

Spatial organization and activity patterns of the masked palm civet (*Paguma larvata*) in central-south China

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Movement and activity patterns are important components of life history, being central to resource acquisition and defense, mating behavior, and individual survival and fitness. Here, we present results from the 1st systematic radiotracking study of the masked palm civet (*Paguma larvata*), a widespread viverrid found in subtropical and tropical forests of Asia. From June 2004 to November 2007, we radiotracked 12 masked palm civets (5 males and 7 females) in central-south China. Mean individual home-range size based on 95% minimum convex polygons was $192.6 \text{ ha} \pm 42.6 \text{ SE}$ (range = 64–451 ha). Although males had larger mean home-range sizes than females (276.8 and 136.5 ha, respectively), these differences were not statistically significant. Males also exhibited greater daily movement distances and extents than females, but we found no evidence of sexual dimorphism in body size. Masked palm civets were predominantly nocturnal, but were active intermittently during the day. No significant seasonal (monthly) differences in daily activity patterns were apparent. We did, however, observe reduced hours of activity—but not continuous inactivity—during winter; consequently, we concluded that our study animals did not hibernate or semihibernate. We speculate that our observations of home-range overlap among individuals may indicate group living in the masked palm civet.

Key words: activity pattern, hibernation, home range, nocturnal, sexual dimorphism, spatial organization, torpor, Viverridae

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The masked palm civet (*Paguma larvata*) is among the 14 genera and 34 species of Viverridae (Jennings and Veron 2009) distributed throughout Europe, Asia, Africa, and Madagascar. About one-half of these species are red-listed by the International Union for the Conservation of Nature and Natural Resources (IUCN 2013), although the status of viverrids in general is poorly known (Jennings and Veron 2009). Viverrids comprise 13% of species in the order Carnivora, but only a few are predominantly carnivorous (e.g., the Abyssinian genet [*Genetta abyssinica*]—Jennings and Veron 2009); most are omnivorous or frugivorous (Jennings and Veron 2009), and they can play important roles in seed dispersal (Rosalino and Santos-Reis 2009).

Masked palm civets inhabit subtropical and tropical forests, farmland, and rural settlements (Jennings and Veron 2009).

They are exploited as a food source and used in traditional medicine in China (Bing et al. 2005); for example, Lee et al. (2004) reported that up to 550 individuals were sold each day in markets in Guangzhou and Shenzhen and priced at up to \$20/kg, raising concerns about their conservation status. Furthermore, masked palm civets have been implicated as hosts of severe acute respiratory syndrome coronavirus (SARS-CoV—Guan et al. 2003) and rabies virus (Yang et al. 2013). The spread of such zoonotic diseases among wildlife hosts depends on contact behavior and the social structure of populations (Macdonald and Bacon 1982). Little is known,



