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COMMUNICATION

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Kangaraj Muthamizh Selvan, Bawa Mothilal Krishnakumar, Pasiyappazham Ramasamy & Thangadurai Thinesh

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Abstract: Sympatric and similar body-sized species exhibit interspecific competition for resources. The present study investigated diel activity of five meso-carnivore species (*Canis aureus*, *Felis chaus*, *Paradoxurus hermaphroditus*, *Viverricula indica*, and *Herpestes edwardsii*) in a human-dominated region of Auroville and around Pondicherry University using camera-trap survey data. Diel activity pattern and overlap were estimated using the kernel density method. The Jungle Cat *Felis chaus* and the Golden Jackal *Canis aureus* exhibited cathemeral diel activity with a high overlap between them ($\hat{\Delta}_1 = 0.78$). The Indian Grey Mongoose *Herpestes edwardsii* displayed a diurnal activity pattern and had low overlap with the Small Indian Civet *Viverricula indica* ($\hat{\Delta}_1 = 0.34$). Moderate overlap was found between the Small Indian Civet and the Palm Civet *Paradoxurus hermaphroditus* ($\hat{\Delta}_1 = 0.32$). Therefore, diel activity patterns of mesocarnivores indicate inter- and intra-specific trade-off competition avoidance resulting in successful foraging. The present camera-trap survey has provided insights into diel activity patterns and more attention is required to be paid to the study of feeding and breeding ecology of these species in human-dominated landscapes.

Keywords: Camera trap, competition avoidance, diurnal, nocturnal, overlap.

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INTRODUCTION

Interspecific competition among carnivores is one of the significant factors which regulate the natural population and therefore determine community diversity (Cruz et al. 2018). Interspecific competition is greatly recognized when competing species are similar in eco-morphology or phylogenetic-proximity and diet adaptations (Morin 1999). A successful species has to forage optimally, find a potential mate, reduce rivals with conspecifics and avoid encounter with predators (Ross et al. 2013). The dominant species may exclude subordinate species from their territory through competition (Polis et al. 1989). The subordinate species usually are displaced to suboptimal habitats, which are less fertile environments, or have the high impact of anthropogenic pressures (Steinmetz et al. 2013). In this kind of situation, coexistence may be facilitated by temporal shift (Case & Gilpin 1974; Carothers & Jaksic' 1984).

A mammalian carnivore is ecologically important as it directly influences the structure and function of an ecosystem (Roemer et al. 2009). Though carnivore guilds are wide, small- to medium-sized mammalian carnivores with less than 15kg body weight are collectively called meso-carnivores (Buskirk 1999; Roemer et al. 2009). The meso-carnivores occurring in forest fragments and disturbed habitats may also serve as indicator species for environmental change (Justina 2000). In India, larger carnivores have received more research and conservation attention than meso or smaller carnivores (Kalle et al. 2013). Here we report the diel activity patterns of a meso-carnivore community (*Canis aureus*, *Felis chaus*, *Paradoxurus hermaphroditus*, *Viverricula indica*, *Herpestes edwardsii*) in a human-dominated tropical dry evergreen forest landscape near the southern coastal areas of Tamil Nadu and Puducherry, India.

The Golden Jackal *Canis aureus* (body weight 8–11 kg), the Jungle Cat *Felis chaus* (2.3–8.6 kg) (Hunter 2015; Mukherjee et al. 2019), the Common Palm Civet *Paradoxurus hermaphroditus* (2.7–4.5 kg), the Small Indian Civet *Viverricula indica* (3–4 kg) and the Grey Mongoose *Herpestes edwardsii* (1.4kg) (Prater 1971; Majumder et al. 2011) are known to occur syntopically and prey on rodents (Mukherjee et al. 2004). In general, both civet species (Su & Sale 2007; Kalle et al. 2013) and Jungle Cats are found to be strictly nocturnal (Majumder et al. 2011; Athar et al. 2017), whereas, the Grey Mongoose displays purely diurnal activity (Ramesh et al. 2015). The Golden Jackals are diurnal at low anthropogenic pressure (Gupta et al. 2016), whilst they shift their activity pattern to nocturnal and crepuscular

at high human activity (Majumder et al. 2011). The present study is the first one to document activities of meso-carnivores in a tropical dry evergreen forest. The findings of the study will help the managers to strategize the management and conservation plan for these meso-carnivores in highly fragmented human-dominated landscapes.

