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Activity patterns and habitat use of sympatric small carnivores in southern Taiwan

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Abstract

Camera-trapping was used to examine the activity patterns and habitat use of a small carnivore community in southern Taiwan from March 1998 to February 2001. Six small carnivore species occurred in disturbed and successional stage forests in southern Taiwan. The small carnivore community was mainly composed of four species, including small Indian civet *Viverricula indica*, masked palm civet *Paguma larvata*, crab-eating mongoose *Herpestes urva*, and ferret badger *Melogale moschata*. There were no significant differences of occurrence between dry and wet seasons for small Indian civet, masked palm civet, and ferret badger ($p>0.05$), whereas occurrence of crab-eating mongoose during the dry season was significantly higher than during the wet season ($p<0.02$). Small Indian civet were closely correlated to disturbed and mosaic secondary forests and seemed restricted to certain elevations, whereas the distribution of the masked palm civet, crab-eating mongoose, and ferret badger could occur from low to moderate elevations. These results show segregation of temporal distribution and habitat use among these four sympatric carnivore species.

Keywords: activity; camera-trapping; carnivores; habitat use; Taiwan.

Introduction

In Taiwan, little research has focused on wildlife occurring in low-elevation mountains adjacent to human settlements. Human activity in these areas is high and includes farming, poaching, and ecotourism. Due to the difficulty of radio-tracking in mountainous terrain and dense forests, camera-trapping has been used to census the population, activity patterns, spatial distribution, and habitat use of wildlife in Taiwan (Chang-Jian et al. 1995, 1996, Pei 1995, 1998, Lin 1996, Pei et al. 1997, McCullough et al. 2000).

A better understanding of the function of tropical carnivore communities is essential for effective management and conservation (Rabinowitz and Walker 1991). In Taiwan, there have been few field studies on small carnivores, and most have involved one species (Zheng 1990, Hwang 1995, Chen 1996, Pan 1996). Exceptions include Chuang and Lee (1997), which studied the food habits of small Indian civet *Viverricula indica*, crab-eating mongoose *Herpestes urva*, and ferret badger *Melogale moschata*, and Wu (1999) which investigated competition between Siberian weasel *Mustela sibirica* and ferret badger.

Many carnivore studies have shown that sympatric species tend to have different diets, habitat use patterns, and activity patterns (Seidensticker 1976, Bothma et al. 1984, Konecny 1989, Sunquist et al. 1989, Grassman et al. 2005). We examined the activity rhythm and habitat use of a small carnivore community with camera-trapping in southern Taiwan. Our objectives were to determine the activity patterns of small carnivores based on the number and temporal distribution of photographs from camera-trapping, and to determine habitat use of carnivores based on the presence or absence of carnivore species at camera locations. This information contributes to an understanding of sympatric carnivores in tropical forest communities, and should assist in developing more appropriate management and conservation strategies for forest communities in mountainous regions exposed to high human use.

Materials and methods

Study area

The small carnivore community was studied in Zhen-Wo Mountain (ZWM) in Kaoshung County, and in Wei-Liao Mountain (WLM) and Tian-Lian-Jing Mountain (TLJM) in Pingtung County in southern Taiwan from March 1998 to February 2001 (Figure 1). The elevations ranged from 200 to 1400 m above mean sea level. The climate was tropical, receiving an annual average of 230 cm of precipitation with peak precipitation occurring in May, July, and August (Central Weather Bureau 2004). Annual mean temperature was 24.7°C with the highest mean temperature in July and the lowest in February (Central Weather Bureau 2004).

The study areas had experienced past timber harvesting which resulted in different growth stages of forest. Consequently, local reforestation was administered in the area. Dominant planted tree species were Taiwan acacia *Acacia confusa*, Malacca albizia *Albizzia falcate*, Tung oil tree *Aleurites fordii*, and Formosan ash *Fraxinus formosana*.

