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ARTICLE

Cullenia exarillata – a potentially important resource for Brown Palm Civet *Paradoxurus jerdoni* during a period of fruit scarcity in the Western Ghats

N. R. ANOOP[1,2*], Anuja DATE[1,2], Jyoti NAIR[1,2] & Soubadra DEVY[1]

[1] Ashoka Trust for Research in Ecology and the Environment (ATREE), Jakkur P.O. Bangalore 560064 India
[2] Manipal Academy of Higher Education, Manipal, Karnataka, India

Correspondence:
N. R. Anoop
anoop.nr@atree.org

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Abstract

Spatio-temporal variation in resource availability influences the diet preferences of mammals. This rapid survey assessed the food preference of the frugivorous Brown Palm Civet *Paradoxurus jerdoni* during a period of fruit scarcity in the Kakachi area of Kalakad-Mundanthurai Tiger Reserve, Western Ghats, India. A systematic survey was carried out for the scats of Brown Palm Civet. We analysed 73 scats collected from two habitats: mid-elevation tropical wet evergreen forest and abandoned cardamom plantations. The flower of the Western Ghats endemic tree *Cullenia exarillata* constituted the major component of the civet diet (72.6%) during the survey. This suggests the possibility of an important ecological relationship between the tree species *Cullenia exarillata* and Brown Palm Civet during periods of resource scarcity in the Kakachi area of Kalakad-Mundanthurai Tiger Reserve.

Keywords: *Cullenia exarillata*, fruit scarcity, Western Ghats, frugivorous carnivores, seed dispersal

Introduction

Studies have documented that tropical forests show clear inter and intra-annual, temporal and spatial variations in fruiting patterns (Ganesh & Davidar 1997, Foerster *et al.* 2012, Polansky & Robbins 2013). Temporal variation in fruiting is an evolutionary strategy of tropical trees to avoid competition for seed dispersal and to attract a large number of frugivores (Schaik *et al.* 1993). Due to fluctuating seasonal availability of fruit resources, the frugivorous animals face inconsistent supply of nutrients and thereby physiological stresses in fulfilling their energy requirements (Goldizen *et al.* 1988, Conklin-Brittain *et al.* 1998, Pereira *et al.* 2010, Vogel *et al.* 2012). Under resource-scarce situations, animals can cope by broadening their trophic niche, increasing feeding time, altering group size, changing their ranging pattern, or by relying on some keystone food resources (Thompson & Colgan 1990, Hanya 2004, Yamagiwa & Basabose 2006, Zhou *et al.* 2008, Thinley *et al.* 2011). These strategies vary based on the behaviour, trophic positions and trophic-niche width of species. In the case of territorial frugivores, floristic composition and productivity within an individual's territory add to the challenge of seasonal fruit scarcity and it are also linked to the fitness of the individual (Borges 1993, Kusch *et al.* 2004).

Civets are known to have diversified food preferences into either largely carnivorous or frugivorous diets (Zhou *et al.* 2008, Mudappa *et al.* 2010, Colon & Sugau 2012). Studies have documented the diet of civets and their resource switching capacity (Bekele *et al.* 2008,

Zhou *et al.* 2008, Mudappa *et al.* 2010, Jothish 2011, Mullu & Balakrishnan 2015), but very little is known about their ability to cope with extreme food shortages. The Brown Palm Civet is an endemic small carnivore of the Western Ghats (Mudappa 2002). It is a canopy-dwelling species, occurring in wet evergreen forests and adjacent plantations (Rajamani *et al.* 2002). This species has a highly frugivorous diet and is assumed to be an important disperser of many plant species; however, very little is known about the ecology of the species on account of their elusive, arboreal and nocturnal nature (Mudappa *et al.* 2010). A study by Ganesh & Davidar (1997) found a decline in community-level fruit resource availability in the wet evergreen forest of the Kalakad-Mundanthurai Tiger Reserve (KMTR) from December to April. In KMTR, the flowering of the most abundant tree species *Cullenia exarillata* coincides with the fruit scarcity period and when most of the other plant species do not flower (Ganesh & Davidar 1997). In this survey, we examined the food preference of Brown Palm Civet during a period of fruit scarcity in KMTR.