STUDY AREA

We conducted this study in an area of 18km² that covers Auroville and its adjacent agricultural lands (belonging to Vanur Taluk of Villupuram District, Tamil Nadu) and Arana Forest, Pondicherry University campus in Puducherry (Fig 1). The vegetation of this region has been classified as tropical dry evergreen forest (TDEF) (Champion & Seth 1968). TDEF is distributed along the coasts of Karnataka, Tamil Nadu, and Nellore District of Andhra Pradesh (Daniel et al. 2007). It also occurs inland, ranging between 30km and 60km (Gamble 1967) of the southeastern seaboard of peninsular India (Champion 1936). *Manilkara hexandra*, *Memecylon* spp., *Diospyros* sp., *Eugenia* spp., *Chloroxylon sweitenia*, and *Albizia amara* (Daniel et al. 2007) are some of the dominant tree species in TDEF, in addition to other species such as *Anacardium occidentale*, *Acacia auriculiformis*, and *A. mangium*. TDEF is populated with a range of birds, mammals, reptiles, fungi and other taxa, some of which play a pivotal role in seed dispersal, pollination and other supporting services (Everard 2018). The major mammalian species are Golden Jackal, Jungle Cat, Common Palm Civet, Small Indian Civet, and the Indian Grey Mongoose. Seemingly, 69% of the trees in the coastal forests are dispersed by jackals, civets, bats and rodents (Daniel et al. 2007). The region experiences a mean annual temperature between 21.6°C and 36.4°C and precipitation between 1311mm and 1172mm (Padmavathy et al. 2010; Ponnuchamy et al. 2013).

METHODS

Camera trapping

We established 20 camera-trap stations deployed for 70 days between December 2017 and February 2018. We set up an independent camera-trap at each camera-trap station (Cuddeback C1-white flash). Cameras were housed in metal camera cases (Cuddeback bear safes) to avoid pilferage. A station was at a regular interval ranging from 1.0–3.0 km close to the animal and man-made trails and ravines to maximize the capture probability. Data were collected without scent lure. We set one-min delay