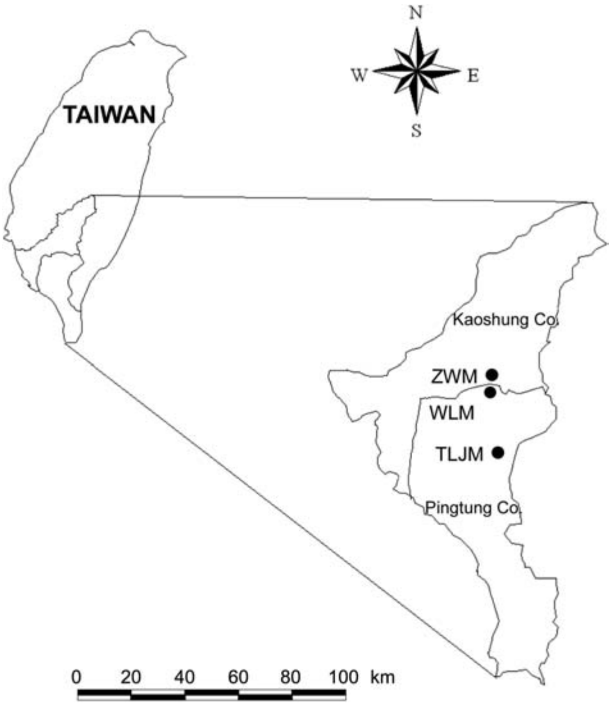

Figure 1 The Zhen-Wo Mountain (ZWM), Wei-Liao Mountain (WLM), and Tian-Lian-Jing Mountain (TLJM) study sites in southern Taiwan.

Camera-trapping

We assembled 34 camera-traps with a Pentax® (Pentax Corp., Tokyo, Japan) automatic 35-mm camera and an infrared-triggered sensor that detected heat and motion within 3–5 m (Lin 1996). Camera-traps were set along three, 2.0–2.5 km transects (ZWM=0.5 km, WLM=2.5 km, and TLJM=2 km). Traps were mounted on trees approximately 1.5 m above the ground and were set at 100 m elevation increments on aboriginal paths, logging routes, and animal trails. Traps were set to run continuously and the sampling period (e.g., effective working hours) was determined by the date and time between the first and last photograph. Multiple photographs of single individuals within a 30-min period were recorded as one effective photograph. The number of effective photographs represented the occurrence frequency of a species during sampling. The occurrence index (OI) of a species was used to represent the activity level of the local population (Pei 1998). Hence, OI equaled the number of effective photographs×1000/number of effective working hours. Effective working hours were calculated as the total working hours minus malfunction hours (i.e., no data able to be collected). To determine the seasonal activity of each carnivore species, photographs were grouped into dry (1 October–31 March) and wet (1 April–30 September) seasons.

Activity patterns

Photographs and effective working hours were classified into hour intervals based on the time printed on each photograph. The activity index (AI) of each 24-h interval for a species equaled the number of effective photographs taken at all the camera sites/number of effective working hours in each 24-h interval at all camera sites with the species present. A diel activity pattern was developed for each species using the 24-h activity indices. Photographic information used to analyze the AI was also used to calculate the seasonal AI of each 24-h interval for each species.

Habitat features

Macro- and micro-habitat variables measured at each camera-trapping site and used for analyses included elevation (EL), slope (SL), aspect (AS), forest type (FT), number of woody species (NW), number of herbaceous species (NH), canopy cover (CC), ground cover (GC), stem density 1 (SD1), stem density 2 (SD2), basal area 1 (BA1), basal area 2 (BA2) and trail type (TR). Habitat measurements were made at the beginning of the dry season to avoid bias related to seasonal effects. The aspects of the camera sites were divided into 16 groups to represent the moisture gradient class (Day and Monk 1974, Su 1987). The 16 aspects with lowest to highest moisture were SSW, SW, S, WSW, SSE, W, SE, WNW, ESE, NW, E, NNW, ENE, N, NE, and NNE, respectively.

Forest types were classified as primary (FT1), secondary (FT2), and plantation (FT3) forests. Number of woody species was measured at diameter breast height (DBH) >1 cm within a 10×10 m plot around the camera-trap. Canopy cover was measured by averaging eight observations from a spherical densitometer 5 m around the camera-trap. Ground cover was measured as percent herbaceous cover (<0.5 m height) within four 1×1 m plots situated 5 m north, south, east, and west of the camera-trap. Stem density was modified from the point-centered-quarter method (PCQ, density=1/mean area [$distance^2$]; Higgins et al. 1996). Stem density 1 was the distance to the nearest woody plant (<10 m from the camera-trap) with a DBH between 1 and 10 cm within each of the four quadrants, whereas SD2 included plants with a DBH >10 cm. Basal area 1 included the four nearest woody plants with a DBH between 1 and 10 cm within each of the four quadrants; whereas, BA2 included woody plants with a DBH >10 cm. Trails were classified into five types: non-trail (TR1), unclear animal trail (TR2), unclear logging route (TR3), clear animal trail (TR4), and clear logging route (TR5). We classified a clear animal trail as a visible trail (narrow or slender) used often and only by animals. An unclear animal trail was a less visible trail, and was used less often by animals. The logging routes were wider and flatter, and were used by both people and animals.