Materials and methods

Study area

The survey was in Kakachi (8°50′ N latitude and 77°30′ E longitude; 1240 m asl) in KMTR in the Agasthyamalai Ranges of the southern Western Ghats, India (Fig. 1). Kakachi is part of one of the largest contiguous stretches of undisturbed tropical mid-elevation evergreen forest (MEF; 700 – 1400 m asl) in the southern Western Ghats and an important catchment area for the Manimuthar River (Ramesh *et al.* 1997). The region experiences heavy rainfall of over 3500 mm annually from both south-west and north-east monsoons (Ganesh & Davidar 1999). The relatively dry spells occur from March to May. The natural forest has a rich floral and faunal diversity (Ganesh *et al.*1996, Ganesh & Davidar 1997, Raman & Sukumar 2002); however, large areas of habitat in the area have been converted to tropical cash crops such as tea, cardamom and coffee. This has led to disruption in the continuity of forest tracts and has created a mosaic of land use.

The MEF of KMTR supports an impressive floral diversity, with about 173 woody plant species belong to 58 families comprising 42 canopy trees and 48 understorey trees (Ganesh *et al.* 1996). The area is dominated by *Cullenia exarillata, Aglaiabourdillonii* and *Palaquium ellipticum* trees (Ganesh *et al.* 1996). This habitat type shows a well-connected canopy with typical stratification of sub-canopy and understory. In the adjacent cardamom plantation (ACP), the understorey trees were removed completely. Canopy trees have been selectively felled to ensure the availability of sunlight for cardamom plants during the establishment of the plantation. This made the canopy less contiguous and the understorey is now dominated by a light-loving and moisture demanding *Solanum erianthum* shrub. The remnant canopy in ACP is dominated by *Cullenia exarillata*. The other civet species that occur in KMTR are Small Indian Civet *Viverricula indica* and Common Palm Civet *Paradoxurus hermaphroditus.* These species are mostly recorded from the deciduous forests

of KMTR with the former species being rarely seen in undisturbed evergreen forests and more frequently recorded in plantations (Mudappa *et al.* 2010).