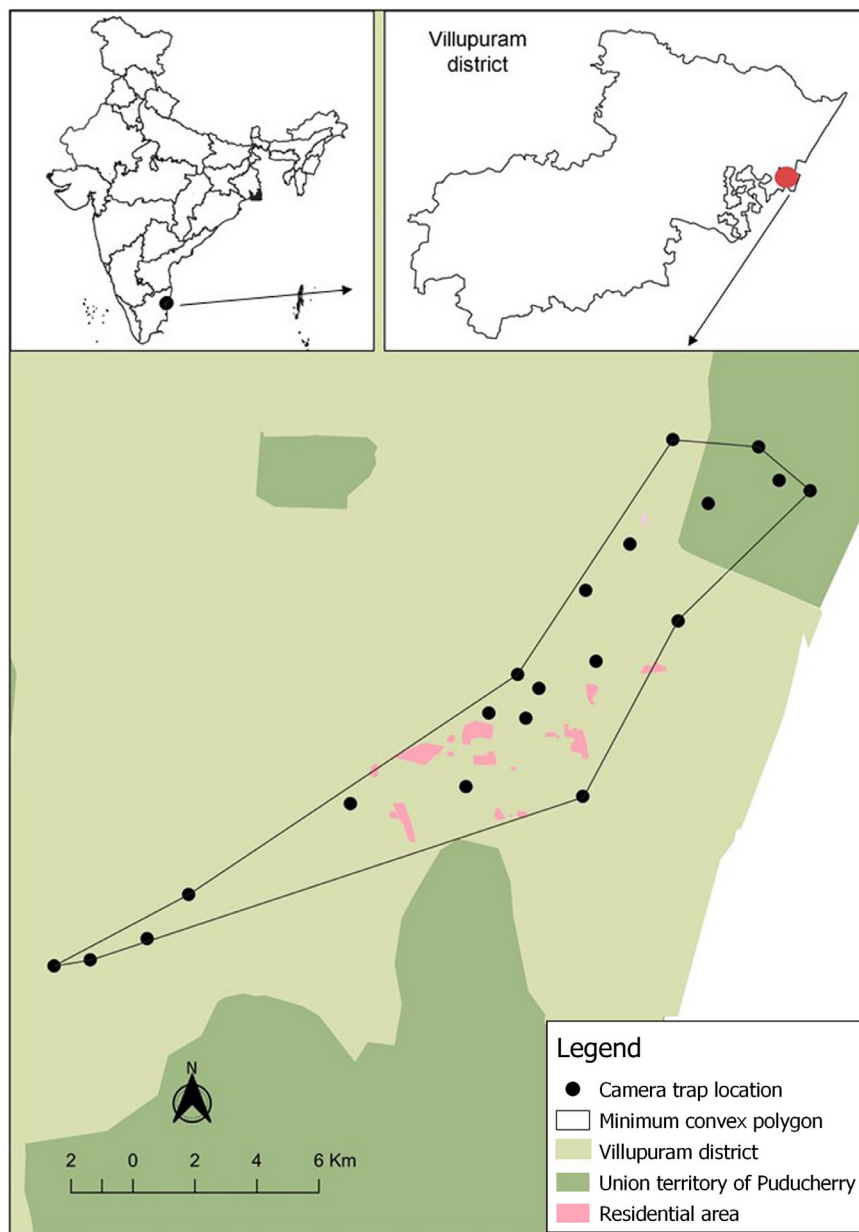


Figure 1. Location of camera traps in tropical dry evergreen in Villupuram District in Tamil Nadu, southern India.

for a subsequent capture.

Analysis of diel activity

We identified species, date, time and camera station for every camera-trap record. In addition, we defined multiple records of the same species at the same camera-trap station as independent capture when pictures were taken at least 30min apart unless we were able to unambiguously distinguish an individual (Linkie & Ridout 2011). Correspondingly, if several individuals of similar or different species were captured in a single image, each individual was considered as a distinct event (Mukherjee et al. 2019).

The timings of sunrise and sunset in the study area were recorded consistently throughout the study period. Sunrise and sunset are approximately at 06:30h and 18:00h, local time (GMT + 5), respectively. We categorized the day into three periods on the basis of sunrise and sunset; day (07:30–17:00 h), night (19:00 to 05:30 h) and crepuscular (dawn 05.30 to 07.30 h and dusk 17.00 to 19.00 h) (Gerber et al. 2012; Ross et al. 2013; Ikeda et al. 2016, 2015). Diel activity of species was classified as diurnal (<10% of records at night), nocturnal (\geq 90% of records at night), mostly diurnal (10–29 % of records at night), mostly nocturnal (70–89 % of records at night), or cathemeral (30–69% of records at night) (Gomez et al.

2005; Azevedo et al. 2018). We used a non-parametric circular kernel-density method to determine diel activity pattern and coefficient of activity overlapping (Ridout & Linkie 2009). The coefficient of overlapping ($\hat{\Delta}$) differs from 0 (no overlap) to 1 (complete overlap) (Ridout & Linkie 2009; Linkie & Ridout 2011). Analysis of species-specific activity pattern and coefficient of overlapping between two species were performed with 'overlap' R-package (Meredith & Ridout 2018) in R environment v.3.5 (R Development Core Team 2014). We have calculated the 95% confidence intervals of Δ with 1000 bootstrap to obtain bias-corrected percentile (Meredith & Ridout 2018).

RESULTS

A total of 431 independent detections were obtained from 1400 trap nights, wherein, 92 were of Common Palm Civet, 121 of Small Indian Civet, 79 of Golden Jackal, 56 of a Jungle Cat and 83 of Grey Mongoose.

Diel activity pattern

Diel activity pattern of each species is shown in Fig. 2. Indian Grey Mongoose showed a strong diurnal pattern of activity (Fig. 2). Small Indian Civet was mostly diurnal with high peak activity from afternoon to before dusk. In contrast, the Common Palm Civet was mostly nocturnal and showed two high peaks of activity, one from midnight to dawn and another right after dusk. The Golden Jackal and Jungle Cat were largely cathemeral, and they had distinct peak activity after dusk. They also were active right after midnight and right before sunrise.

