34	*	*
F32	Tine	F	Young Adult	3.1	59.8	34.9	17.7	35	9.9	28.2	30.5	12	4.8
F33	Liv	F	Juvenile	2.3	54.9	28.7	16.6	33	9.1	25.7	29	2.9	2
F17	Sahudin	F	Adult	3.35	61	30	17.8	42	9.8	31.7	29.5	9.5	3.5
F12	Magdalena	F	Old Adult	4.35	63.2	30.5	19.5	36.8	10.5	31	30.2	9	5
F35	Foxy	F	Sub-adult	3	57.2	31	19.2	40	9.8	28.6	27.5	10.6	4.7
M44 or F34	Sam	?	Juvenile	1.45	43	19	13	30	8	23	28	4	2
M?	?	M	Adult	*	*	*	*	*	*	*	*	*	*

Abundance

Density calculation using the total home range method (MCP 100%) resulted in a density of 1/32.2 ha (193.3/6). The effective trap area method resulted in 1/8.5 ha (238.6/28).

Home range size

Home range size for six civets radio tacked during fieldwork and the additional individuals from Jennings *et al.* (2006) ranged from 17-197 ha (MCP 100%) and 13-189 ha (MCP 95%; Table 2) The mean home range size was 69.9 ± 50.9 ha (MCP 100%) and 51.9 ± 44.7 ha (MCP 95%). Home range sizes for different individuals are presented in Table 2. There was no significant difference in home range size between males and females (t= 1.03. d.f. = 12. P=0.323). Positioning of the male and female home ranges (MCP 95%) can be seen in Figure 8.

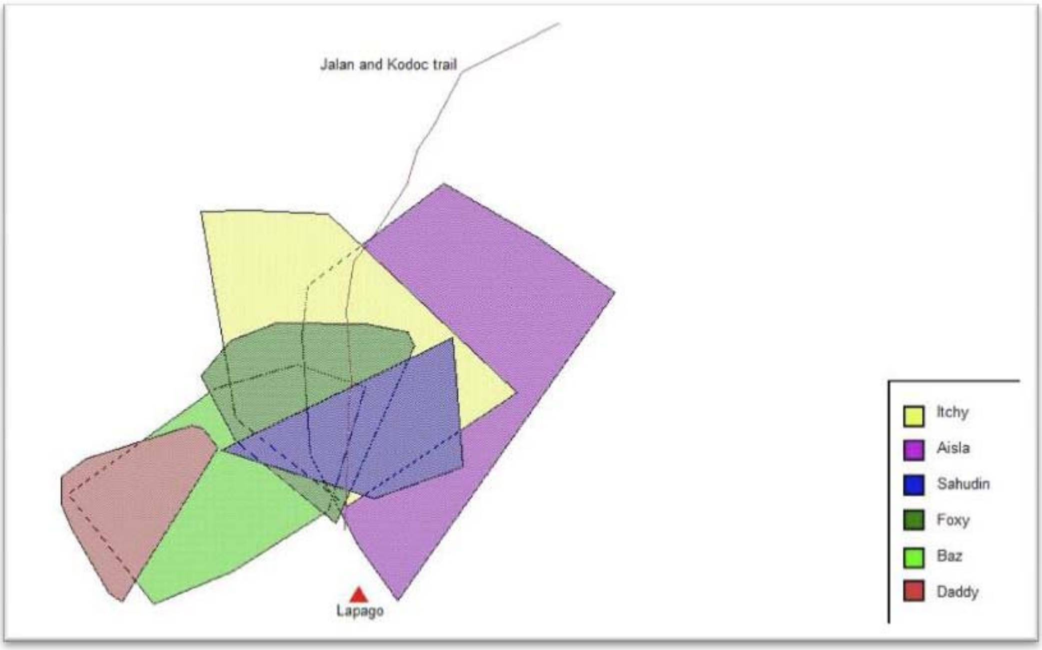

Figure 8. Diagram of estimated home ranges (MCP 95%) from radio-tracked Malay civets (*V. tangalunga*) in the Lambusaong forest, Buton Island, Indonesia.