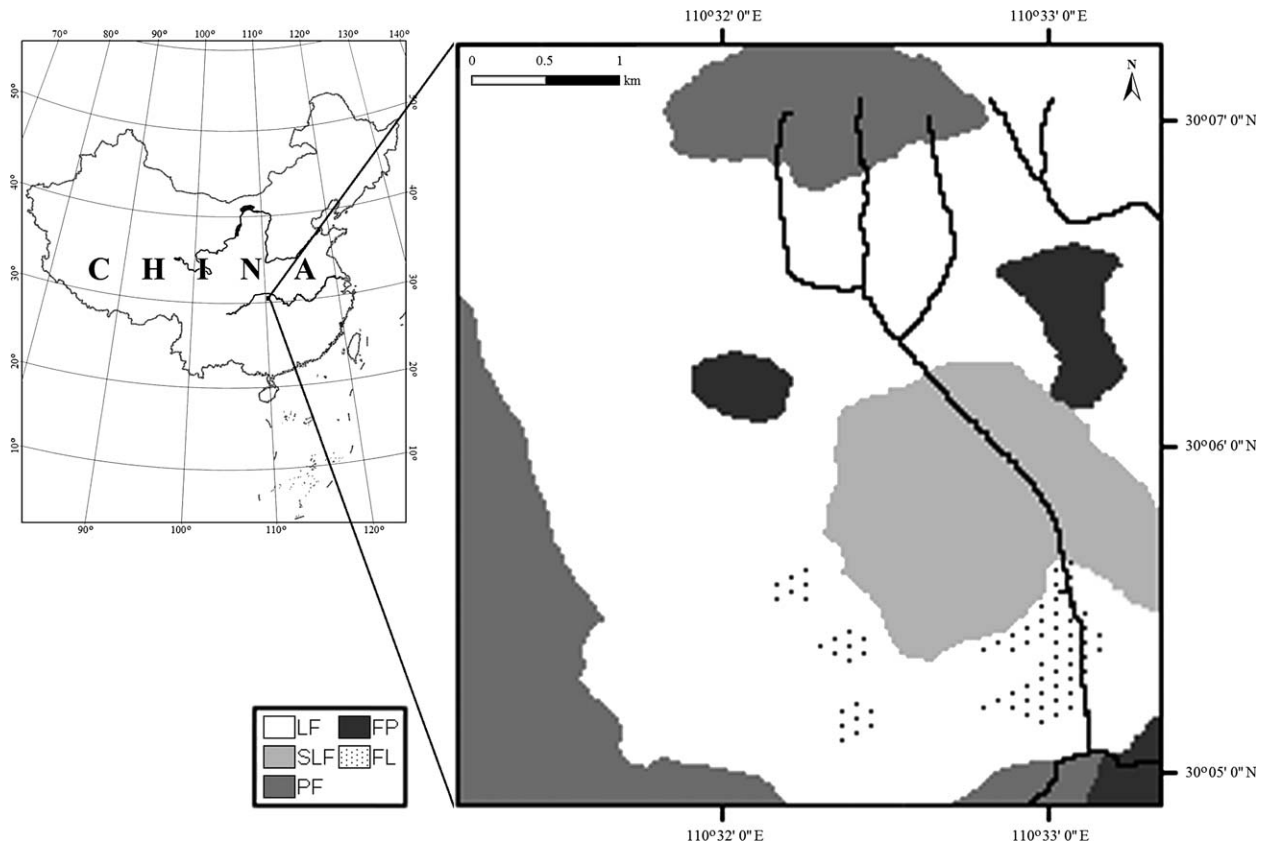


FIG. 1.—Map of the study area in Houhe National Nature Reserve in central-south China. The extent and distribution of the 5 primary habitat types (PF, primary forest; SLF, selectively logged forest; LF, logged forest; FP, forest plantation; FL, farmland) that occur within the study area are shown; solid lines denote streams.

however, about the sociobiology or ecology of masked palm civets. Existing information is limited to descriptions of the sleeping sites of 5 individuals (Wang 1999; Wang and Fuller 2001), the ranging behavior and activity patterns of 2 translocated individuals in Thailand (Rabinowitz 1991; Grassman et al. 1998), dietary habits from fecal analysis (Wang and Fuller 2003; Zhou et al. 2008; Matsuo and Ochiai 2009), nocturnal activity patterns from camera trapping (Chen et al. 2009), and the observation that farmed masked palm civets are less active in winter, suggesting that they may hibernate (Zhang et al. 1991; Kang et al. 1997).

Home range, as defined by Burt (1943), is the area traversed by an individual during the course of its normal foraging, mating, and parental activities (Ford and Krumme 1979), where resource dispersion and energetic budgets are key factors determining territory size, shape, and extent of segregation, therefore affecting sociospatial organization (Carr and Macdonald 1986; Mitchell and Powell 2012). Analyses of home-range metrics and movement patterns are therefore pertinent to a broader understanding of sociobiology (Macdonald 1983), and fundamental to a species' natural history (Börger et al. 2008; Powell and Mitchell 2012).

The objectives of this study are to investigate home-range metrics of the masked palm civet in China, including home-range size and use, exclusivity or overlap, and interactions

between sexes; whether activity levels decreased in winter, suggestive of torpor, semihibernation, or hibernation; and the extent of sexual dimorphism in body size.

MATERIALS AND METHODS

Study area.—This study was conducted in the Houhe National Nature Reserve (30°2'45"–8'40"N, 110°29'25"–40'45"E), Hubei Province, central-south China (Zhou et al. 2008, 2013a), which is located in the transitional belt between the middle and northern subtropical zones (Fig. 1). It has a mean annual temperature of 11.5°C, mean annual precipitation of 1,814 mm, and 4 distinct seasons (cold winter, variable and transitional conditions in spring, hot and humid summer, and warm autumn; Köppen climate classification = Cfa). Elevations in the study area ranged from 1,000 to 1,800 m with subalpine habitat conditions and rugged dolomite and limestone geology (Song and Liu 1999).

Animal capture.—We live-trapped and radiocollared masked palm civets from June 2004 to November 2007 during 2 or 3 trapping sessions each year. We used 2 trap designs: 20 wire-mesh live traps (80 × 40 × 30 cm) and 30 traditional wooden live traps made locally (triangular with sides 100 cm long and an interior depth of 40 cm). Traps were placed 100 m apart in areas with evidence of recent civet activity (fresh scats, tracks,

or foraging sites), and left in place for at least 2 months before being moved to new locations. Traps were positioned under cover (e.g., leaves, branches, or bamboo) to provide shade for captured animals, and the trap floor was covered with soil and leaf litter to maintain continuity with the surrounding substrate (Jennings et al. 2006). Wild fruit and dead chickens were used as bait and placed at the back of the trap. Traps were left open continuously and checked each morning and afternoon.

