

Diet Composition and Overlap of Two Mesocarnivores, Leopard Cat (*Prionailurus bengalensis*) and Javan Mongoose (*Urva javanica*), in Java, Indonesia

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ABSTRACT

Dietary study of carnivores has garnered a great deal of attention for a very long time since it provides information for comprehending ecological processes and tracking the economic effects of animals on food production. Few studies reported alternative prey that is detrimental to food production, such as rodents and insects, in addition to the numerous studies on livestock predation. Therefore, this study aims to provide information on the diet composition and overlap of two mesocarnivore species, Javan mongoose (*Urva javanica*) and leopard cat (*Prionailurus bengalensis*), in Java, Indonesia. The macroscopic observation technique was applied for identifying food remnants found in the 90 feces of the mongoose and 100 feces of the cat collected in 2018. Twenty three and 21 taxa of prey were found in the leopard and Javan mongoose feces. Rodentia was the most frequent taxa found in the feces of both species, followed by Galliformes. Insects comprised the majority of diet items but at low frequencies. Two mesocarnivores were specialists (Levin's index of leopard cat: 0.08; Javan mongoose: 0.26) with fairly high diet overlap (Pianka's index = 0.78). The results provided compelling evidence of the positive and negative impacts of mesocarnivores on food production in Java.

1. Introduction

Dietary study of carnivores has attracted a great deal of attention for a very long time since it provides data for understanding ecological processes and tracking the economic effects of animals on food supply. Through the analysis, the food composition of an animal can be revealed, possible interactions with the environment can be assessed, and the following impacts can be anticipated. The analyses have been frequently conducted to provide data for mitigating economic loss due to livestock depredation. For example, domestic animal predation by the wolf (Imbert *et al.* 2016), caracal (Jansen *et al.* 2019), and leopard have been reported (Ott *et al.* 2007). Besides those prominent studies on depredation, study on the indirect effect of carnivores on food production through trophic interaction received less attention (Baker *et al.* 2008). This effect is intense, particularly in

the mixed agricultural landscape (Verdade *et al.* 2011) where the carnivores are expected to control pest abundance, as described in the top-down population control approach (Elmhagen and Rushton 2007), leading to beneficial impacts on food productions.

Many studies confirmed the expectation, even though it is still incomplete. For example, Ćirović *et al.* (2016) reported rodent control by Jackal (*Canis aureus*). Another study showed evidence of rodent predations by mesocarnivore species (Mahmood and Adil 2017; Xiong *et al.* 2017). A review asserted the expectation by various mesocarnivore species (Williams *et al.* 2018). It is important to note that all these studies illuminated rodents as a pest to be controlled. Even though many animal species were also reported as the diet items, it was elucidated with less attention. Few studies described other preys that are potentially harmful to food production, such as the work of Mahmood and Adil (2017). This incomplete information undermines the expectation because there are substantial pests other than rodents infrequently reported as being controlled by carnivores.

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This study provided information diet of the Javan mongoose (*Urva javanica*) and leopard cat (*Prionailurus bengalensis*), inhabiting an agricultural landscape of Java, Indonesia, with a specific interest in insects. It also aimed to assess the diet composition and niche overlap of those species, and they were selected because their diet is only rarely reported. Only a little information about the diet of the leopard cat (Hoogerwerf 1970; Permatasari 2020) and mongoose (Subrata *et al.* 2020) is known. According to IUCN, conservation status of both species were least concern (Chutipong *et al.* 2016; Ghimirey *et al.* 2022). Supposedly, both species exchange food items, such as mice and insects, as revealed by prior study. The method used was macro-histological observation for identifying food remnants discovered in the feces of the Javan mongoose and leopard cat. Meanwhile, diet information is used as evidence of ecological function as a pest predator. Niche segregation data provides an indication of their effectiveness in predated those pest species. Therefore, the indirect effect of two Javan mesocarnivore on food production was revealed with a suggestion for its population management.