Table 2. Estimated home range size of radio-tracked Malay civets (*V. tangalunga*) in the Lambusango forest, Buton Island, Indonesia.

Civet	**MCP 100% (ha)**	**MCP 95% (ha)**
This study		
Aisla (F)	127	70
Baz (M)	50	38
Daddy (M)	17	14
Foxy (F)	42	25
Itchy (M)	110	52
Sahudin (F)	37	19
Jennings *et al.* (2006)		
F01	18	13
F02	71	60
F03	28	24
F10	109	66
M01	39	37
M03	197	189
M04	49	43
M05	84	76
Mean	69.9 ± 50.9	51.9 ± 44.7
Mean (M)	78.0 ± 60.7	64.1 ± 58.1
Mean (F)	61.7 ± 42.1	39.6 ± 24.6

Overlap

Mean home range overlap ranged from 10.7-38.8 ha, constituting between 46.6-100% of individual home ranges (Table 3). Overall, the mean home range overlap was estimated to 75.7 ± 20.4%. Mean overlap for males was 70.4 ± 8.2% whereas female home range overlap was somewhat higher (81.1 ± 29.9; Table 3).

Table 3. Estimated home range overlap of radio-tracked Malay civets (*V. tangalunga*) in the Lambusango forest, Buton Island, Indonesia.

Civet	Home range size (MCP 95%)	Overlap (ha)	Overlap %
Aisla	70	32	47
Baz	38	23	61
Daddy	14	11	75
Foxy	25	24	97
Itchy	52	39	75
Sahudin	19	19	100
Mean	36.3 ± 21.49	24.7 ± 9.9	75.7 ± 20.4
Mean (M)	34.2 ± 19.7	24.3 ± 14,1	70.4 ± 8.2
Mean (F)	38.0 ± 27.9	25.1 ± 6,8	81.1 ± 29.9

Between-study comparison

Morphology

A One-Way Anova revealed several significant morphological differences between studies (Table 4). However, morphological differences were mainly demonstrated between animals measured by Jennings *et al.* (2006) and Colón (2002). In the current study, only right fore footpad length portrayed any significant differences from Jennings *et al.* (2006)

Table 4. Analysis of variance (ANOVA) of the morphological data from the three studies.

Variable	**This study (Mean ± SD)**	**Colón (2002) (Mean ± SD)**	**Jennings *et al.* (2006) (Mean ± SD)**	**F**	***P***
Overall weight (g)	3719 ± 275 ^{1}	3637 ± 330 ^{1}	3828 ± 313 ^{1}	1.28	0.293
Male weight (g)	3809 ± 293 ^{1}	3757 ± 316 ^{1}	3944 ± 370 ^{1}	0.73	0.494
Female weight (g)	3542 ± 311 ^{1}	3428 ± 268 ^{1}	3678 ± 122 ^{1}	1.83	0.206
Overall head and body length (mm)	629 ± 19 ^{2}	650 ± 29 ^{2}	600 ± 30 ^{1}	11.42	0.00
Male head and body length (mm)	634 ± 20 ^{2}	663 ± 20 ^{2}	602 ± 29 ^{1}	9.95	0.001
Female head and body length (mm)	619 ± 15 ^{1}	629 ± 10 ^{1}	596 ± 34 ^{1}	2.17	0.16
Overall tail length (mm)	328 ± 20 ^{2}	324 ± 13 ^{2}	310 ± 14 ^{1}	5.07	0.012
Male tail length (mm)	333 ± 21 ^{2}	329 ± 13 ^{2}	311 ± 18 ^{1}	3.74	0.043
Female tail length (mm)	317 ± 16 ^{1}	315 ± 6 ^{1}	308 ± 9 ^{1}	1.18	0.342
Overall neck circumference (mm)	195 ± 10 ^{1}	198 ± 11 ^{1}	202 ± 13 ^{1}	1.16	0.325
Male neck circumference (mm)	201 ± 6 ^{1}	203 ± 10 ^{1}	210 ± 10 ^{1}	1.86	0.183
Female neck circumference	183 ± 6 ^{1}	188 ± 6 ^{1}	193 ± 8 ^{1}	1.89	0.196