Captured individuals were weighed and then sedated using Telezol (tiletamine hydrochloride and zolazepam hydrochloride) or Ketaset (ketamine hydrochloride; both products from Beijing Double-crane Pharmaceutical Co., Ltd., Beijing, China) at a dosage of 10 mg/kg body mass (Zhang et al. 2010). Most civets became immobile within 5 min of injection and remained so for at least 30 min. During immobilization, we measured head–body and tail lengths, determined sex from external genitalia, and evaluated reproductive status from teat condition in females and testes descent in males (Jennings et al. 2010). Study animals were classified in 1 of 4 age classes: juvenile (relatively small body size and deciduous teeth still present; < 1 year), young adult (almost full size but not sexually mature; 1–2 years), adult (full size and showing signs of sexual maturity; > 2 years), and old adult (full size with advanced tooth wear—Jennings et al. 2010). Study animals were placed back into the trap and allowed to recover fully for 3–4 h before being released at the site of capture. To increase sample sizes for investigations of sexual dimorphism in body size (Jennings et al. 2006), we also took morphometric measurements on adult civets road-killed between May 2007 and March 2008.

Masked palm civets were captured and radiocollared in collaboration with the Wildlife Conservation Station, Wufeng County Forestry Bureau, in Hubei Province, China, with approval from the the State Forestry Administration of China and the Ethics Committee of the Chinese Academy of Sciences. Our protocols followed the guidelines of the American Society of Mammalogists (Sikes et al. 2011) for the use of wild mammals in research and teaching.

Radiotracking.—We tracked radiocollared civets on foot using a handheld, 3-element folding AY/C yagi antenna attached to a 26-K receiver (Titley Electronic, Pty., Ltd., Ballina, New South Wales, Australia). To monitor their status and condition after capture and handling, all study animals were tracked immediately after release. To account for behavioral changes that may have resulted from these activities, the first 3 days of radiotracking data were excluded from home-range analyses.

To investigate variation in space-use among individuals, we radiotracked civets at 2 levels of resolution. High-resolution movement data were based on 3 consecutive days (72-h period) of intensive tracking each month, recording contemporaneous locations and activities at 15-min intervals on a subsample of radiocollared animals. Lower-resolution movement data were based on 3–5 fixes per week for all collared animals.

Study animals were located using ground-based triangulation (Macdonald and Amlaner 1980); for each location, 3–5

bearings were taken by a single observer at global positioning system points established along trails, with a maximum of 5 min between successive bearings to reduce error due to movement of the study animal (Jennings et al. 2006). Locations were established when 3 or more bearings intersected at 1 location. The reliability of telemetry locations was confirmed by civet sightings and tracks, whenever possible. Masked palm civets undergo significant seasonal changes in body mass, and juveniles grow rapidly (Zhang et al. 1991; Kang et al. 1997). We therefore fitted radiocollars as loosely as possible to avoid constriction injuries (Koehler et al. 2001).

Home-range estimation.—To avoid autocorrelation, we used only independent point locations in home-range estimates (Swihart and Slade 1985), based on the time required for fixes to be independent. We estimated time to independence as the time after which the location of the animal between consecutive fixes is no longer dependent upon its location in the previous fix. For some study animals, independence may never have been attained if their movements occurred at relatively small spatial scales. For these individuals, the time interval with the least dependence was used (Colón 2002). We calculated home-range sizes using 100%, 95%, 75%, and 50% minimum convex polygon (MCP) methods (MCP100, MCP95, MCP75, and MCP50, respectively). This approach facilitated comparisons to other studies that have reported data on civet home ranges (Rabinowitz 1991; Joshi et al. 1995; Grassman et al. 1998; Wang 1999; Colón 2002; Jennings et al. 2006, 2010; Nakashima et al. 2013). Comparison of MCP100 and MCP95 home ranges enabled us to identify outliers that resulted from occasional long-distance forays (Colón 2002; Jennings et al. 2010), whereas MCP75 and MCP50 were used to delineate core use areas (Zhang et al. 2010; Powell 2012) for comparisons with other studies (Rabinowitz 1991; Wang 1999; Jennings et al. 2006, 2010). Carnivores typically exhibit site fidelity and live in discrete areas (where they know the locations of resources, escape routes, and potential mates) for long periods (Palomares 1994; Phillips et al. 1998; Costello 2010), enabling the calculation of contemporaneous home-range overlap (Powell 2000, 2012; Fieberg and Kochanny 2005). Following Fieberg and Kochanny (2005), home-range overlap was defined as:

$$HR_{i,j} = A_{i,j}/A_i,$$

where $HR_{i,j}$ represents the proportion of animal i 's home range that is overlapped by animal j 's home range, A_i represents the area of animal i 's home range, and $A_{i,j}$ represents the area of overlap between the 2 animals' home ranges.