Diel activity overlap

Diel activity overlap patterns of five meso-carnivores detected in the study area are presented in Fig. 3. The highest diel activity overlap was observed between the Golden Jackal and Jungle Cat with $\hat{\Delta}_1$ of 0.78 (0.66–0.87), followed by Palm Civet and Jungle Cat ($\hat{\Delta}_1$ 0.77; 0.53–0.74), and then Palm Civet and Golden Jackal ($\hat{\Delta}_1$ 0.65; 0.55–0.77). A moderate overlap was observed in small Indian Civet and Golden Jackal with $\hat{\Delta}_1$ of 0.45 (0.36–0.56), Small Indian Civet and Jungle Cat ($\hat{\Delta}_1$ 0.44; 0.35–0.55), whereas, the least overlap was observed between Common Palm Civet and Indian Grey Mongoose with $\hat{\Delta}_1$ of 0.11 (0.06–0.17), Grey Mongoose and Golden Jackal ($\hat{\Delta}_1$ 0.27; 0.18–0.37), Grey Mongoose and Jungle Cat ($\hat{\Delta}_1$ 0.28; 0.19–0.39), Palm Civet and Small Indian Civet ($\hat{\Delta}_1$ 0.32; 0.24–0.41), and between Small Indian Civet and Grey Mongoose ($\hat{\Delta}_1$ 0.34; 0.25–0.44).

DISCUSSION

The present study provides significant information in relation to temporal activity pattern of meso-carnivores in a human-modified environment. The most cost-efficient and non-invasive method of camera-trap survey provides very detailed information on diel activity patterns.

In the present study, the Jungle Cat was found to be cathemeral, which is contrary to the finding from Dachigam National Park (Athar et al. 2017) and Pench Tiger Reserve (Majumder et al. 2011), wherein it was found to be strictly nocturnal. Due to the hunting efficiency, the activity patterns of many felids highly depend on their prey's activity patterns (Harmsen et al. 2011; Bashir et al. 2013; Mugerwa et al. 2017). The main reason for the Jungle Cat being cathemeral in the study area could be because of the secondary importance of birds (e.g., Grey Francolin *Francolinus pondicerianus*, Jungle Bush Quail *Perdica asiatica*) in their diet. The Jungle Cat may have preyed more often on these birds than on nocturnal rodents which is the case in other regions (Sunquist & Sunquist 2002; Mukherjee et al. 2004; Majumder et al. 2011). Even a pair of Grey francolin was captured in a camera-trap during the study period. The temporal activity pattern of the Jungle Cat had the greatest overlap with the Golden Jackal and the Palm Civet. A detailed study of its diet could provide comprehensive details about its overlap, coexistence and competition avoidance.

The Golden Jackal exhibited cathemeral activity which correlated highly with the Palm Civet. This observation concurs with the earlier report at Pench Tiger Reserve (Majumder et al. 2011) and Bulgaria (Georgiev et al. 2015). Conversely, it contradicts the observations in Gujarat and Bangladesh (Aiyadurai & Jhala 2006; Jaeger et al. 2007), where it was reported to be active at twilight and night. Unified diel activity generally occurs between closely related and unrelated species (Stensland et al. 2003). The strong overlap in diel activity between the Golden Jackal and Palm Civet might be a foraging strategy of the former. The jackals may be feeding on the fruits dropped by the activity of the Palm Civet as the diet of the jackal has been known to include vegetative matter (Khan et al. 2017). Such synchrony has been documented in other taxa (Newton 1989; Ramesh et al. 2012). Concurrently, interspecific competition is avoided through arboreal and terrestrial feeding habits of Palm Civet (Nakabayashi et al. 2016) and Golden Jackal, respectively.

The activity of two morphologically similar-size species *P. hermaphroditus* and *V. indica*, overlapped minimally because the former was primarily active