(mm)					
Overall right hind foot length (mm)	102 ± 3 $^{1.2}$	104 ± 4 ^{2}	99 ± 3 ^{1}	6.59	0.004
Male right hind foot (mm)	103 ± 2 $^{1.2}$	106 ± 4 ^{2}	100 ± 3 ^{1}	5.18	0.016
Female right hind foot (mm)	99 ± 1 ^{1}	102 ± 4 ^{1}	98 ± 2 ^{1}	2.18	0.16
Overall right ear length (mm)	40 ± 3 ^{1}	37 ± 3 ^{1}	37 ± 8 ^{1}	0.66	0.522
Male right ear length (mm)	41 ± 3 ^{1}	37 ± 3 ^{1}	36 ± 10 ^{1}	0.53	0.596
Female right ear length (mm)	39 ± 3 ^{1}	37 ± 1 ^{1}	38 ± 4 ^{1}	0.35	0.714
Overall right upper canine length (mm)	11 ± 4 ^{1}	10 ± 8 ^{1}	9 ± 2 ^{1}	1.58	0.222
Male right upper canine length (mm)	11 ± 5 ^{1}	10 ± 1 ^{1}	9 ± 2 ^{1}	0.84	0.449
Female right upper canine length (mm)	10 ± 1 ^{1}	10 ± 1 ^{1}	9 ± 2 ^{1}	1.01	0.397

^{12} Fishers subset from the One-Way Anova

Table 5. T -test of right footpad length and width between this study and Jennings *et al.* (2006).

Variable	**This study (Mean ± SD)**	**Jennings *et al.* (2006) (Mean ± SD)**	**d.f**	**t**	***P***
Overall right fore foot pad length	31.2 ± 1.3	33.8 ± 3.2	23	-2.28	0.032
Male right fore foot pad length	31.4 ± 1.5	33.6 ± 2.8	13	-1.75	0.104

Female right fore footpad length	30.9 ± 0.9	34.0 ± 3.8	8	-1.34	0.216
Overall right fore footpad width	33.7 ± 2.7	34.6 ± 3.5	23	-0.65	0.52
Male right fore footpad width	34.4 ± 2.5	33.7 ± 3.6	13	0.45	0.66
Female right fore footpad width	32.2 ± 2.8	35.7 ± 3.3	8	-1.62	0.144

Home range

Home range sizes for individual civets tracked in the three different studies are presented in Table 6. There was no significant difference in home range size between the studies (Table 7). However, individuals tracked by Colón (2002) appear to have larger home ranges (Table 7), and this difference is near significant.

Table 6. Estimated home ranges calculated with two different methods for radio-tracked Malay civets (*V. tangalunga*) in the three studies.

Civet	**MCP 100% (ha)**	**MCP 95% (ha)**
This study		
Aisla (F)	127	70
Baz (M)	50	38
Daddy (M)	17	14
Foxy (F)	42	25
Itchy (M)	110	52
Sahudin (F)	37	19
Mean	63.8 ± 44.1	36.3 ± 21.5

Mean (M)	59.0 ± 47.1	34.7 ± 19.2
Mean (F)	68.7 ± 50.6	38.0 ± 27.9
Colón (2002)		
FP 3 (F)	98	81
FP 6 (F)	92	78
MP 1 (M)	139	111
MP 2 (M)	199	94
MP 5 (M)	69	56
MP 7 (M)	133	111
Mean	121.7 ± 46.1	88.5 ± 21.3
Mean (M)	135.0 ± 53.1	93.0 ± 25.9
Mean (F)	95.0 ± 4.2	79.5 ± 2.1
Jennings *et al.* 2006		
F01	18	13
F02	71	60
F03	28	24
F10	109	66
M01	39	37
M03	197	189
M04	49	43
M05	84	76
Mean	74.4 ± 58.0	63.5 ± 55.0
Mean (M)	92.3 ± 72.4	86.3 ± 70.6

Mean (F)	56.5 ± 41.9	40.8 ± 26.2

Table 7. Analysis of variance (ANOVA) of home ranges from the three studies.