Movement patterns.—To determine how far animals traveled each day (24-h period beginning at noon), we used the accumulated distance between locations taken every 15 min during each 72-h intensive tracking period. Movement patterns were characterized by calculating the following parameters (Colón 2002; Schmidt et al. 2003; Ayalew et al. 2013):

- 1) daily linear distance (DLD): the sum of straight-line distances between consecutive locations recorded at 15-

TABLE 1.—Morphometric measurements taken on adult masked palm civets (*Paguma larvata*) in Houhe National Nature Reserve in central-south China ($\bar{X} \pm SE$). Sample sizes for each group are shown in parentheses.

| | All adults (33) | Males (16) | Females (17) | <i>t</i> | <i>P</i> |
|-----------------------|------------------|------------------|------------------|----------|----------|
| Body mass (kg) | 4.22 \pm 0.06 | 4.24 \pm 0.09 | 4.20 \pm 0.08 | 0.306 | 0.762 |
| Head–body length (cm) | 53.73 \pm 0.42 | 53.88 \pm 0.56 | 53.60 \pm 0.64 | 0.321 | 0.750 |
| Tail length (cm) | 48.28 \pm 0.64 | 48.68 \pm 0.89 | 47.89 \pm 0.92 | 0.616 | 0.542 |

min intervals during continuous 24-h radiotracking sessions;

- 2) daily movement range (DMR): the area encompassing the daily movement route (MCP100) during continuous 24-h radiotracking sessions;
- 3) daily movement extent (DME): the largest extent of DMR;
- 4) straight-line distance (SLD): the distance between noon locations on consecutive days;
- 5) the ratio SLD/DLD: characterizes variation in civet movements, which theoretically ranges from 0 (if an individual returned to its location of origin after 24 h) to 1 (if the individual moved only along a straight-line trajectory); and
- 6) the intensity of movements (IM): length of the route (m) the civet moved per 1 km² of its total home range (THR) per day, calculated as DLD/THR; this index describes how intensively civets use their home ranges (i.e., whether daily routes were diffuse or concentrated).

Activity regime.—Activity was determined based upon the nature of the telemetry signal (Joshi et al. 1995; Colón 2002; Zhang et al. 2010). An animal was recorded as “active” if there was fluctuation in the signal strength, and “inactive” if the signal strength was steady (Jennings et al. 2006, 2010). Activity was monitored at 2 timescales: during the 3 days of intensive radiotracking each month and, whenever possible, intensive activity data were collected for all collared animals for 6–12 h per week. During these monitoring periods, an animal’s activity was recorded every 15 min. Mean activity rate per civet per month was calculated by dividing the number of active records by the total number of intensive 24-h tracking periods.

Data analysis.—All spatial analyses were conducted using Arcview 3.3 Animal Movement software with the Home Range Extension (Rodgers and Carr 1998). For parametric analysis of variance (*F*) and *t*-tests, assumptions of normality and homoscedasticity were tested prior to data analyses using Kolmogorov–Smirnov tests. Nonparametric Mann–Whitney and Kruskal–Wallis tests were used when parametric assumptions were not met. Statistical significance was set at $\alpha \leq 0.05$ (2-tailed test). All statistical analyses were performed in R version 2.14.1 (R Development Core Team 2012). Data are presented as mean \pm SE, unless otherwise noted.

RESULTS

Capture rates and morphometrics.—During 8,126 trap-nights from 12 July 2004 to 16 September 2007, we captured, examined, and measured 29 masked palm civets (15 females

and 14 males, including 13 juveniles, 4 young adults, 10 adults, and 2 older adults). The mean capture rate was 1 civet per 72.0 \pm 8.8 trap-nights (range = 10–188 trap-nights). The mean capture rate for box traps was 1 capture per 46.2 \pm 5.3 trap-nights (5 captures in 2,012 trap-nights) and, for traditional traps, 1 capture per 77.4 \pm 10.3 trap-nights (24 captures in 6,114 trap-nights); however, no significant difference in trapping success was detected between the 2 trap designs (Mann–Whitney test, $Z = 1.213$, $P = 0.225$). The mean capture rate differed among years (Kruskal–Wallis test, $\chi^2 = 7.956$, $P = 0.047$), but not among age classes (Kruskal–Wallis test, $\chi^2 = 2.527$, $P = 0.470$), nor between sexes (Mann–Whitney test, $Z = 0.960$, $P = 0.337$). Significantly more trap-nights were required to capture a civet in year 2 of the study (2005: 107.2 \pm 19.1 trap-nights) compared to year 1 (2004: 44.6 \pm 5.3 trap-nights; Bonferroni corrected, $P = 0.011$); other years were not significantly different (2006: 63.0 \pm 14.6 trap-nights, $P = 0.186$; 2007: 74.0 \pm 8.0 trap-nights, $P = 0.726$).