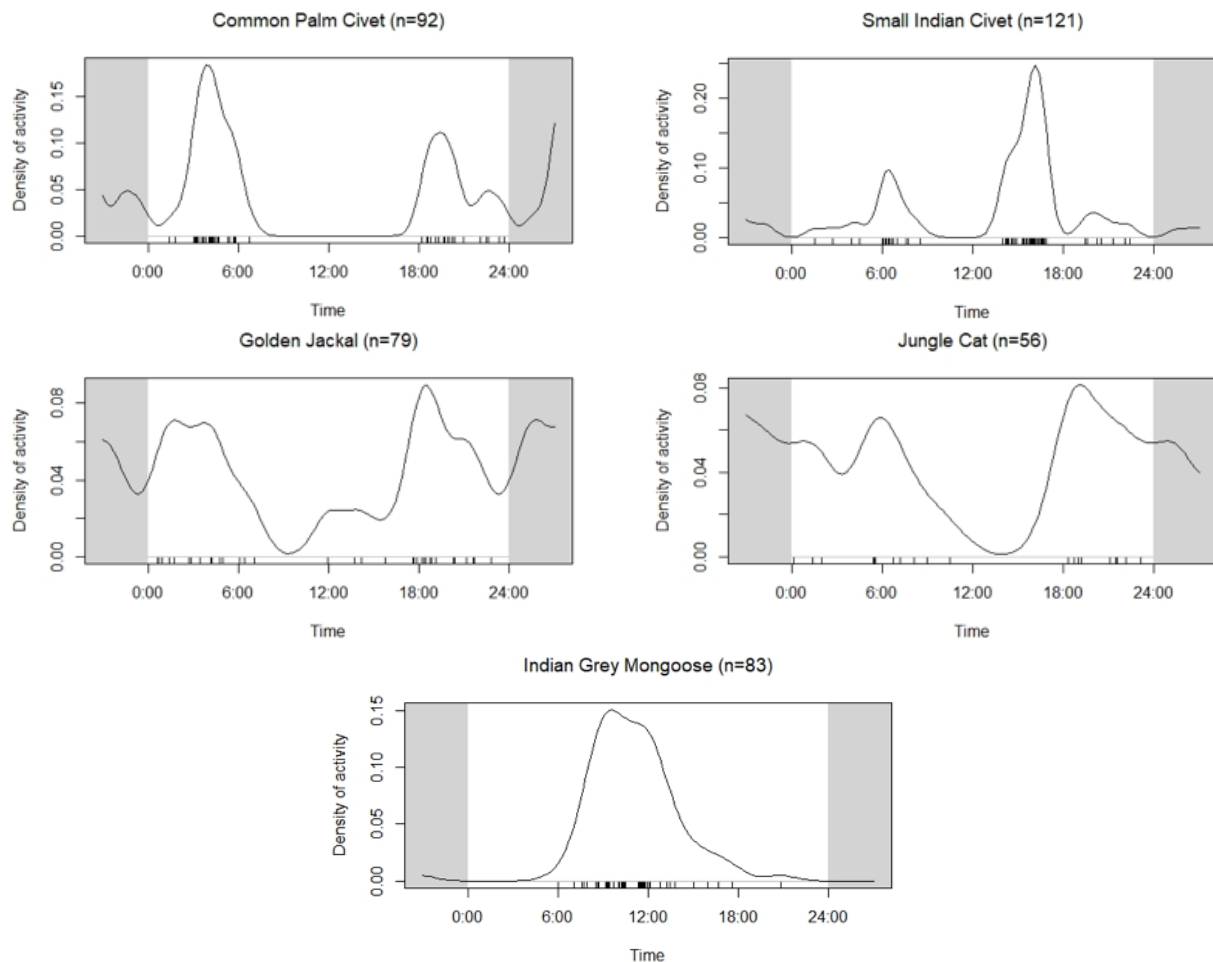


Image 2. Activity patterns of five meso-carnivores based on camera-trap surveys in the study area.

from midnight to dawn and right after dusk, while the latter was active from afternoon to before dusk. Documentation of available data on *P. hermaphroditus* and *V. indica* implies that they share a similar generalist diet, which often consist of fruits, seeds, arthropods, lizard, mice, rats and gerbils (Prater 1971; Rabinowitz 1991; Su & Sale 2007), which may account for why these two species have such dissimilar temporal activity, that in turn allows coexistence.

Though the Small Indian Civet is mostly diurnal, it exhibited a relatively high movement from afternoon to before dusk during the study period. In Hlawga Wildlife Park, Myanmar, the Small Indian Civet is active immediately after dusk (Su & Sale 2007). It could do so to avoid interspecific interference with the Jungle Cat which is active immediately after dusk. Temporal activity pattern of the Grey Mongoose had the least overlap with the Palm Civet, the Golden Jackal and the Jungle Cat, whereas, it overlapped moderately with the activity of the Small Indian Civet as it is mostly diurnal. Moreover,

the Grey Mongoose is also observed as diurnal and well acclimatized with human activity.