Variable	**This study (Mean ± SD)**	**Colón 2002 (Mean ± SD)**	**Jennings *et al.* 2006 (Mean ± SD)**	**F**	**P**
Home range (MCP 95%)	36.3 ± 21.5 [1]	88.5 ± 21.3 [1]	63.5 ± 55.5 [1]	2.70	0.096

[1] Fishers subset from the One-Way Anova

Discussion

Morphology

The *V. tangalunga* individuals measured in this study showed little sexual dimorphism with only neck circumference, right hind foot, and right canine length significantly different. The main morphological variables, such as overall size (weight and head and body length) showed no differences. This is consistent with Colón (2002) who found no significant difference in overall body size between sexes. Similar results have been reported for the large Indian civet (*Viverra zibetha*). However, there have been reports of sexual dimorphism for species such as the small Indian civet (*Viverricula Indica*) and *P. hermaphroditus* (Confoti, 1996). Similarly, the study by Jennings et al. (2006) did not corroborate the current findings, as males were reported to be heavier than females. Since the current study and Jennings *et al.* (2006) were performed in the same locality, limited sample size may have caused the observed difference. Nevertheless, Raia and Meiri (2006) also support results found in this study, as they demonstrate that sexual dimorphism is unlikely to increase on islands compared with mainland habitats.

The between-study comparison highlighted several morphological differences (Table 4 and 5), particularly between civets on Buton Island (this study and Jennings *et al.* 2006) and Sabah (Colón, 2002). Several theories may explain morphological differences between populations on islands and mainland areas. The founder effect, for example, suggests that morphological traits of isolated populations may be strongly influenced by its founding individuals (Osborne, 2000) and has been observed for red deer (*Cervus elapfus corsicanus*; Hajji *et al.* 2008) and the Tasmanian devil (*Sarcophilus harrisii*; Jones *et al.* 2004). The "island rule" (or Foster's rule; Foster, 1964) on the other hand suggests that there is a tendency of dwarfism of large animals and gigantism of small animals in island populations (Lomolino, 1985; Raia and Meiri, 2006). The competitive release theory proposes that a lack of competitors may provide higher food availability and thus facilitate morphological changes (Grant, 1967; Dayan and Simberloff, 1998).

In all significant tests, Malay civets measured by Jennings *et al.* (2006) were smaller compared to one or both of the comparative studies. Jennings *et al.* (2006) speculate that the difference between their study and Colón (2002) might be attributed to competitive release (Dayan and Simberloff, 1994). However, Raia and Meiri (2006) demonstrate that competition, predation and diet have little effect on carnivore morphology. Instead they present resources availability as the main influence on carnivore morphology (Raia and Meiri, 2006). This suggests that the variation between Jennings *et al.* (2006) and Colón (2002) may be caused by variation in food availability rather than competitive release. Raia and Meiri (2006) also demonstrate that morphological differences in carnivores cannot be attributed to environmental conditions such as island size or isolation. It is therefore unlikely that the island rule or competitive release is the primary cause of the morphological differences.

The Founder effect could be a possible cause for the variation in morphology, particularly “overall right hind foot length” and “male right hind foot length” where there was no significant difference between this study and Jennings *et al.* (2006). Morphological variables with no significant differences, or where the study by Jennings *et al.* (2006) is significantly different from both comparative studies, cannot be attributed to the founder effect. Since morphological data differ between study area (between Jennings *et al.* and Colón, 2002) as well as within the same study area (this study and Jennings *et al.* 2006) this suggest limited sample sizes may cause the observed variation and that further research is required to accurately determine the potential morphological differences.