Statistical analysis

Wilcoxon signed-rank tests were used to test for significant differences ($p \leq 0.05$) of the AI between seasons for each carnivore species. Correlation analysis determined if a linear relationship existed between the OI of mammals in the community. Analyses were determined using SPSS® (v. 9.0; SPSS, Inc., Chicago, IL, USA). Camera sites were divided into two groups (used and unused sites) based on the OI for the four carnivore species. The OI of a carnivore species equal to 0 was defined as an "unused site", whereas an OI>0 was defined as a "used site". The OI=0 indicated that the camera-trap site did not produce any photos of a target species, and was named an "absent" site for logistic regression analysis. The OI>0 indicated that the camera-trap site yielded photo(s) of target species, and was named a "present" site for logistic regression analysis. Model selection was estimated by backward conditional regression, using the probability (p=0.30) for removal as a criterion for elimination (Lee and Koval 1997, Hosmer and Lemeshow 2000). Lee and Koval (1997) examined the issue of significance level for forward stepwise logistic regression and found that p=0.05 was too stringent, often excluding important variables from selection by the model. Hosmer and Lemeshow (2000) suggested that using p=0.25 or larger as a reasonable option. Three determinants were used to select the optimal logistic regression model to analyze habitat use by a species; higher model χ^2-value, higher prediction rate, and fewer numbers of variables.

Results

Camera-trapping

Data were collected from March 1998 to October 1999 for the TLJM transect, and June 1999–February 2001 for the ZWM and WLM transects. There were 12, 13, and 9 camera sites with sufficient data in ZWM, WLM, and TLJM, respectively. The number of effective working days, photographs, and mammalian species were recorded for each study site (Table 1). A total of 21 mammal species were photographed: Formosan macaque *Macaca cyclopis*, Formosan hare *Lepus sinensis*, red-bellied tree squirrel *Callosciurus erythraeus*, Owston's long-nosed tree squirrel *Dremomys pernyi*, Formosan stripped squirrel *Tamiops swinhoei*, Formosan giant flying squirrel *Petaurista petaurista*, Old World wood mouse *Apodemus semotus*, spinous country rat *Niviventer coxingi*, Chinese pangolin *Manis pentadactyla*, small Indian civet, masked palm civet *Paguma larvata*, crab-eating mongoose, Siberian weasel *Mustela sibirica*, yellow-throated marten *Martes flavigula*, ferret badger, wild boar *Sus scrofa*, muntjac *Muntiacus reevesi*, serow *Capricornis swinhoei*, domestic goat *Capra hircus*, domestic dog *Canis familiaris*, and domestic cat *Felis silvestris catus*.

Of six small carnivore species identified from photographs, small Indian civet, masked palm civet, crab-eating mongoose, and ferret badger were photographed most often and were used for analysis in this study (Table 2). The OI of small Indian civet was greatest in ZWM (0.70±SD 1.17) and lowest in TLJM (0.23±0.35). The greatest OI of masked palm civet was in TLJM (0.75±0.71), whereas the lowest was in WLM (0.17±0.33). The OI of crab-eating mongoose and ferret badger were greater in ZWM (1.01±0.67 and 3.92±3.17, respectively) and lower in TLJM (0.06±0.17 and 0.31±0.33, respectively; Table 3).

Table 1 Number of camera sites, effective working days, identified photographs, and mammal species recorded during Zhen-Wo Mountain (ZWM), Wei-Liao Mountain (WLM), and Tian-Lian-Jiang Mountain (TLJM) transects, southern Taiwan (March 1998–February 2001).

	Sites	Working days (n)	Photographs (n)	Mammal species (n)
ZWM	12	1992	1514	14
WLM	13	2271	1104	16
TLJM	9	1074	312	11

Table 2 Number of effective photographs of small carnivore species camera-trapped in Zhen-Wo Mountain (ZWM), Wei-Liao Mountain (WLM), and Tian-Lian-Jing Mountain (TLJM) transects, southern Taiwan (March 1998–February 2001).

Species	ZWM (n=12)	WLM (n=13)	TLJM (n=9)
Small Indian civet	33	21	5
Masked palm civet	21	6	18
Crab-eating mongoose	46	47	1
Ferret badger	193	148	9
Siberian weasel	0	3	0
Yellow-throated marten	0	0	2

The number of camera sites in each study area is shown in parentheses.