2. Materials and Methods

The study sites were located in the southern mountains of Yogyakarta, on Java Island (Figure 1), comprising naturally growing (Wonosadi; 7.82°S, 110.68°E) and plantation forests (Wanagama; 7.89°S, 110.54°E). Wonosadi forest is dominated by *Mischocarpus sundaicus*, *Eugenia aquea*, *Cassia seamea*, and *Anthocephalus cadamba* trees (Sudomo 2021), meanwhile in the Wanagama *Pinus merkusii*, *Swietenia macrophylla*, *Schleichera oleosa*, *Tectona grandis*, *Melaleuca leucadendron*, and *Gliricidia sepium* are the dominant stands (Widodo *et al.* 2009). The sites are spaced around 18 kilometers apart, representing one of the native geographic ranges of the leopard cat and Javan mongoose. Remnants of the natural forests still exist alongside restoration in some parts of the area. In addition, agroforestry lands and villages space those forests in which fieldwork was conducted during the dry season of March–October 2019 to collect putative feces samples. Furthermore, burrows, tracks, and creeks were explored, in the search for the feces.

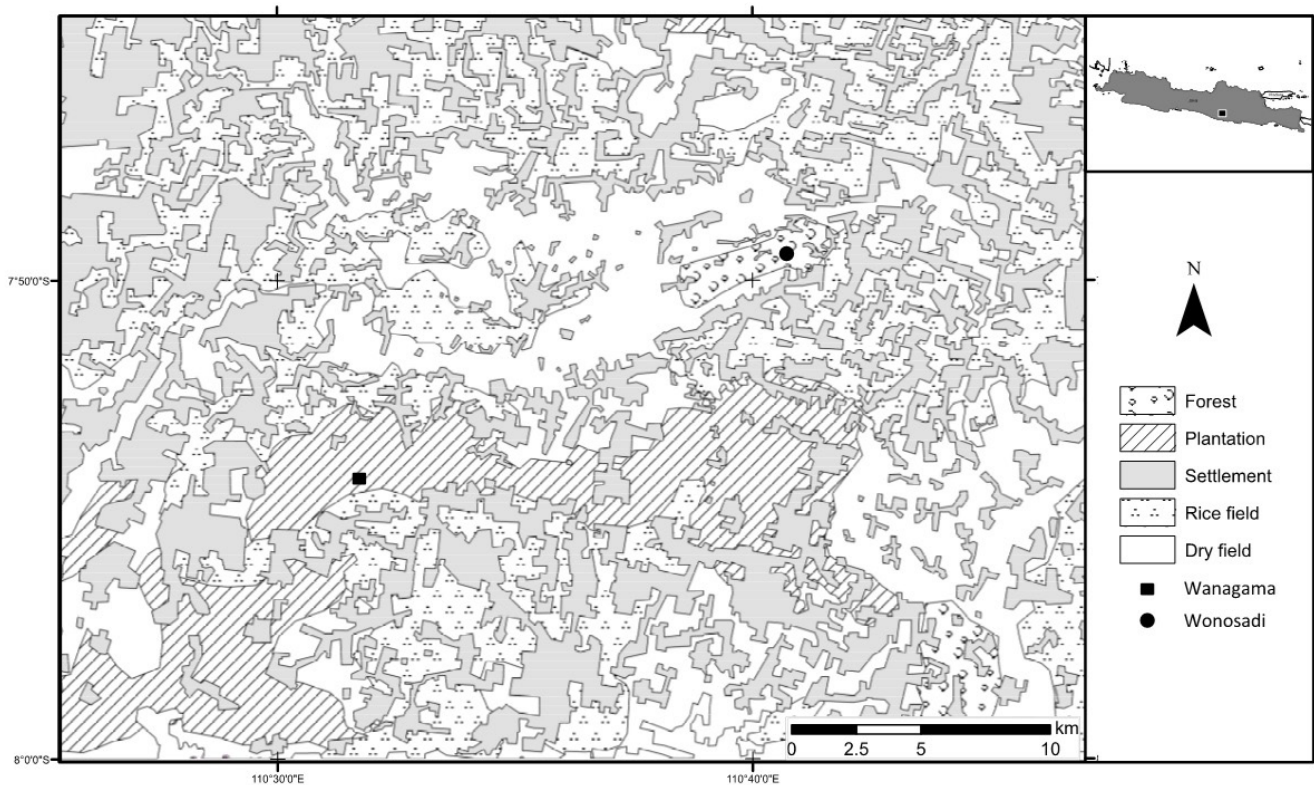


Figure 1. Study sites and their surrounding land cover consisted of forests, plantations, settlements, rice fields, and dry fields. The dot (Wonosadi) and square (Wanagama) represent locations where many feces samples were collected