Abundance

Density estimates in this study were similar to those found elsewhere (Colón 2002). However, results obtained from the two different methods (total home range method and effective trap area method) differed by a factor four (32.2 ha compared to 8.5 ha). Although both methods are sensitive to incursion of unknown animals, the total home range methods should produce the most reliable results as this method is based on a smaller area, thus reducing the potential amount of incursive animals. However, both the current study and Colón (2002) have a study area with several man-made paths. As man-made trails often are used by carnivores, this may facilitate unknown animal incursions (Silver *et al.* 2004). Colón (1999) proposes that these trails may function as an important resource for civets, and also suggests that this is the reason for the high density of civets observed in her study.

Nevertheless, while trails may increase civet abundance, these trails also aid incursions by people. An increase in illegal logging has been reported in the current study area. For example, between 2005 and 2006 a large area adjacent to the Jalan and Kodoc trail was illegally logged (Winarni and Jones, 2006; Coles and Purwanto, 2007). Colón (2002) found that the density of *V. tangalunga* differed with nearly 60% between logged and unlogged areas. This suggests that the species is sensitive to major forest disturbance, despite the general belief that *V. tangalunga* is an adaptive species that thrives in a multitude of areas (Nowak, 1999; Colón 2002; Jennings *et al.* 2006). It is possible that the sensitivity is linked to decreasing food supplies such as fruit and insects. These are abundant in the forested areas and are one of the main food sources for *V. tangalunga* (Wemmer and Watling, 1986; Colón 1999; Jennings *et al.* 2006). Similar sensitivity has been reported for primates (Struhsaker, 1973) and other civets (Heydon and Bulloh 1996). Nevertheless, further research should be performed in logged and unlogged areas on Buton Island to determine any potential threat to the Malay civet from major disturbances.

Home range

Results from this study indicate that there was no significant intersexual difference in home range size (Table 2). This contrasts significantly with theories which suggest that male and female home ranges should differ. For example, Sandell (1989) and Johnson *et al.* (2000) suggest that male home ranges should be larger than those of females, since male home ranges are based on maximising the chances of mating, whereas the female home ranges are exclusively influenced by food resources. On the other hand Lindstedt *et al.* (1986) suggest that female ranges increase in size when they rear young. Jennings *et al.* (2006) found that females were rearing young in the study area at the time of year when the current fieldwork was carried out. Likewise, juvenile individuals were caught during the fieldwork of this study (Table 1). It is therefore possible that results from the current study portray a scenario where male home ranges were larger, but female ranges had been expanded due to the rearing of young. However, to fully determine potential differences in intersexual home range size, additional year-round tracking studies need to be conducted on Buton Island. Instead my current results support McNab (1989) who suggests that energy requirements (based on weight) determine home range size. Therefore, since morphological results showed no significant intersexual difference in weight, no significant difference in home range size should expected between sexes.

There was no significant difference in home range size between the studies. No difference between this study and Jennings *et al.* (2006) was expected since both where carried out in the same area. That the study by Colón (2002) showed no significant difference from the other two studies was somewhat unexpected. There was, however, a large difference in mean home range size between this study and Colón (2002; Table 7). In fact, a t-test between estimated home range sizes of the current study and that of Colón (2002) shows that these are significantly different (t= -4.22, d.f.= 10, P= 0.002). The animals studied by Colón (2002) had considerably higher competition from other mammals with similar food preferences. On Sabah there are eight sympatric civet species and a high number of additional mammalian carnivores (Heydon & Bulloh, 1996). On Buton Island, Malay civets only have one additional scarcely distributed civet species (*M. musschenbroekii*) and no other mammalian carnivores to compete with (Musser, 1987). In addition, there are a handful of non-mammalian carnivore competitors present on Buton Island; Buton macaque (*Macaca ochreata*), monitor lizard (*Varanus salvator*), reticulated python (*Python reticulates*) and Sulawesi serpent-eagle (*Spilornis rufipectus*). However, these species (or congeners) are also present at the study site in Sabah (Colón 1999). Competition is therefore a likely explanation for the difference in home range size between the study locations. However, Raia and Meiri (2006) suggest that competition is unlikely to influence carnivore home ranges sizes, illustrating the need for further research on this topic.