Activity patterns

Small Indian civet, masked palm civet, and ferret badger were nocturnal, whereas crab-eating mongoose displayed a diurnal activity pattern (Figure 2). No significant differences of occurrence was found between the dry and wet seasons for small Indian civet (Z=-0.41, p>0.67), masked palm civet (Z=-0.46, p>0.64), and ferret badger (Z=-0.29, p>0.70). However, the OI of crab-eating mongoose during the wet season was significantly lower than during the dry season (Z=-2.40, p<0.02).

Table 3 Mean (±SD) of occurrence indices (OIs) for four small carnivore species in Zhen-Wo Mountain (ZWM), Wei-Liao Mountain (WLM), and Tian-Lian-Jing Mountain, southern Taiwan.

Species	ZWM (n=12)	WLM (n=13)	TLJM (n=9)
Small Indian civet	0.70±1.17	0.44±0.65	0.23±0.35
Masked palm civet	0.39±0.49	0.17±0.33	0.75±0.71
Crab-eating mongoose	1.01±0.67	0.82±0.78	0.06±0.17
Ferret badger	3.92±3.17	2.73±1.39	0.31±0.33

Camera sites in each study area are shown in parentheses. Data are mean±SD.

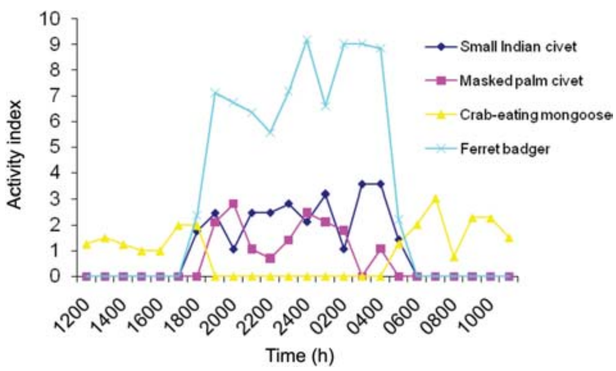

Figure 2 Diel activity patterns of small Indian civet, masked palm civet, crab-eating mongoose, and ferret badger in southern Taiwan during March 1998–February 2001.

Habitat use

Slopes of the 34 sites ranged between 9° and 48°, and EL between 360 and 1300 m. We documented 49, 62, and 49 plant species at the camera sites in ZWM, WLM, and TLJM, respectively. Canopy cover ranged from 56% to 91% and GC from 1% to 83%. Number of woody and NH ranged between 1–8 and 1–9 species, respectively. Stem densities 1 and 2 ranged from 0.02–0.50 to 0.02–0.29 stems/m^2, respectively. Basal areas 1 and 2 ranged from 0–0.20 to 0.40–19.25 cm^2/m^2, respectively (Table 4).

The model χ^2-value obtained from fitting the logistic regression of model 1 (Table 5) to the small Indian civet was 36.94 ($p<0.0001$, d.f.=9). This model had a prediction accuracy of 88%. The coefficients of slope, elevation, FT2, and number of woody species were significantly different from zero at the 30% level. Non-significant coefficients for the dummy variable (e.g., a numerical variable used to represent subgroups of the sample in the study) of FT1 indicated that the probabilities of occurrence in FT1 were approximately the same as the probabilities for the standard FT3. Non-significant coefficients for the dummy variable TR indicated that the probabilities of occurrence in TR1, TR2, TR3, and TR4 were similar to the probabilities for the standard TR5. Hence, there was a greater OI at gradual slopes than at steeper slopes. There was also a greater OI at higher elevations than at lower elevations. The OI was greater in FT2, whereas it was similar between FT1 and FT3. Moreover, the OI was greater for fewer numbers of woody species, but was similar among the five trail types.

The model χ^2-value obtained from fitting the logistic regression of model 2 (Table 5) to the small Indian civet was 30.42 ($p=0.0002$, d.f.=8). Model 2 was similar to model 1, although the χ^2-value was less. Model 2 predicted with an accuracy of 91%. Based on this model, the OI of small Indian civet increased when humidity increased and was greater at gradual slopes. The OI was also greater at higher elevations and with fewer numbers of woody species; however, it was similar among the five trail types.