To test for sexual dimorphism in masked palm civets, we took external measurements on 17 adult females and 16 adult males (12 captures and 21 roadkills). No significant differences in body mass, head–body length, or tail length were detected between sexes (Table 1). In addition, no significant differences were detected between data sources ($t_{31} = 0.014$ – 1.861 , $P > 0.05$ for all measurements).

Home-range sizes.—We selected a subsample of 12 civets (7 females and 5 males) for radiotracking, based on body condition as a proxy for good health (Table 2). Eight civets were fitted with GP1-C collars manufactured by Titley Electronic, Pty., Ltd. (2-year life span) and 4 were fitted with TW-3 collars manufactured by Biotrack Ltd. (Wareham, Dorset, United Kingdom; 1-year life span). Two study animals shed their collars within 1 month and were therefore excluded from home-range analyses (F04 and M06; Table 2). We monitored the remaining 10 civets (6 females and 4 males), for 1–15 months (5.36 \pm 1.38 months), yielding a total of 2,501 locations (Table 2). All home-range sizes reached an asymptote after 20 independent locations. Radiotracking data, including the number of independent data points used to delineate home-range boundaries for each animal, are presented in Table 2. The average size of MCP95 home ranges for all study animals was 192.6 \pm 42.6 ha (range = 64–451 ha; Fig. 2), with no significant difference among age classes (Kruskal–Wallis test: $\chi^2 = 1.390$, $P = 0.499$). Males generally had larger home ranges than females (276.8 \pm 77.4 ha, range = 74–451 ha, $n = 4$ versus 136.5 \pm 38.3 ha, range = 64–293 ha, $n = 6$, respectively); but these differences were not significant (Mann–Whitney test: $Z = 1.390$, $P = 0.171$).

TABLE 2.—Radiotracking data for 12 masked palm civets (*Paguma larvata*) captured from August 2004 to November 2007 in Houhe National Nature Reserve in central-south China. MCP = minimum convex polygon.

| Study animal | Sex | Age class | Body mass (kg) | No. locations | | Home-range size (ha) | | | |
|--------------|--------|-------------|----------------|---------------|-------------|----------------------|-------|-------|-------|
| | | | | Total | Independent | MCP100 | MCP95 | MCP75 | MCP50 |
| M01 | Male | Adult | 4.3 | 46 | 27 | 153 | 74 | 19 | 9 |
| F02 | Female | Adult | 4.2 | 148 | 78 | 580 | 293 | 17 | 8 |
| M03 | Male | Young adult | 3.5 | 133 | 45 | 392 | 288 | 63 | 18 |
| F04 | Female | Juvenile | 2.8 | 0 | 0 | — | — | — | — |
| F05 | Female | Young adult | 3.8 | 110 | 39 | 507 | 64 | 5 | 4 |
| M06 | Male | Adult | 4.5 | 33 | 8 | — | — | — | — |
| F07 | Female | Adult | 4.5 | 678 | 303 | 194 | 95 | 28 | 6 |
| F08 | Female | Juvenile | 2.1 | 80 | 48 | 274 | 211 | 66 | 13 |
| F09 | Female | Juvenile | 2.4 | 29 | 23 | 136 | 74 | 11 | 4 |
| M10 | Male | Adult | 4.5 | 896 | 553 | 893 | 294 | 58 | 16 |
| F11 | Female | Adult | 3.5 | 197 | 128 | 187 | 82 | 14 | 4 |
| M12 | Male | Adult | 4.6 | 151 | 81 | 584 | 451 | 314 | 145 |

MCP95 home ranges for adult civets averaged 214.9 ± 63.2 ha (range = 74–451 ha, $n = 6$) in size.

The MCP75 core areas (59.5 ± 29.2 ha, range = 5–314 ha) averaged only 14.7% ($n = 10$, $SE = 4.9\%$) of the MCP100 areas (390.0 ± 78.5 ha, range = 136–893 ha) and accounted for < 20% of the total range for 8 individuals. MCP50 core areas (22.7 ± 13.7 ha, range = 4–154 ha) averaged only 5.2% ($n = 10$, $SE = 2.2\%$) of MCP100 (< 4% for 6 individuals), and core areas were almost always located centrally.