The feces of the leopard cat and Javan mongoose were identified based on physical characteristics. General and special characters were used to identify feces, and carnivore has cylindrical feces (sausage-shaped), with sub-divisions, and tapered at one of the extremities (Chame 2003). Other characteristics such as typical odor and occurrence of the remnant of hairs, bones, feathers, and insect bodies were also considered. The characters were used as initial guidance in determining feces. Furthermore, special characters recognized from a local zoo were used to identify putative feces. Feces of leopard cat has characteristics are brighter color as compared to other carnivore species, sub-divisions, diameter c.a. 10–15 mm (Figure 2B). Feces of this species are most likely found on edge of open tracks inside the forests. The Javan mongoose has smaller feces with subtle subdivisions (Figure 2A). Unlike leopard cats,

feces of Javan mongoose are most probably found near burrows, beneath and above rocks, and in agricultural areas. There is a possibility of samples mistaking when identifying feces because in this area both species co-exist with other mesopredators such as Asian small-clawed otters (*Aonyx cinerea*), small Indian civet (*Viverricula indica*), and common palm civet (*Paradoxurus hermaphroditus*). However, the possibility is slight because the latter two species have feces with different characteristics. The feces of the Asian small-clawed otter is not found in the forest, but close to the rivers, while that of common palm civet are the longest and frequently has seeds or fruit remnant within them (Figure 2D). The feces of the small Indian civet is the shortest and relatively wide (Figure 2C), and unlike felids, feces of civets have subtle or no subdivisions.