Table 4 Mean ($\bar{x}$) and standard deviation (SD) for slope (SL), elevation (EL), canopy cover (CC), ground cover (GC), number of woody species (NW), number of herbaceous species (NH), stem density 1 (SD1), stem density 2 (SD2), basal area 1 (BA1), and basal area 2 (BA2) for habitat at camera sites (n=34) in southern Taiwan during March 1998–February 2001.

Habitat variable	$\bar{x}$	SD	Range
SL (%)	31	9	9–48
EL (m)	750	234	360–1300
CC (%)	78.00	7.30	56–91
GC (%)	29.79	20.96	1–83
NW	3.97	1.90	1–8
NH	5.09	2.08	1–9
SD1 (stems/m^2)	0.15	0.13	0.02–0.50
SD2 (stems/m^2)	0.06	0.06	0.02–0.29
BA1 (cm^2/m^2)	0.52	0.45	0.01–2.00
BA2 (cm^2/m^2)	4.38	4.29	0.40–19.25

The fittest logistic regression model for the masked palm civet included seven variables (Table 5). The model χ^2-value was 27.09 ($p=0.0003$, d.f.=7), and this model predicted with an accuracy of 88%. Based on this model, the OI of the masked palm civet decreased when moisture increased. There was a higher OI at steeper slopes than at gradual slopes, and the OI was greater at lower elevations than at higher elevations. Furthermore, the OI increased as canopy cover increased. Masked palm civet OI was also greater in FT2 and BA2.

The model χ^2-value obtained from fitting the logistic regression (Table 5) to the crab-eating mongoose was 31.04 ($p=0.0003$, d.f.=9). This model had an accuracy prediction rate of 94%. The OI of the crab-eating mongoose increased when the moisture increased and when there was greater ground cover. However, the OI was lower in FT1 than in FT3, whereas it was similar between

Table 5 Independent variables included in the best logistic regression models for habitat use of small Indian civet, masked palm civet, crab-eating mongoose, and ferret badger in southern Taiwan during March 1998–February 2001.

Variable	Small Indian civet (model 1) Coefficient (p-value)	Small Indian civet (model 2) Coefficient (p-value)	Masked palm civet Coefficient (p-value)	Crab-eating mongoose Coefficient (p-value)	Ferret badger Coefficient (p-value)
Aspect (moisture)		0.228 (0.25)	-0.502 (0.34)*	0.672 (0.05)*	0.239 (0.10)
Slope	-0.342 (0.14)	-0.129 (0.12)	0.172 (0.04)*		0.084 (0.18)
Elevation	0.025 (0.15)	0.008 (0.03)*	-0.019 (0.01)*		0.005 (0.20)
Ground cover				0.106 (0.12)	
Canopy cover			0.269 (0.07)		-0.107 (0.29)
Primary forest	-1.876 (0.58)		1.721 (0.36)	-11.576 (0.10)	
Secondary forest	9.363 (0.15)		6.178 (0.01)*	1.428 (0.48)	
n woody spp.	-2.319 (0.15)	-0.539 (0.21)			
n herbaceous spp.					
Stem density 1					15.522 (0.06)
Stem density 2				170.368 (0.06)	
Basal area 1					
Basal area 2			5353.039 (0.02)*		
Non-trail	-42.809 (0.774)	-23.668 (0.83)		7.377 (0.17)	1.088 (0.65)
Unclear animal trail	-24.536 (0.78)	-14.561 (0.82)		21.787 (0.15)	1.933 (0.39)
Unclear logging trail	-11.985 (0.85)	-9.393 (0.88)		22.986 (0.74)	3.782 (0.14)
Clear animal trail	-15.739 (0.85)	-10.824 (0.86)		10.506 (0.06)	-2.388 (0.17)
Constant	15.056 (0.86)	9.494 (0.88)	-12.363 (0.16)	-23.570 (0.16)	-1.122 (0.86)

*Indicates significant value.

FT2 and FT3. There was a higher OI for greater SD2. Moreover, the OI for trails (highest to lowest) were TR2, TR4, TR1, and TR5, whereas it was similar for TR5 and TR3.

The model χ^2-value obtained from fitting the logistic regression (Table 5) to the ferret badger was 23.96 ($p=0.004$, d.f.=9), with a prediction accuracy of 94%. The OI of the ferret badger increased when moisture increased. There was a greater OI at steeper slopes and higher elevations than at gradual slopes and lower elevations. The OI was lower for the higher canopy cover; however, the OI was higher when the SD1 was greater. The lowest to the highest OI was for TR4, TR5, and TR3, respectively; and the OI was similar for TR2, TR1, and TR5. Because ferret badgers were common in the three transects (only 5 of 34 camera sites did not capture ferret badgers), camera sites were divided into two groups using OI=1 (1 photograph taken per 41 days) as the separation value.