Mean home-range overlap.—We observed substantial amounts of home-range overlap both within and between sexes (Fig. 2). Mean overlap for MCP95 home ranges for all radiotracked civets was $15.5\% \pm 2.9\%$ ($n = 90$), and was similar for adults only ($15.5\% \pm 5.5\%$, $n = 30$); no significant differences were detected between adult and juvenile or young-adult civets ($t_{76} = 0.394$, $P = 0.695$). Among adults, the mean

contemporaneous home-range overlap was $16.2\% \pm 12.1\%$ ($n = 6$) for females and was $20.9\% \pm 16.4\%$ ($n = 6$) for males; no significant differences were detected between the sexes (Mann–Whitney test: $Z = 0.191$, $P = 0.937$). For all adults, mean home-range overlap between sexes was $13.5\% \pm 6.8\%$ ($n = 18$). However, range overlap was more extensive among certain individuals (F02, M03, and F07: $61.3\% \pm 11.3\%$, $n = 6$; and M01, F08, F10, and F11: $64.7\% \pm 8.6\%$, $n = 12$; Fig. 2), which may indicate the presence of spatial groups or cliques.

Movement patterns.—Eighty-four continuous 24-h records of the movements of 5 civets (3 females and 2 males) yielded sufficient data to support statistical analysis of movement patterns. Mean values for DMR, DME, and DLD were significantly greater for males than for females ($P < 0.001$; Table 3), whereas IM was significantly lower for males than for females ($P < 0.001$; Table 3). The greatest distance traveled in a 24-h period was 15.5 km by an adult male in June 2007; this individual also recorded the 2nd longest distance movement of 2.9 km in November 2006. Based on MCP95 home ranges, the largest area used in a 24-h period was 232.7 ha by an adult male in September 2007.

Activity rhythms.—A total of 2,516 h of continuous monitoring yielded 10,209 activity records for 11 of 12 radiocollared animals. Mean overall activity by males ($35.5\% \pm 15.3\%$ SD, $n = 68$) was not significantly different from that of females ($36.0\% \pm 17.2\%$ SD, $n = 77$; $t_{143} = -0.173$, $P = 0.143$). Civets were significantly more active from 1800 to 0559 h ($61.4\% \pm 24.3\%$ SD, $n = 100$) compared with 0600–1759 h ($23.7\% \pm 13.4\%$ SD, $n = 145$; $t_{243} = 15.560$, $P < 0.001$; Fig. 3). During the night, there was usually a distinct peak in activity from 2300 to 0059 h, and in the daytime, from 0800 to 1059 h, revealing that periods of activity were often separated by rest periods. Despite limitations of sample size, no significant differences in activity rates, calculated as hours of activity per day in each month, were detected among months (Kruskal–Wallis test: $\chi^2 = 15.762$, $P = 0.150$); the lowest level of activity was in August (38.9%), and the highest was in May (60.1%; Fig. 4).

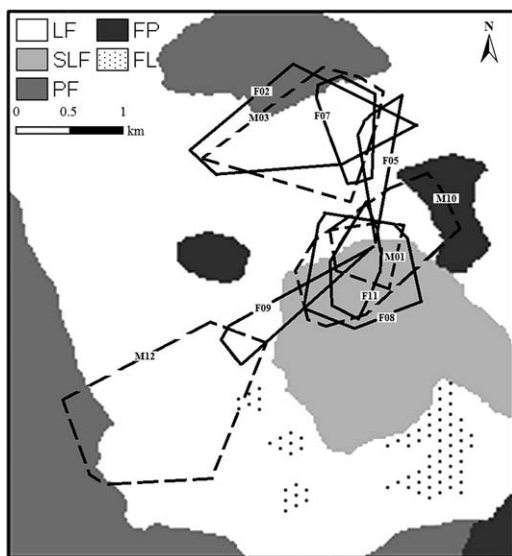


FIG. 2.—Home ranges of 10 masked palm civets (*Paguma larvata*) radiotracked in Houhe National Nature Reserve in central-south China using the 95% minimum convex polygon method. The sex and number of each study animal is indicated on each polygon.

TABLE 3.—Movement characteristics of masked palm civets (*Paguma larvata*) in Houhe National Nature Reserve in central-south China. DMR = daily movement range; DME = daily movement extent; DLD = daily linear distance; SLD = straight-line distance of daily movements; and IM = intensity of movements. Values are mean \pm SE (ranges).

| | Total | Female | Male | <i>t</i> | <i>P</i> |
|-------------------------|--|-----------------------|--------------------|----------|----------|
| <i>n</i> | 84 | 42 | 42 | | |
| DMR (ha) | 39.26 \pm 5.24 (0.50–232.73) | 17.41 \pm 3.17 | 61.11 \pm 8.82 | 4.66 | < 0.001 |
| DME (km) | 1.44 \pm 0.08 (0.13–2.86) | 1.01 \pm 0.08 | 1.87 \pm 0.09 | 7.22 | < 0.001 |
| DLD (km) | 5.60 \pm 0.35 (0.43–15.46) | 3.55 \pm 0.31 | 7.64 \pm 0.45 | 7.48 | < 0.001 |
| SLD (km) | 0.55 \pm 0.06 (0.00–2.72) | 0.36 \pm 0.06 | 0.73 \pm 0.09 | 3.33 | 0.001 |
| Ratio SLD/DLD | 0.12 \pm 0.02 (0.00–0.93) | 0.14 \pm 0.03 | 0.10 \pm 0.01 | 1.32 | 0.189 |
| IM (m/km ²) | 1,204.17 \pm 80.99 (229.64–3,778.69) | 1,489.50 \pm 139.46 | 918.84 \pm 56.00 | 3.80 | < 0.001 |