Though camera-traps are effective in recording temporal activity patterns, there was a certain constraint in detection probability with species. Thus, placement of the camera might be biased towards ground-dwelling animals which would consequently affect the capture rate of semi-arboreal species such as civets. The present study examining diel activity in meso-carnivores suggests no difference in activity were observed between the Golden Jackal and Jungle Cat, whereas the Small Indian Civet, Palm Civet and mongoose exhibited a difference in their activity. Diet analysis of meso-carnivore could give comprehensive information on its temporal segregation.

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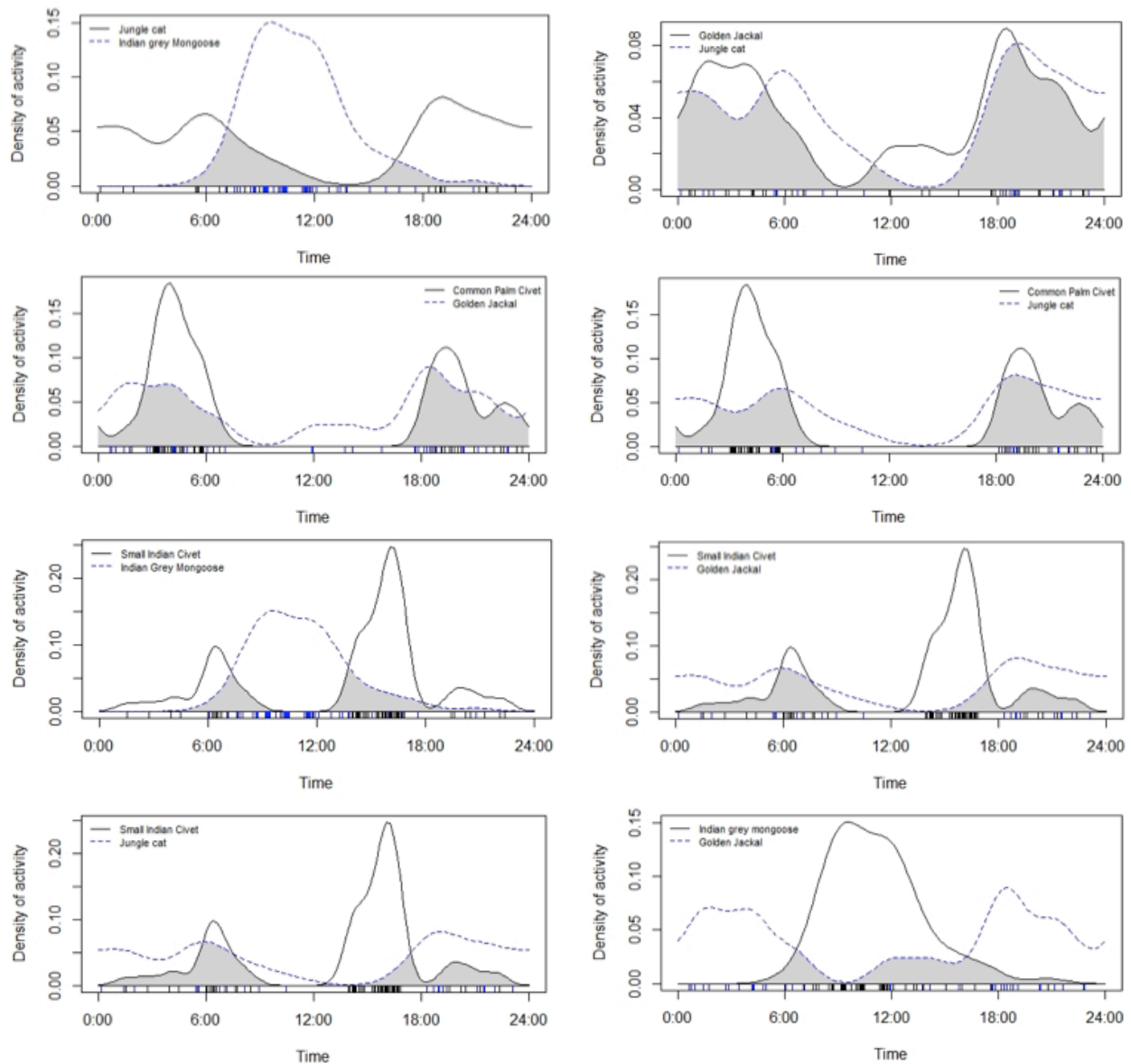


Image 3. Activity overlap of the meso-carnivores. The coefficient of overlapping is represented by the shaded area.