The logistic regression models showed habitat segregation among these four carnivore species (Table 6). Small Indian civet, crab-eating mongoose, and ferret badger occurred more frequently in areas with high moisture and at higher elevations, whereas masked palm civet occurred less frequently. Small Indian civet occurred more frequently on flatter slopes, whereas masked palm civet and ferret badger occurred less frequently. Furthermore, masked palm civet occurred more frequently in areas with higher canopy cover, whereas ferret badger occurred less frequently.

Discussion

Activity patterns of wildlife have typically been derived from radio-tracking data. While radio-telemetry data may reflect movements or activity around daybeds or grooming, camera-trapping reflects locomotion movements and can include more individuals. Although camera-trapping is generally limited in data collection, given the difficulty of trapping and radio-collaring wildlife in mountainous areas, activity patterns collected with camera-traps may provide a better representation of travel activity patterns of a population.

No significant difference in activity patterns occurred between the wet and dry seasons for small Indian civet and masked palm civet. In contrast, Rabinowitz (1991) found that activity decreased in the dry season for these two species. Zhang et al. (1991) noted lower activity during the cold and dry season for masked palm civet. Rabinowitz (1991) and Zhang et al. (1991) also concluded that activity was influenced by time of sunset and sunrise, seasons, temperature, light, and gender. Results from this study and others throughout Asia (Rabinowitz 1991, Zhang et al. 1991, Wang 1999) suggest that activity patterns of some carnivore species vary in different regions.

Although there is disagreement on the number and timing of nocturnal activity peaks of masked palm civet, most studies generally agreed that this species is nocturnal (Wang 1999). Rabinowitz (1991) reported masked palm civet activity between 16:30 and 04:30 h with one peak between 19:30 and 22:30 h. Wang (1999) suggested the masked palm civet did not have a particular activity peak but were active throughout the night. This study showed masked palm civet activity peaks between 19:00 and 05:00 h, which is consistent with Rabinowitz (1991).

Hwang (1995) found that crab-eating mongoose activity in Fushan (northern Taiwan) began and ended earlier during autumn (wet season), began later in winter (dry season), and ended later in spring (dry season) and winter. However, we found that the beginning and cessation of activity did not differ between dry and wet seasons. Hwang (1995) further suggested there was no significant difference in activity levels between seasons. In this study, the OI of crab-eating mongoose was significantly higher during the dry season than the wet season. Furthermore, the diel activity pattern fluctuated more intensely during the dry season. These variations indicated that the activity patterns of crab-eating mongoose in the Fushan area and in our study area were different, possibly related to different habitat types.

In this study, ferret badger activity remained high between 00:01 and 05:00 h without obvious fluctuation. Wang (1999) suggested that ferret badger were exclusively nocturnal; however, Wang (1999) only examined ferret badger activity between 05:00 and 19:00 h. Pei (1998, 2001) found that the activity level of ferret badger gradually increased and reached the highest level between 02:00 and 04:00 h or between 05:00 and 06:00 h.

The results of our logistic regression models indicated that the occurrence of small Indian civet and masked palm civet was highest in secondary forests, and the occurrence of crab-eating mongoose was lowest in primary forest. Angelici et al. (1999) studied the distribution and habitat of carnivores and also found a greater number of observations in secondary rainforests than in primary rainforests. Rabinowitz (1991) reported that the core area of a small Indian civet in Thailand comprised 57% of dry deciduous dipterocarp forest which had a more open canopy with soil and floral composition indicative of an artificial sub-climax community. The logistic regression models for small Indian civet showed that this

Table 6 Positive and negative relationships of activity patterns and habitat use of camera-trapped small Indian civet, masked palm civet, crab-eating mongoose, and ferret badger from southern Taiwan (March 1998–February 2001).

Species	Activity	Habitat use			
		High moisture	High elevation	High slope	High canopy cover
Small Indian civet	Nocturnal	+	+	-	
Masked palm civet	Nocturnal	-	-	+	+
Ferret badger	Nocturnal	+	+	+	-
Crab-eating mongoose	Diurnal	+			

species preferred fewer woody species; a characteristic of plantation forests in the study area. Small Indian civet may have used this habitat because the mosaic of secondary and plantation forests resulted in several ecotones or edges.