DISCUSSION

Home ranges.—Considerable regional variation in home-range sizes has been found for common palm civets (*Paradoxurus hermaphroditus*—Rabinowitz 1991; Joshi et al. 1995; Grassman et al. 1998) and Malay civets (*Viverra zibellina*—Colón 2002; Jennings et al. 2006, 2010), which is thought to result from differences in habitat quality (Colón 2002; Jennings et al. 2006, 2010) or food availability (Joshi et al. 1995; Colón 2002). Although we observed considerable variation in home-range sizes among individuals (64–451 ha), our values were similar to those reported by Wang (1999) for masked palm civets in subtropical habitats (182–410 ha), and to values of 370 and 590 ha reported for a single male and female, respectively, in tropical forests by Rabinowitz (1991) and Grassman et al. (1998).

Male spatial organization in carnivores is influenced not only by the dispersion of food but also by the dispersion of females (Macdonald 1983; Gehrt and Fritzell 1998). Although sexual dimorphism in home-range sizes has not been reported previously for other civet species (Colón 2002; Jennings et al. 2010), we found that the average home-range size for males (276 ha) was almost twice that for females (136 ha); we also

observed differences in maximum and minimum home-range sizes between sexes. These differences were not statistically significant, however, suggesting that our analyses may have been limited by small sample sizes.

We observed overlapping home ranges in our study, especially within sexes. Similar patterns have been found for common palm civets in Nepal (Joshi et al. 1995) and Malay civets in Borneo (Macdonald and Wise 1979; Colón 2002), but not for Malay civets in Sulawesi and Peninsular Malaysia (Jennings et al. 2006, 2010). Joshi et al. (1995) found that home-range overlap in common palm civets was minimal when food was abundant and uniformly distributed, and increased when food patches were more clumped in distribution; they concluded that the lack of territoriality indicated that food resources were either too abundant to warrant defense or too sparse to be efficiently defended. Colón (2002) also speculated that spatial and temporal variation in the abundance and distribution of food resources in rain forests might account for the overlapping home ranges of Malay civets in Borneo, whereas Jennings et al. (2006, 2010) posited that spatiotemporal variations in diet and food availability may account for the different spatial organization they observed in Peninsular

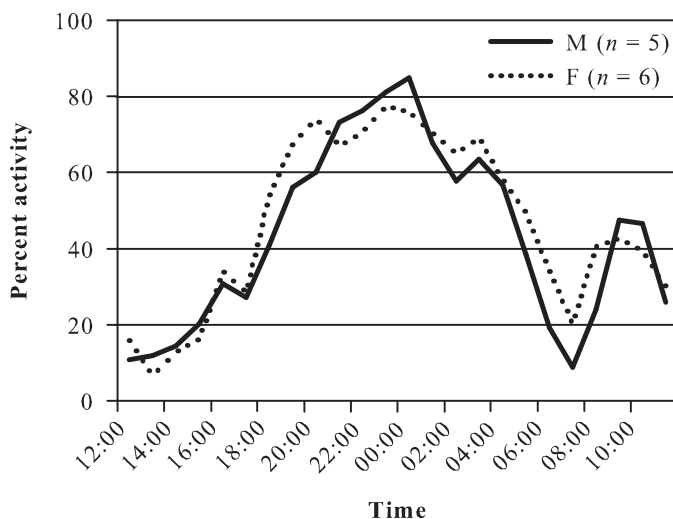


FIG. 3.—Mean percent activity levels of 11 masked palm civets (*Paguma larvata*) radiotracked in Houhe National Nature Reserve in central-south China. Dawn occurred at about 0600 h and dusk at about 1800 h.

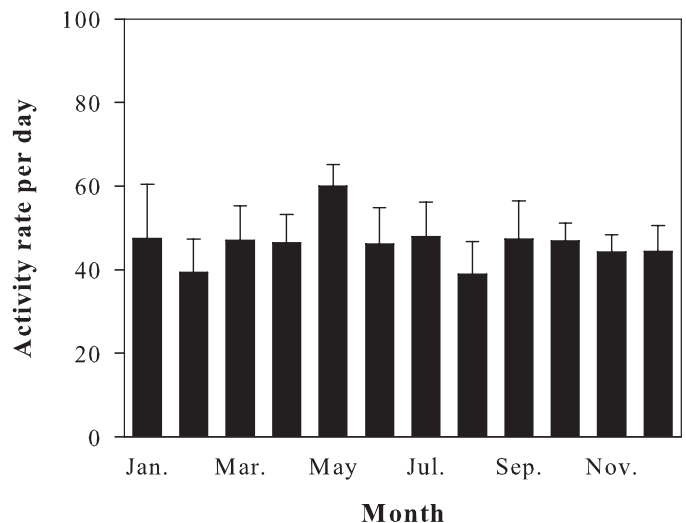


FIG. 4.—Monthly variation in mean daily activity rates during intensive 24-h tracking of 5 masked palm civets (*Paguma larvata*; 3 females and 2 males) in Houhe National Nature Reserve in central-south China.