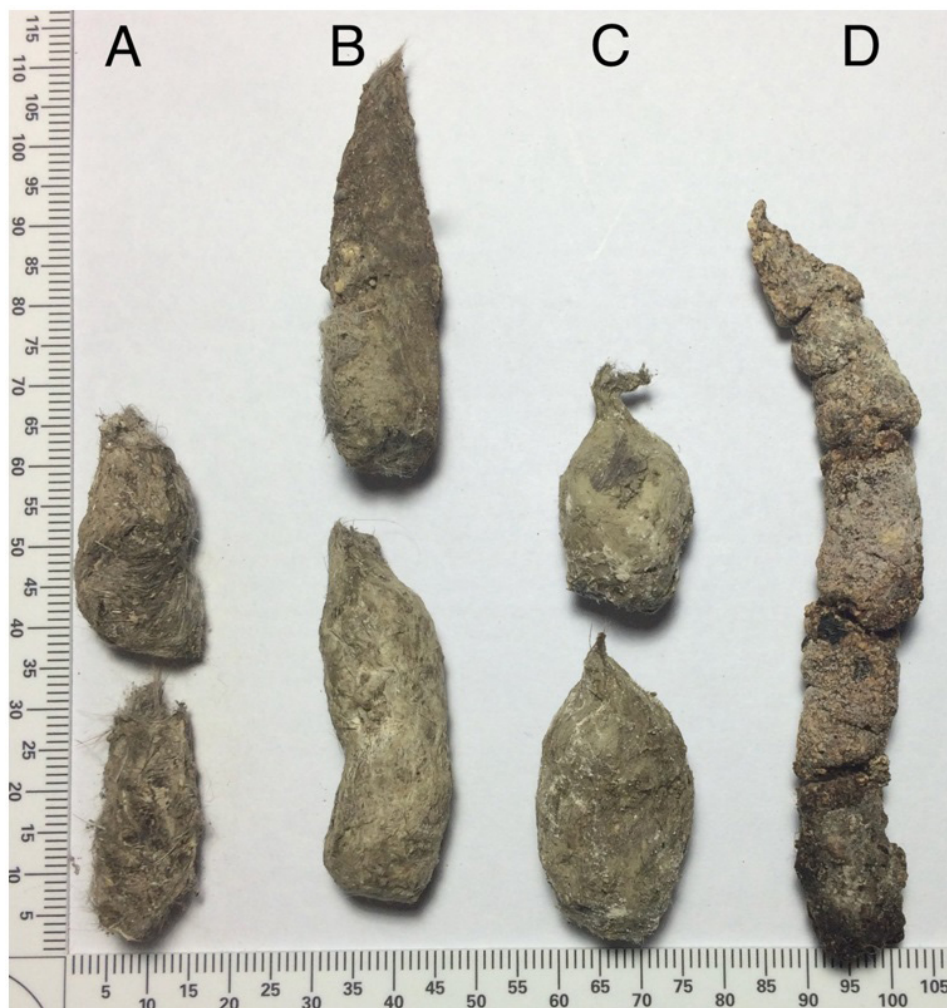


Figure 2. Feces of the mesocarnivore found in the study sites: Javan mongoose (A), leopard cat (B), small Indian mongoose (C), and common palm civet (D). Scale is in millimeters

Based on these characteristics, the samples were determined and not to be confused with the feces of other animals. The putative feces were placed in a 50 mL plastic tube preloaded with silica beads for its preservation. In addition, the geographic coordinates and habitat types with the feces' identity were also recorded.

The sample was processed in the laboratory within 1-2 weeks after collection and was screened for further analysis based on identity and intactness. The initial step was conducted by placing the feces in a funnel coated with a paper filter, which was placed over a plastic cup. Subsequently, warm water was poured into the funnel and left for 3-4 days until all water was tapped into the cup, and the feces air-dried. This technique diluted mucus and loosened food remnants in the feces which was followed by further drying in an oven at 70°C for 2-3 days. The dried feces were evenly spread over the filter paper. A few possible diet items in the samples were picked and glued to a clean paper using transparent tape and further identified macroscopically. Particularly for hair and feather, a microscope slide was created by gluing a single hair or feather on an object glass. Furthermore, the diet item was identified using a microscope based on morphological recognition and compared to references such as hair (E. Lee *et al.* 2014) and feather (Dove and Koch 2011), as well as insects (Triplehorn and Johnson 2005) for taxonomical identification. Based on macroscopic identification, the frequency of occurrence of each diet item found in all feces samples was tabulated.

To assess the adequacy of the sample size, the number of the family was plotted against fecal samples and projected up to more than the two-fold sample size. Rarefaction techniques were used based on Hill's number with 95% confidence intervals for the projection. The R package (iNEXT) was used to calculate and create the projected rarefaction curve (Hsieh *et al.* 2016), and the adequacy of the sample size was justified when a few additional family numbers were reported. Diet composition data was presented as a table showing the proportion of occurrence of diet items (Deagle *et al.* 2019). It was simply rescaling of frequency of occurrence (FOO; the number of samples containing a given food item expressed in 5) to increase the sum across all food items to 100%. The difference in diet composition between sites for each species was assessed using the chi-square test (Wright 2010). Meanwhile, dietary niche breadth

was measured using Levins's index (Levins 1968) and standardized on a scale of 0–1 (Colwell and Futuyma 1971). The overlap between leopard cat and Javan mongoose was calculated according to the Pianka index (Pianka 1973) which represented a value between 0–1. An R package "Spaa" (Jinlong 2016) was used to calculate dietary niche breadth and overlap. Additionally, diet overlap was also assessed using Bray-Curtis dissimilarity index (Bray and Curtis 1957).

3. Results

Over the study period, 111 and 107 feces samples of leopard cat and Javan mongoose were collected from the field, and most of the samples were discovered on the edge of the forest patches. After thorough screening in the laboratory for morphological similarity, 11 feces samples of leopard cat and 7 of Javan mongoose due to doubtful identity were discarded. Only 100 leopard cats (50 samples each from Wanagama and Wonosadi) and 90 Javan mongoose samples (41 from Wanagama and 49 from Wonosadi), were processed for diet identification. The diet item reported in the feces up to the family or order levels was successfully identified.