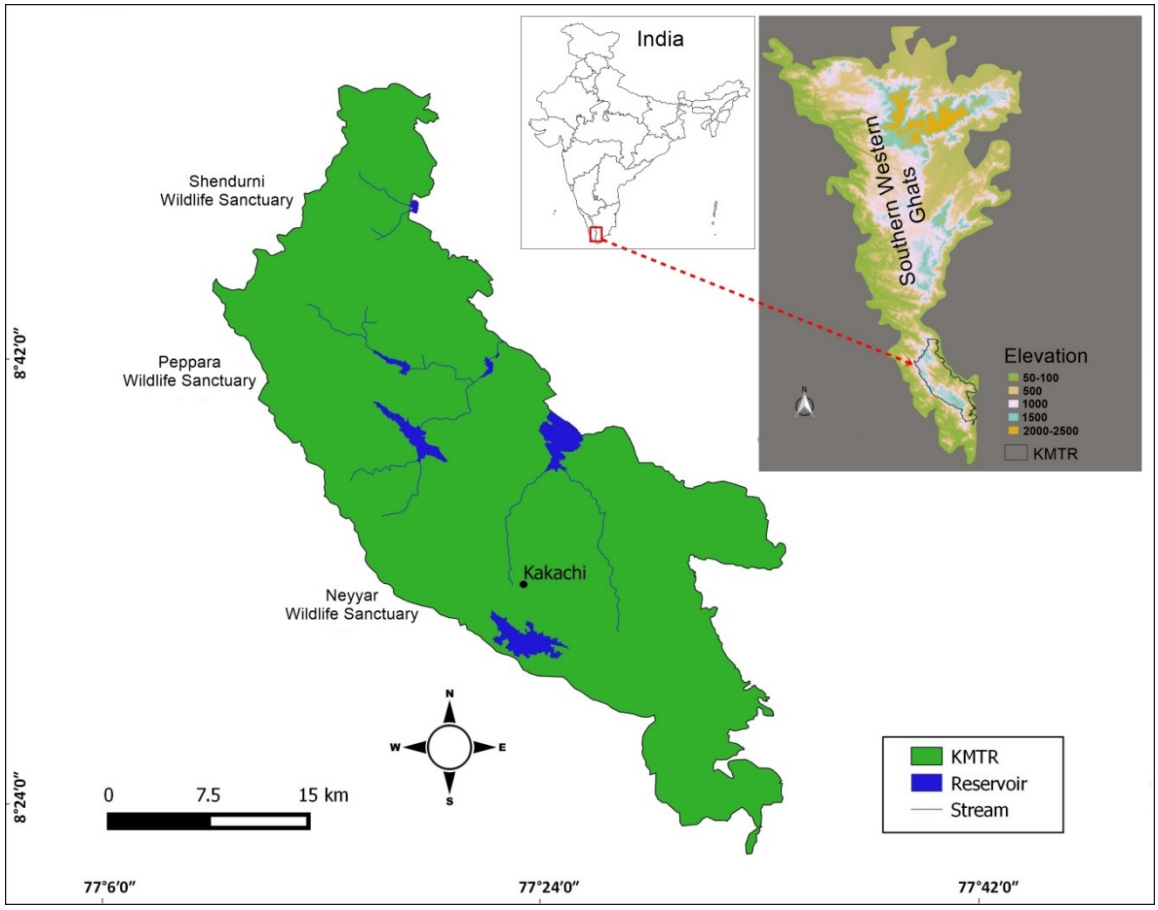

Fig 1. Map of the study area showing Kakachi area within the boundary of KMTR.

Collection and analysis of scats

In order to understand the resource availability and diet preferences of Brown Palm Civet (Fig. 2**)** during a fruit scarcity period, sampling was carried out in the mid-elevation evergreen forest and the adjacent cardamom plantation, which had been abandoned for over 20 years. To assess the diet composition of Brown Palm Civets, we used the technique of analysing scat samples for trophic components (Habtamu *et al.* 2017, Aroon 2008, Bekele *et al.* 2008, Mudappa *et al.* 2010, Jothish 2011). The scat of the Brown Palm Civet is distinguished from Small Indian Civet and other small mammals in the study area on the basis of their size, shape and location. The scats of Brown Palm Civets are straight, cylindrical (≤ 2 cm in diameter), rounded at both ends, and usually found as a single bolus in prominent places like on fallen logs, buttress roots and rocks along the trails. The scat also

lacks pungent odour (Mudappa *et al.* 2010). No DNA analysis of the collected faeces was done; it is, therefore, unknown if there were any species misidentification errors.

Fig. 2. Brown Palm Civet *Paradoxurus jerdoni* in the wet evergreen forest of the southern Western Ghats, Southern India.

Extensive scat sampling was carried out for three days (6 to 9 May 2016) in MEF and ACP. For scat collection, transects of 2–3 km lengths were identified from pre-existing trails in the selected habitats. Each route was sampled once by a team consisting of 3–5 persons moving along the trails searching for the scats and paying special attention buttress roots, roots, fallen trees and rocks. A 10-m distance on either side of the transect was searched for scats. The trails were walked between 9:00 and 17:00. A total of 9 km was surveyed in MEF and 8 km in ACP. Since the focus was on food preferences of civets during the resource-scarce season, which starts at the end of April, scats older than 2–3 weeks at the time of the survey in early May were not sampled.

The collected scat samples were individually bagged in Ziploc polythene bags. For each collection event, the following data were recorded; coordinates (using a GPS), identification number, date of collection and habitat type. The analysis of scat was carried out at the field station, where the flowers, fruit seeds and other plant matter as well as insect and other animal material in the scats were identified with the help of specialist botanists and zoologists. The flowers of *Cullenia exarillata* in the scat were easily distinguishable by their colour, partially digested sepals and undigested pollen. The identified materials were segregated based on species/genus and estimated as the percentage of different components (number of times a specific item was found as a percentage of all items found) in the scats.