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Communications

The status of wild canids (Canidae, Carnivora) in Vietnam

– Michael Hoffmann, Alexei Abramov, Hoang Minh Duc, Le Trong Trai, Barney Long, An Nguyen, Nguyen Truong Son, Ben Rawson, Robert Timmins, Tran Van Bang & Daniel Willcox, Pp. 13951–13959

Diel activity pattern of meso-carnivores in the suburban tropical dry evergreen forest of the Coromandel Coast, India

– Kangaraj Muthamizh Selvan, Bawa Mothilal Krishnakumar, Pasiyappazham Ramasamy & Thangadurai Thinesh, Pp. 13960–13966

On the importance of alpha behavior integrity in male *Capybara Hydrochoerus hydrochaeris* (Mammalia: Rodentia: Caviidae) following immuno-contraceptive treatment

– Derek Andrew Rosenfield & Cristiane Schilbach Pizzutto, Pp. 13967–13976

Dietary analysis of the Indian Flying Fox *Pteropus giganteus* (Brunnich, 1782) (Chiroptera: Pteropodidae) in Myanmar through the analysis of faecal and chewed remnants

– Moe Moe Aung & Than Than Htay, Pp. 13977–13983

Report on three ectoparasites of the Greater Short-nosed Fruit Bat *Cynopterus sphinx* Vahl, 1797 (Mammalia: Chiroptera: Pteropodidae) in Cachar District of Assam, India

– Anisur Rahman & Parthankar Choudhury, Pp. 13984–13991

A checklist of mammals of Tamil Nadu, India

– Manokaran Kamalakannan & Paingamadathil Ommer Nameer, Pp. 13992–14009

A comparative study on dragonfly diversity on a plateau and an agro-ecosystem in Goa, India

– Andrea R.M. D'Souza & Irvathur Krishnananda Pai, Pp. 14010–14021

Review

Contributions to the knowledge of moths of Bombycoidea Latreille, 1802 (Lepidoptera: Heterocera) of Bhutan with new records

– Jatishwor Singh Irungbam & Meenakshi Jatishwor Irungbam, Pp. 14022–14050

Short Communications

First camera trap documentation of the Crab-eating Mongoose *Herpestes urva* (Hodgson, 1836) (Carnivora: Feliformia: Herpestidae) in Barandabhar Corridor Forest in Chitwan, Nepal

– Trishna Rayamajhi, Saneer Lamichhane, Aashish Gurung, Pramod Raj Regmi, Chiranjibi Prasad Pokheral & Babu Ram Lamichhane, Pp. 14051–14055

First camera trap record of Red Panda *Ailurus fulgens* (Cuvier, 1825) (Mammalia: Carnivora: Ailuridae) from Khangchendzonga, Sikkim, India

– Tawqir Bashir, Tapajit Bhattacharya, Kamal Poudyal & Sambandam Sathyakumar, Pp. 14056–14061

First record of black scavenger fly of the genus *Meropterus* Rondani, 1874 (Diptera: Sepsidae) from Pakistan

– Noor Fatima, Ansa Tamkeen & Muhammad Asghar Hassan, Pp. 14062–14064

Scully's Balsam *Impatiens scullyi* Hook.f. (Balsaminaceae): a new record for India from Himachal Pradesh

– Ashutosh Sharma, Nidhan Singh & Wojciech Adamowski, Pp. 14065–14070

Notes

Odisha's first record of a free-tailed bat (Mammalia: Chiroptera: Molossidae): what could it be?

– Subrat Debata & Sharat Kumar Palita, Pp. 14071–14074

Additions to the flora of Arunachal Pradesh State, India

– Umeshkumar Lalchand Tiwari, Pp. 14075–14079

A report on additions to the flora of Andaman & Nicobar Islands, India

– Johnny Kumar Tagore, Ponnaiah Jansirani & Sebastian Soosairaj, Pp. 14080–14082

Range extension of *Trigonella uncata* Boiss. & Noë (Leguminosae) in peninsular India and a new record for Maharashtra State, India

– Shrikant Ingahlalikar & Aditya Vishwanath Dharap, Pp. 14083–14086

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