3.1. Sample Size Adequacy

Based on the frequency of prey families and the number of feces samples, the sample size was almost adequate, as reflected by a gentle rarefaction curve near the point but not flat (Figure 3). The curves suggested that as the sample size increased a few additional families could be reported until saturated. The curve indicates that both species share substantial diet items, as shown by the overlapped area of confidence interval (grey areas of Figure 3). This indication was analyzed further by observing dietary overlap in the following subsection.

3.2. Diet Composition

Most of the items were fragmented and several of them are unidentified because of the very small-size fragments. The items were found in the form of feathers, hairs, bones, scales, exoskeletons, and plant remains. Furthermore, vertebrate remnants (bones, hairs, and feathers) were the most often reported in the feces of both species (more than half of the samples), while exoskeletons were the most diverse forms of diet items.

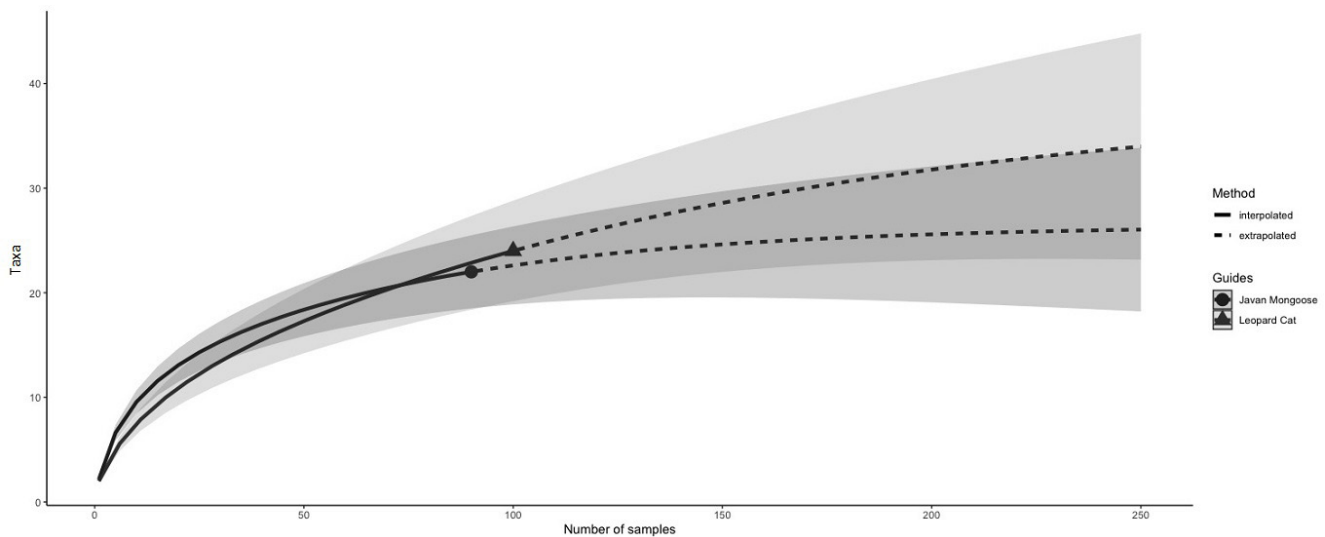


Figure 3. Extrapolated accumulation curve of Javan mongoose and leopard cat prey. The curve was created using a rarefaction technique based on Hill's index, with a 95% confidence interval. Taxa included family, class, order and undetermined

Based on the morphological recognition of the remnants, 19 and 16 families reported in the leopard cat and Javan mongoose feces, respectively, were identified (Table 1). These families belong to aves, reptiles, and insects. The order of Mammalia and Malacostraca and a class of fish have been identified in the feces of both species, and a class of Diplopoda is found in the feces of leopard cat only. Mammalia (rodents) was the most frequent family reported in the feces of Javan mongoose and leopard cat, followed by aves (Galliformes), as shown in Table 2. Insects were the most diverse item reported in the feces of both species, and the taxa comprised most diet items found in the feces of both species but at low frequencies (Table 2). The dung beetle (*Scarabaeidae*) had a probability to be a non-food item. There was no difference in the diet composition of Javan mongoose inhabiting Wanagama and Wonosadi (Cochran-Mantel-Haenszel test: $X^2 = 0.24$; $p > 0.05$). In contrast, the leopard cat was significantly different between both sites (Cochran-Mantel-Haenszel test: $X^2 = 9.78$; $p < 0.05$).