Malaysia and Sulawesi. These findings align closely with the resource dispersion hypothesis (see Macdonald 1983; Carr and Macdonald 1986; Johnson et al. 2002), where exclusive home ranges in carnivores are expected only when food resources are stable and evenly distributed (Macdonald 1983; Sandell 1989). We thus speculate that observed home-range overlaps in masked palm civets may be related to shifting seasonal dynamics in the availability and distribution of food resources in our high-elevation subtropical study area (Zhou et al. 2008, 2011).

Movements.—Masked palm civets moved relatively long distances each day, traversing their home range through a dense network of tortuous routes. Although we observed masked palm civets climbing trees, these routes represent only their linear movement patterns, mapped in 2 dimensions. Few other studies on wild civets presented detailed analysis of 24-h movements, and most previous studies present only data on straight-line distances between consecutive daily locations. For example, Wang (1999) reported mean Euclidean distances between consecutive day-bed sites for 4 individuals in a similar subtropical habitat, ranging from 0.2 to 0.7 km; and Rabinowitz (1991) and Grassman et al. (1998) reported distances of 0.6 and 0.9 km for a male and female, respectively, in tropical forests. Our study produced similar values when we calculated movement distances that way (0.6 ± 0.1 km, range = 0–2.7 km). Other civets (except for the large Indian civet [*Viverra zibetha*], which had greater straight-line distances: range = 0.8–3.7 km [Rabinowitz 1991]) also had daily relocation distances within this range (Malay civet: range = 0.3–0.4 km [Jennings et al. 2006]; and common palm civet: range = 0.2–1.0 km [Rabinowitz 1991; Grassman et al. 1998]).

Male and female spacing patterns and movements are typically the product of different reproductive strategies and behaviors during the breeding season (Macdonald 1983; Sandell 1989; Colón 2002). Female masked palm civets used a smaller total area and a smaller proportion of their total home ranges than did males, which may be linked to time periods when females have dependent young. The only female with young that we monitored (F07; Table 2) exhibited particularly limited and highly localized movements in the vicinity of the den. Masked palm civets are polyestrous and promiscuous (Jia et al. 2002); thus, the greater daily movement distances and extents exhibited by males may increase their chances of reproducing with more females (Schmidt et al. 2003) or their foraging efficiency (Manfredi et al. 2011), and may contribute to home-range defense (Sandell 1989).

Activity.—Masked palm civets are mainly nocturnal and this may be linked to the availability of small mammal prey (Zhou et al. 2008), which are part of their diet, although fruit also is a major dietary component (Wang and Fuller 2003). Masked palm civets also may be vulnerable to larger predators and adjust their activity patterns to avoid them (Palomares and Caro 1999). Joshi et al. (1995) observed that common palm civets were susceptible to predation in Nepal. Larger predators are no longer present in our study area (tigers [*Panthera tigris*] and leopards [*Panthera pardus*] were present historically);

consequently, the “ghosts of predators past” (sensu Connell 1980) also could contribute to their nocturnality (see also Burnham et al. 2012).

Zhang et al. (1991) and Kang et al. (1997) reported that masked palm civets held in captivity (farmed animals) decreased their activity levels in winter, suggesting that they hibernate or semihibernate. However, we found no statistically significant differences in monthly activity rates among our study animals (Fig. 4). Moreover, we detected no continuous periods of torpor (inactivity) during the winter months. Day length varies by only 2 h between summer and winter solstice in our subtropical study area. However, masked palm civets still maintained 39–47% of their typical daily (1200 h to 1200 h) activity rates from December through February (Fig. 4), which probably reflects the greater energetic costs of foraging in cold temperatures (Zhou et al. 2008, 2013b).

Ours is the 1st study to provide detailed and reliable information on the morphology, sexual dimorphism, movements, activity patterns, and spatial organization of the masked palm civet. Sociality in palm civets has not been described previously; however, some individuals exhibited extensive home-range overlap, indicating that group living (at least cliques) may occur in this species under certain circumstances (sensu Macdonald 1983). In the future, we plan to investigate the potential implications of such range overlaps in the social organization of the masked palm civet.

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