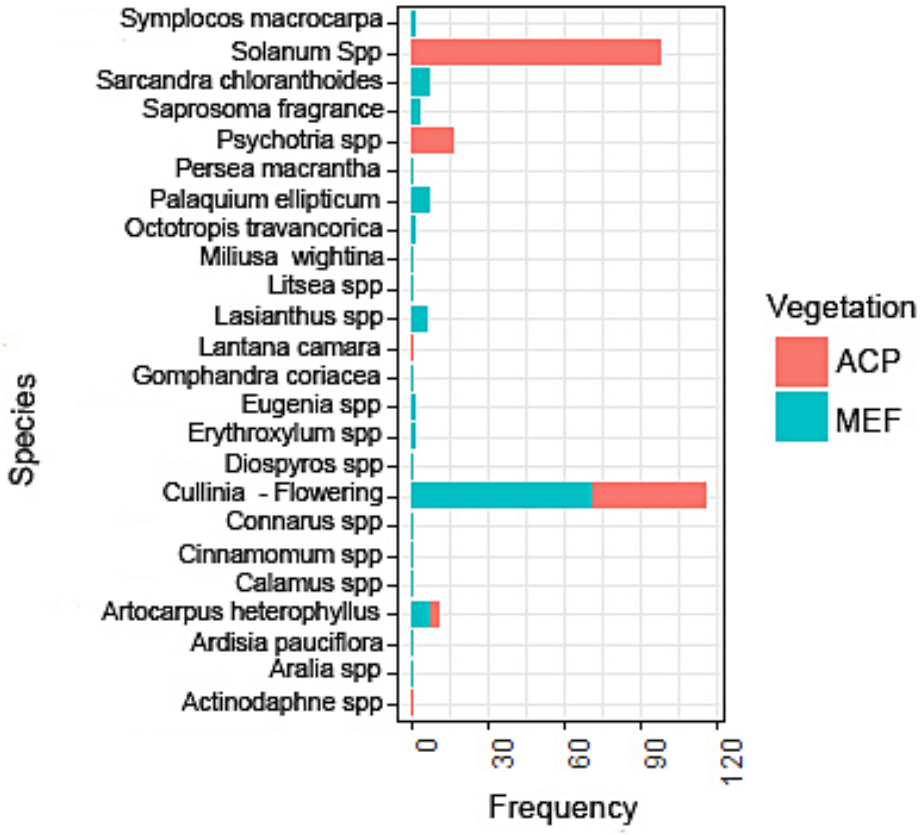

Fig. 3. Frequency of occurrence of different plant species with food resource (fruit and flower) recorded in MEF and ACP of KMTR during the study period (May 2016).

Vegetation sampling

During the study period, a vegetation survey was conducted to record the food resource availability for civets. A total of 14 linear vegetation plots (seven in each of the two habitat types) of 250 m × 5 m were laid along the scat routes. Both understorey and overstorey plant species with fruit resources within the plots were recorded. Overstorey tree species were observed with the help of a pair of binoculars. Since several arboreal mammals, including the Brown Plam Civet and Lion-tailed Macaque (*Macaca silenus*) (Ganesh & Davidar 1997, Mudappa *et al.* 2010, Krishnadas *et al.* 2011), are known to consume the flower of *Cullenia exarillata*, both fruiting and flowering trees were recorded for this species. Plant species that the team were unable to identify in the field were photographed and identified with help of a botanist. The species richness (total number of species in each plot) and Shannon-Weiner Diversity index (H; Shannon & Weiner 1949) of the plants were used to assess plant species diversity in the two habitat types.