The species shared the same plant item (*Poaceae*) in their diet at a substantial frequency. However, plants from the further analysis were excluded because its frequency of the occurrence was much lower. These species shared the other 13 taxa of animals in their diet, where 10 and 7 taxa were reported only in the leopard cat diet and Javan mongoose feces, respectively. It was assumed that the item in the feces

was a prey of the species, except for diet with sensible reason.

3.3. Dietary Niche Breadth and Overlap

A narrow dietary niche of leopard cat (Levins' Index = 3.67; standardized Levins' Index = 0.08) and Javan mongoose (Levins' Index = 7.18; standardized Levins' Index = 0.26) was obtained. These narrow niches were attributed to higher occurrence of several families of vertebrates and a low frequency of many families of insects (Table 2). These patterns were similarly observed in both the leopard cat and Javan mongoose diet. Furthermore, diet overlap between them is relatively high (Pianka's niche overlap = 0.78), and it was also indicated by the overlapping areas of the confidence interval in Figure 2, as well as sharing several items at a moderate proportion of occurrence (Table 2). Further examination found that the species share an intermediate level of diet items as shown by Bray-Curtis dissimilarity index of 0.49. In Wanagama, these species share more diet items than Wonosadi as revealed by Bray-Curtis dissimilarity index of 0.42 and 0.63, respectively.

4. Discussion

Many prior works, Ćirović *et al.* (2016), Xiong *et al.* (2017), Mahmood and Adil (2017), Watanabe *et al.* (2003), as well as Williams *et al.* (2018), have a well-documented diet of mesocarnivores. Detailed

Table 1. Diet composition of leopard cat and Javan mongoose as measured in the number of the family of prey

	Javan mongoose	Leopard cat	Taxonomic rank
Insect	14	18	Family
Malacostraca	1	1	Order
Mammalia	1	1	Order
Reptilia	1	0	Family
Aves	1	1	Family
Diplopoda	1	0	Class
Fish	1	1	Class
Plant	1	1	-

Table 2. Diet composition of the Javan mongoose (*Urva javanica*) and leopard cat (*Prionailurus bengalensis*) as represented in a proportion of occurrence

Class	Order	Family	Javan mongoose		Leopard cat	
			Wanagama (n: 49)	Wonosadi (n: 41)	Wanagama (n: 50)	Wonosadi (n: 50)
Insecta	Coleoptera	Buprestidae			0.01	0.01
Insecta	Coleoptera	Carabidae	0.01		0.01	
Insecta	Coleoptera	Cicindelidae			0.05	
Insecta	Coleoptera	Dynastidae			0.01	0.01
Insecta	Coleoptera	Elateridae	0.01			
Insecta	Coleoptera	Melolonthidae	0.02	0.01		
Insecta	Coleoptera	Oedemeridae	0.01			
Insecta	Coleoptera	Rutelidae	0.02		0.01	
Insecta	Coleoptera	Scarabaeidae	0.07	0.03	0.01	0.03
Insecta	Coleoptera	Tenebrionidae	0.04			0.01
Insecta	Diptera	Psychodidae			0.01	
Insecta	Hemiptera	Cicadidae			0.01	
Insecta	Hemiptera	Membracidae			0.01	
Insecta	Hymenoptera	Chalcididae				0.01
Insecta	Hymenoptera	Formicidae	0.09		0.08	0.16
Insecta	Hymenoptera	Pulicidae			0.02	
Insecta	Isoptera	Termitidae	0.02		0.01	
Insecta	Neuroptera	Corydalidae		0.03	0.01	
Insecta	Odonata	Libellulidae	0.01	0.01		
Insecta	Orthoptera	Acrididae	0.07	0.09	0.06	0.03
Insecta	Orthoptera	Gryllidae	0.03	0.01	0.02	
Insecta	Orthoptera	Gryllacrididae			0.07	0.01
Insecta	Orthoptera	Tettigoniidae			0.01	
Insecta	Plecoptera	Perlidae	0.01			
Malacostraca	Decapoda		0.01	0.05	0.01	
Mammalia	Rodentia		0.30	0.27	0.50	0.67
Reptilia	Squamata	Colubridae	0.01	0.20		
Aves	Galliformes		0.21	0.27	0.04	0.04
Diplopoda			0.01			
Fish			0.05	0.03	0.04	