The coexistence of sympatric species is influenced by habitat use, food habits, temporal distribution, body size, morphology, physiology, geographic distribution, and predation risk (Bothma et al. 1984, Jaslow 1987, Konecny 1989, Sunquist et al. 1989, Johnson et al. 1996). Dietary partitioning is considered the most important factor related to ecological separation, compared to spatial and temporal differences in some sympatric carnivores (Bothma et al. 1984, Sunquist et al. 1989). In this study, there was segregation for at least one niche parameter if overlapping of other parameters occurred. Separation of habitat use by sympatric carnivores has occurred with diet overlap as seen with the South American grey fox (*Dusicyon griseus*) and culpeo fox (*D. culpaeus*) in Chile (Johnson and Franklin 1994). Furthermore, use of different proportions of food items (sometimes in different seasons) among sympatric carnivores may have reduced interspecific competition, even when food habits overlapped (Theberge and Wedeles 1989).

In this study, segregation of temporal activity and habitat use occurred among four sympatric carnivore species, although other studies suggest that there may be diet overlap between some of these species (Chuang and Lee (1997), Wang 1999, Wu 1999). Small Indian civet, masked palm civet, and ferret badger showed nocturnal activity, whereas the crab-eating mongoose was diurnal. Although ferret badger and masked palm civet were nocturnal, there was separation in habitat use.

This study provided ecological information on four small carnivores in disturbed low elevation forests in southern Taiwan. Activity patterns and habitat use differed for small Indian civet, masked palm civet, crab-eating mongoose, and ferret badger. Small Indian civet seemed restricted to certain elevations, whereas the distribution of the masked palm civet, crab-eating mongoose, and ferret badger could occur from low to moderate elevations. Furthermore, the occurrence of small Indian civet was closely correlated to disturbed and mosaic secondary forests.

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References

Angelici, F.M., L. Luiselli and E. Politano. 1999. Distribution and habitat of selected carnivores (Herpestidae, Mustelidae, Viverridae) in the rainforests of southeastern Nigeria. Z. Säugetierkunde. 64: 116–120.

Bothma, J.P., J.A.J. Nel and A. MacDonald. 1984. Food niche separation between four sympatric Namib Desert carnivores. J. Zool. (Lond.) 202: 327–340.

Chang-Jian, L., H. Zheng and S. Chang. 1995. The investigation of population and distribution for masked palm civet (*Paguma larvata*). In: The annual results of researches and planning (in Chinese). Taiwan Endemic Species Research Institute, Nantou. pp. 245–255.

Chang-Jian, L., H. Zheng, S. Chang and Y. Chen 1996. The investigation of population and distribution for masked palm civet (*Paguma larvata*). In: The annual results of researches and planning (in Chinese). Taiwan Endemic Species Research Institute, Nantou. pp. 109–136.

Chen, D. 1996. Ranging behavior and spatial distribution of crab-eating mongooses (*Herpestes urva*) at Fushan Forest (in Chinese). MS thesis, National Taiwan University, Taipei, Taiwan, ROC. 74 pp.

Chuang, S.A. and L.L. Lee. 1997. Food habits of three carnivore species (*Viverricula indica*, *Herpestes urva*, and *Melogale moschata*) in Fushan Forest ecosystem, northern Taiwan. J. Zool. (Lond). 243: 71–79.

Central Weather Bureau. 2004. Central Weather Bureau, Taiwan. http://www.cwb.gov.tw/V4e/index.htm (Assessed 28 October, 2004).

Day, F.P. and C.D. Monk. 1974. Vegetation patterns on a southern Appalachian watershed. Ecology 55: 1064–1074.

Grassman, L.I. Jr., M.E. Tewes, N.J. Silvy and K. Kreetiyutanont. 2005. Ecology of three sympatric felids in a mixed evergreen forest in north-central Thailand. J. Mammal. 86: 29–38.

Higgins, K.F., J.L. Oldemeyer, K.J. Jenkins, G.K. Clambey and R.F. Harlow. 1996. Vegetation sampling and measurement. In: (T.A. Bookhout, ed) Research and management techniques for wildlife and habitats. The Wildlife Society, Bethesda, MD. pp. 567–591.

Hosmer, D.W. and S. Lemeshow. 2000. Applied logistic regression. Wiley Press, New York. 373 pp.

Hwang, M. 1995. The population and resource use of crab-eating mongoose (*Herpestes urva*) at Fushan Forest (in Chinese). MS thesis, National Taiwan University, Taipei, Taiwan, ROC.