Results

Seventy-three scat samples were collected and analysed in total: MEF (N = 65) and ACP (N = 8). The analysis of faecal contents identified *Cullenia* flowers (72.6 %), fruits of 13 species (26.4%), insects (12.1 %), leaves (2.2%) and reptiles (1.1 %) during the survey period. The number of identifiable species consumed and the percentage and frequency of occurrence of different items in the scats are shown in Table 1. The MEF vegetation plots had the maximum number of species bearing fruits or flowers, with 21 species belong to 16 families (H = 1.43, species richness/plot = 5.4 ± 2.9; see Fig 3). In contrast, only six species belonging to five families (H = 0.9 and species richness/plot = 2.7 ± 0.8) were recorded fruiting or flowering in the ACP plots. In MEF and ACP, flowering *Cullenea exarillata* was the most abundant tree species, with a density of 65.71 and 58 per hectare, respectively. In the MEF, *Artocarpus heterophyllus* and *Palaquium ellipticum* were the next most abundant trees. In ACP, it was the exotic *Solanum erianthum*. Comparison of the abundance of flowering, fruiting and non-flowering trees of *Cullenia* in the two habitat types showed that the trees with flowers (61.7 %) were more abundant in MEF, followed by non-flowering (36.4%) and fruiting (1.7 %).

Table 1. Percentage frequency of occurrence of different food items as shown by scat sample analysis (n = 73) during the study in two habitat types.

Sample no.	Food categories	Percentage of occurrence	Frequency of occurrence
1	*Cullenia exarillata* (flower)	72.6	39.1
2	*Elaeocarpus munroii* (seed)	1.4	0.7
3	*Solanum erianthum* (seed)	8.2	4.4
4	*Bentinckia condapanna* (seed)	1.4	0.7
5	*Acronychia pedunculata* (seed)	5.5	2.9
6	*Annonaceae* sp. (seed)	1.4	0.7
7	*Embelia* spp.(seed)	1.4	0.7
8	*Mesua* sp. (seed)	1.4	0.7
9	*Gomphandra* sp. (seed)	2.7	1.4
10	*Ficus* spp. (seed)	4.1	2.2
11	*Fagaria* sp. (seed)	1.4	0.7
12	*Toddalia asiatica* (seed)	1.4	0.7
13	Leaf (unidentified)	2.7	1.4
14	Insects	15.1	8
15	Reptiles	1.4	0.7
16	Unidentified items (seeds of two species)	9.6	5

Discussion

For the effective implementation of the community-level conservation planning, it is important to understand which plants are more important for frugivore communities. For example, the genus *Ficus* was recorded as a 'keystone' resource provider for frugivore communities in several forest ecosystems (Goodman *et al*. 1997, Korine *et al.* 2000). *Cullenia exarillata* is a mammal-pollinated tree species that is an important resource for several vertebrates during resource-scarce seasons (Ganesh & Davidar 1999, Ganesh & Devy 2006). Hence, this species could be considered as one of the 'keystone' species in the MEF of the Western Ghats (Ganesh & Davidar 1997, Ganesh & Devy 2006). Previous research in KMTR identified very high levels of intra- and inter-annual variation in the diets of Brown Palm Civet (Mudappa *et al.* 2010). Although the scats collected during the research reported here indicated that the civets in the survey area had a strong seasonal preference for *Cullenia* flowers, the scats were collected over three days: this is too short a sampling period to assess the relative importance of *Cullenia exarillata* to the survival of Brown Palm Civet.

Studies have documented the importance of civets in seed dispersal (Su & Sale 2003, Bekele *et al.* 2008, Zhou *et al.* 2008, Mudappa *et al.* 2010, Jothish 2011, Mullu & Balakrishnan 2015). Civets play an important role in maintaining forest structure and the passive restoration of disturbed habitats through the dispersal of viable seeds (Zhou *et al.* 2008, Mudappa *et al.* 2010). Mudappa *et al.* (2010) documented that Brown Palm Civet feed on fruits of 57 species from KMTR. The results from this survey also support the important role that civets have in dispersing seeds from a variety of plant species, including both canopy and understorey species.

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