information about insect taxon fed by the carnivores was unavailable from the reports, except from the work of Watanabe *et al.* (2003). In those reports, prey identification focused on coarse food remnants found in the stomach or feces of the carnivores. Therefore, the identification is biased toward animals larger than insects. In this study, all the biological remnants discovered in the feces of Javan mongoose and leopard cats were identified and assured adequacy of sample

size. Following that rigorous method, insects were the most diverse item found in the feces of both species with various taxa of mammals, birds, fish, diplopods, and decapods.

The result is consistent with previous study, confirming that the diet of both species mainly consisted of rodents, birds, and insects, but with substantial variation. Rodents were the most common prey in the feces of leopard cats, followed by birds

(Galliformes). The Galliformes taxa likely include poultry species because it is commonly found in the study site. This pattern was also reported as the diet composition of leopard cats inhabiting various types of habitats in their native range (Kamler *et al.* 2020; E. Lee *et al.* 2014; Lorica and Heaney 2013; Xiong *et al.* 2016). Furthermore, the result showed no family of reptiles found in the feces of the leopard cats. This was quite different from several studies (Chua *et al.* 2016; O. Lee *et al.* 2014; Lorica and Heaney 2013; Rabinowitz 1990), where reptiles were a substantial diet of the leopard cat. Regarding the diet composition of the Javan mongoose, small mammals and birds were the most frequent diet item found in the feces, along with various insect families. However, no literature for precise comparison was reported. The available literature refers to the closest-related species, the small Indian mongoose. In the native range, the diet of this species is similar to Javan mongoose and frequently feeds on small mammals and birds (Akrim *et al.* 2019; Javed *et al.* 2003).

The above patterns in diet composition were also reflected in the narrow dietary niche breadth. Since both species preyed unequally on numerous groups of prey, their dietary niche index was low. This finding was comparable with the food habit of leopard cats in Asia as reported in the literature summarized by Hisano and Newman (2020). The summary reported that leopard cat has various diets with Levin's index between 1.49–4.74. Meanwhile, the Javan mongoose has a narrower dietary niche breadth than its closest related species, the small Indian mongoose. This species was reported to have a Levin standard's dietary niche breadth of 0.59 and 0.46 during summer and winter in Pakistan (Akrim *et al.* 2019). This comparison may not be entirely appropriate due to differences in species and habitat. Therefore, this only indicates that the food habit of those mongooses varies.

The food habit of both leopard cat and Javan mongoose was most likely determined by food availability. In addition to the general pattern of diet composition commonly reported, the species were observed to feed on specific diet items abundant in the locality. As evidenced by the Iriomote leopard cat, it was believed that the abundance of reptiles on Iriomote Island, Japan, was the key factor in determining their particular diet (Nakanishi and Izawa 2016; Watanabe *et al.* 2003). The availability of various insects in the study site, as stated by previous studies (Rahayu and Sulistyawati 2017; Triyogo *et al.* 2020), was the reason

many insect families were preyed on by the leopard cat, and this is rarely reported. Similarly, many insect families in the diet of Javan mongoose correlated with the availability on the site. This was also seen in small Indian mongoose (Akrim *et al.* 2019).

This result raises a query about diet competition between leopard cats and Javan mongoose. Indication of the competition is shown by a fairly high level of diet similarity, as evidenced by the overlapped area of the confidence interval of rarefaction curves (Figure 2), sharing 13 of 30 taxa of preys (Table 2), moderate level diet shares as revealed by Bray-Curtis dissimilarity index of 0.49 and Pianka's overlap index of 0.78. On the contrary, different active times of both species lessen the possibility of competition. Since the leopard cat is strongly nocturnal (Chua *et al.* 2016; Lynam *et al.* 2013), it often preys on the night-active animal, but less often on some day-active. Conversely, the diurnal Javan mongoose (Gilchrist *et al.* 2009) frequently preys on diurnal animals and less on nocturnal. The query warrants detailed diet identification up to species level to verify the diet similarity measurements.