Jaslow, C.R. 1987. Morphology and digestive efficiency of red foxes and gray foxes in relation to diet. Can. J. Zool. 65: 72–79.

Johnson, W.E. and W.L. Franklin. 1994. Partition of spatial and temporal resources by sympatric *Dusicyon griseus* and *Dusicyon culpaeus* in the Patagonia of southern Chile. Can. J. Zool. 72: 1788–1793.

Johnson, W.E., T.K. Fuller and W.L. Franklin. 1996. Sympatry in canids: a review and assessment. In: (J.L. Gittleman, ed) Carnivore behavior, ecology, and evolution. Vol. 2. Cornell University Press. Ithaca, NY. pp. 189–218.

Konecny, M.J.. 1989. Movement patterns and food habits of four sympatric carnivore species in Belize, Central America. In: (K.H. Redford and J.F. Eisenberg, eds) Advances in Neotropical Mammalogy. Sandhill Crane Press, Gainesville, FL. pp. 243–264.

Lee, K. and J.J. Koval. 1997. Determination of the best significance level in forward stepwise logistic regression. Commun. Stat. 26: 559–575.

Lin, Z. 1996. Study of activity pattern of spinous country rat (*Niviventer coxingi*) in Wutou Mountain Nature Reserve (in Chinese). MS thesis, National Sun Yat-Sen University, Kaohsiung, Taiwan, ROC.

McCullough, D.R., K.C.J. Pei and Y. Wang. 2000. Home range, activity patterns, and habitat relations of Reeves' muntjac in Taiwan. J. Wildl. Manage. 64: 430–441.

Pan, F.-S. 1996. Yearbook – The investigation and research of forestry biodiversity (in Chinese). Taiwan Forestry Research Institute, Taipei, Taiwan, ROC.

Pei, K. 1995. Activity rhythm of the spinous country rat (*Niviventer coxingi*) in Taiwan. Zool. Stud. 34: 55–58.

Pei, K. 1998. An evaluation of using auto-trigger camera to record activity patterns of wild animals (in Chinese with English abstract). Taiwan J. Forestry Sci. 13: 317–324.

Pei, K. 2001. Daily activity budgets of the Taiwan ferret badger (*Melogale moschata subaurantiaca*) in captivity. Endemic Species Res. 3: 1–11.

Pei, K., C. Chen, S. Wu and M. Teng. 1997. Use of camera-trapping and geographic information system to study spatial distribution of forest wildlife (in Chinese with English abstract). Q. J. Chin. Forestry 30: 279–289.

Rabinowitz, A.R. 1991. The behavior and movement of sympatric civet species in Huai Kha Khaeng Wildlife Sanctuary, Thailand. J. Zool. (Lond.) 223: 281–298.

Rabinowitz, A.R. and R.S. Walker. 1991. The carnivore community in a dry tropical forest mosaic in Huai Kha Khaeng Wildlife Sanctuary, Thailand. J. Trop. Ecol. 7: 37–47.

Seidensticker, J. 1976. On the ecological separation between tigers and leopards. Biotropica 8: 224–234.

Su, H.J. 1987. Forest habitat factors and their quantitative assessment. Q. J. Chin. Forestry 20: 1–14.

Sunquist, M.E., F. Sunquist and D.E. Daneke. 1989. Ecological separation in a Venezuelan llanos carnivore community. In: (K.H. Redford and J.F. Eisenberg, eds) Advances in neotropical mammology. Sandhill Crane Press, Gainesville, FL. pp. 197–232.

Theberge, J.B. and C.H.R. Wedeles. 1989. Prey selection and habitat partitioning in sympatric coyote and red fox populations, southwest Yukon. Can. J. Zool. 67: 1285–1290.

Wang, H. 1999. Wildlife conservation in rural southeastern China: wildlife harvest and the ecology of sympatric carnivores. PhD dissertation, University of Massachusetts, Amherst, MA, USA.

Wu, H. 1999. Is there current competition between sympatric Siberian weasels (*Mustela sibirica*) and ferret badger (*Melogale moschata*) in a subtropical forest ecosystem of Taiwan? Zool. Stud. 38: 443–451.

Zhang, B., X. Su, G. Gao and W. Zhang.1991. Note on the activity and winter dormancy of masked palm civet (in Chinese). Chinese J. Zool. 26: 19–22.

Zheng, S. 1990. Biological research of masked palm civet in Taiwan. MS thesis, National Taiwan Normal University, Taipei, Taiwan, ROC.