Overlap and social interaction

The results in this study present a mean overlap of 68.1% with smallest overlap 46.6%. This is similar to the values reported by Colón (2002) for Malay civets in Sabah. However, these results contrast significantly with those presented by Jennings *et al.* (2006) where the overlap was calculated to only 4%. This difference can most likely be attributed to the study methodology chosen by Jennings *et al.* (2006), where radio-tracked civets were spread out across a large study area. In this study, where the field methodology focused on animals within a relatively small area of the forest, home range overlap dramatically increased (Table 3). This suggests that overlap estimates from Jennings *et al.* (2006) were not representative for the study area.

Colón (2002) suggested that human made trails are likely to be used by civets. Similar observations were made during the current study and by Jennings *et al.* (2006). Positioning of home range areas show that all but one radio-tracked civet had their home range on the main trail leading from the Labundo Bundo road down to the Lapago camp (Figure 8). The use of this trail could explain the high rates of overlap seen in the current study. However, further studies are needed to investigate potential differences in home range overlap between nature reserves and areas heavily influenced by man on Buton Island.

Sandell (1989) proposes that exclusive home range only can be assumed if overlap of home ranges is < 10%. The high overlap reported in this study (68.1%) therefore indicates that Malay civets on Buton Island have non-exclusive home ranges. Non-exclusive home ranges have also been documented for the palm civet in Nepal (Joshi *et al.* 1995) and in Thailand (Rabinowitz, 1991). Several theories are available to explain the lack of carnivore territoriality. The resource dispersion hypothesis (RDH) suggests that solitary carnivores - when faced with food supplies that are unreliable and patchily distributed - will resort to non-territorial behaviour to facilitate food acquisition and thus increase fitness (MacDonald, 1983; Sandell, 1989; Johnson *et al.* 2002). Colón (2002) showed that food resources vary both temporally and spatially in a tropical forest environment, thereby suggesting that the RDH is a potential explanation for the observed overlap.

The high degree of overlap could also be explained by the territory inheritance hypothesis (TIH) (Lindström, 1986). Two animals studied during previous years in the same study area portray a possible mother-daughter relationship where the home range of the daughter is totally encompassed by the home range of the mother (Seymour, unpubl.). This conclusion is based on capture year and age classification, a high degree of home range overlap and similarities in radio-tracked data

Nevertheless, the results from this study support the RDH hypothesis, since Colón (2002) show that high overlap and varying food resources are interconnected. However, the TIH cannot be completely disregarded and further studies focusing on social interactions are clearly needed to determine the underlying causes for the high degree of overlap observed for a supposedly solitary carnivore such as *V. tangalunga*.

Conclusion

No major morphological differences were observed between this study and Colon (2002). It therefore appears that no essential morphological changes have occurred since the Malay civet was introduced on Buton Island. The small morphological differences seen between the current study and Jennings *et al*. (2006) suggest that variation seems to vary greatly between study years rather than between study areas. Alternatively, it may be caused by limited sample sizes. Abundance of *V. tangalunga* was found to be similar to that of the study performed in Sabah (Colón, 2002). The similarity in abundance between the current study and Colón (2002) suggests that the Malay civet is an adaptable species, which can tolerate the high levels of competition that it is faced with on Sabah, without decreasing significantly in density. However, home range size was significantly larger in Sabah. The lower competition on Buton Island may thus have reduced the size of required home range.

The resource dispersion hypothesis (RDH) appears to best explain the high amount of overlap presented in this study. Given that the Malay civet supposedly is a solitary carnivore, the current results suggest that it is more social than previously thought. Further investigations of the social behaviour of this species are therefore necessary.

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