Besides comparison of diet composition as elaborated above, this study showed important results that the main diet comprises various taxa of insects, rodents and birds. Among the insect taxa of interest are grasshopper (Acrididae) and dung beetle (Scarabaeidae) due to their high proportion of occurrence (Table 2). However, the dung beetles in the feces would not be diet, and they would had just come after defecation. Several species of the insects are known as major pests causing a substantial economic loss in many parts of the world (Song *et al.* 2018). Predation of the grasshopper by Javan mongoose and leopard cat may control the abundance of those insects to reduce the risk of food production damage. Similarly, the predation of rodents has been widely known to be beneficial for production.

This finding provided compelling evidence of the potential impacts of mesocarnivores on food production. It implies the population management of Javan mongoose and leopard cat in Java. Meanwhile, the mesocarnivore holds potential functions as an effective predator of various pest species. The efficacy is shown by matching the temporal occurrence of the mesopredators and their prey. It was supposed that the leopard cat and Javan mongoose predate their prey at night and day, respectively. Some species of Acrididae were diurnal, while the others were nocturnal (Lockwood *et al.* 1996). Member of rodents

were known as day- and night-active species, and this ecological functioning will work as long as the predator population is maintained. Recently, the leopard cat is a locally protected species, indicating that the population is small and or narrowly distributed. These impairing predators lead to a skew in the population abundance of pests toward night-active species. Therefore, their population management should strive for a balanced abundance to effectively control the pest population. However, the species have negative impacts on food production, particularly poultry. They likely preyed on domestic fowl species as indicated by remnants of Galliformes in their feces.

This study also revealed the necessity of increasing sampling effort, in terms of size and replication, to infer a more robust conclusion. In terms of size, we suggested to collect samples of more than a hundred feces in tropical areas, particularly in an agricultural landscape. In this study, a total of 111 and 107 feces samples of leopard cat and Javan mongoose were collected. However, the species accumulation curve still suggested a few additional diet items as the sample size increases (Figure 3). Even though the sample is within the range of several studies on the leopard cat diet (21-350 feces; Hisano and Newman 2020), the optimal size cannot be determined due to lack of the adequacy report as additional information. Similarly, an optimal sample size of the Javan mongoose diet study cannot be suggested since no report of the adequacy was found in several studies (Akrim *et al.* 2019; Mahmood *et al.* 2011; Mahmood and Adil 2017). In terms of replication, collecting samples during the wet season is suggested. The results represented dry season conditions only, and different diet compositions were expected, particularly insects when sampling is conducted during the wet season. Insect abundance in the sites likely varies seasonally as indicated by Priawandiputra *et al.* (2020), showing a high abundance of dung beetle during dry as compared to wet season in another part of Java Island. Rats are likely in abundance in years on the island as indicated by ricefield rat (*Rattus argentiventer*) populations (Tristiani *et al.* 1998). Differences in diet composition between seasons are also shown by leopard cats in the temperate ecosystem, where food availability varies sharply (Khaton *et al.* 2019; O. Lee *et al.* 2014). Meanwhile, in tropical ecosystems particularly in the agricultural landscape, the leopard cat showed no difference in major prey diet (Rajaratnam *et al.* 2007) due to the high abundance of the major diet. A

similar pattern of seasonal diet is also found in small Indian mongoose (*Herpestes javanicus*), showing high diversity of insects during summer, but no variation in rodent (Mahmood and Adil 2017). Therefore, collecting samples that represent temporal variation in food abundance is suggested to draw a more robust conclusion on the diet composition.

This study suggests the need for species-level identification when conducting diet analysis of carnivores. Even though classical diet analysis has been accepted to show the diet of an animal (Litvaitis 2000), using a sophisticated technique, such as DNA metabarcoding (Gosselin *et al.* 2017) can provide more information. These include reliable identification of the host of the feces, appropriate assessment of the adequacy of sample size, diet segregation, and population control of prey. Therefore, macroscopic observation is appropriate for the initial assessment of diet analysis when no prior information is available.

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