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Potential prey traces of the javan leopard in Bromo Tengger Semeru National Park

Jejak satwa mangsa potensial macan tutul jawa di Taman Nasional Bromo Tengger Semeru

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ABSTRACT

The Javan leopard (*Panthera pardus melas*) is a subspecies of *Panthera pardus* endemic to Java Island, with a limited distribution on Java, Kangean, Nusakambangan, and Sempu Islands. It is the last remaining large carnivore on the island following the extinction of *Panthera tigris sondaica*. The species has been protected by the Indonesian government since 1970 under Decree No. 421/Kpts/Um/8/1970 and subsequent regulations, with continued protection through Government Regulation No. 7/1999, Law No. 5/1990, and Ministry of Environment and Forestry Regulation No. 106/MENLHK/SETJEN/KUM.1/12/2018. It is listed as Endangered on the IUCN Red List and in Appendix I of CITES. The population of *P. p. melas* continues to decline due to habitat degradation, reduced prey availability, and poaching. Bromo Tengger Semeru National Park (TNBTS) serves as a critical habitat for its survival. This study aims to document potential prey traces of *P. p. melas* in TNBTS. Field methods included direct observation of tracks and analysis of traces such as feces, skin derivatives (hair, scales, spines), footprints, feeding marks, nests, and wallows. The results identified *Sus scrofa* (40.9%) as the most frequent potential prey species, followed by *Muntiacus muntjak (*24.2%), *Macaca fascicularis* (10.6%), *Hystrix javanica* (9.1%), and both *Viverricula malaccensis* and *Manis javanica* (7.6% each). These findings highlight the essential role of prey availability in supporting *P. p. melas* populations in TNBTS. This information is expected to provide a basis for prey-based ecological conservation strategies and sustainable habitat management for the long-term survival of this keystone species.

Keywords: Conservation, Javan leopard, Potential Prey, Traces

INTISARI

Macan tutul Jawa (*Panthera pardus melas*) merupakan subspesies dari *Panthera pardus* yang endemik di Pulau Jawa, dengan sebaran terbatas di Pulau Jawa, Kangean, Nusakambangan, dan Sempu. Spesies ini merupakan karnivora besar terakhir yang tersisa di pulau tersebut setelah punahnya *Panthera tigris sondaica*. Macan tutul Jawa telah dilindungi oleh pemerintah Indonesia sejak tahun 1970 melalui Keputusan No. 421/Kpts/Um/8/1970 dan peraturan-peraturan selanjutnya, dengan perlindungan yang berlanjut melalui Peraturan Pemerintah No. 7/1999, Undang-Undang No. 5/1990, serta Peraturan Menteri Lingkungan Hidup dan Kehutanan No. 106/MENLHK/SETJEN/KUM.1/12/2018. Spesies ini terdaftar sebagai "Terancam Punah" (*Endangered*) dalam Daftar Merah IUCN dan Apendiks I CITES. Populasi *P. p. melas* terus menurun akibat degradasi habitat, berkurangnya ketersediaan mangsa, dan perburuan. Taman Nasional Bromo Tengger Semeru (TNBTS) berfungsi sebagai habitat penting bagi kelangsungan hidupnya. Penelitian ini bertujuan untuk mendokumentasikan jejak satwa mangsa potensial *P. p. melas* di TNBTS. Metode lapangan meliputi observasi langsung terhadap jejak dan analisis tanda-tanda seperti feses, turunan kulit (rambut, sisik, duri), jejak kaki, bekas makan, sarang, dan kubangan. Hasil penelitian mengidentifikasi *Sus scrofa* (40,9%) sebagai spesies mangsa

potensial yang paling sering ditemukan, diikuti oleh *Muntiacus muntjak* (24,2%), *Macaca fascicularis* (10,6%), *Hystrix javanica* (9,1%), serta *Viverricula malaccensis* dan *Manis javanica* (masing-masing 7,6%). Temuan ini menyoroti peran penting ketersediaan mangsa dalam mendukung populasi *P. p. melas* di TNBTS. Informasi ini diharapkan dapat menjadi dasar strategi konservasi ekologi berbasis mangsa dan pengelolaan habitat yang berkelanjutan untuk kelangsungan hidup jangka panjang spesies kunci ini.

Kata kunci: Jejak, Konservasi, Macan tutul Jawa, Mangsa potensial

INTRODUCTION

Panthera pardus melas is a subspecies of *Panthera pardus* (Linnaeus, 1758). Its distribution is restricted to Java Island, including Kangean, Nusakambangan, and Sempu Islands (Santiapillai & Ramono, 1992; Meijaard, 2004; Santoso & Restanto, 2021). This species is the last remaining large carnivore on Java, following the extinction of the Javan tiger (*Panthera tigris sondaica*) in 1980. *P. p. melas* has been protected since 1970 through Minister of Agriculture Decree No. 421/Kpts/Um/8/1970 and subsequently through PP No. 7/1999, Law No. 5/1990, and Minister of Environment and Forestry Regulation No.106/MENLHK/SETJEN/KUM.1/12/2018. This species is also categorized as Endangered by the IUCN Red List and included in Appendix I of CITES. In addition to hunting, decreasing natural habitats, and the declining availability of prey species, its population remains unknown and is expected to continue decreasing (Santoso & Restanto, 2021). Most of the information on *P. p. melas* presence comes from camera trap monitoring, which places the species' population on Java Island between 491 and 596 individuals (KLHK, 2016).

The suitable habitat for *Panthera pardus melas* includes steep topography (slopes >60°) and natural shelters such as cave-like alcoves, rocky outcrops, and dense vegetation, which provide concealment, resting sites, and support ambush-based hunting strategies (Cleave et al., 2018). These features also offer protection from human disturbance and contribute to the formation of stable microhabitats that support both the leopard and its prey. The species' home range size is influenced by environmental variability, particularly in temperature and precipitation, as well as biological factors such as sexual dimorphism and reproductive behavior. Males generally occupy much larger home ranges (6–63 km²) than females (6–13 km²) (Alikodra & Gunawan, 2013). This difference is largely due to their larger body size, which requires greater energy intake and thus a wider foraging area. In addition, *P. p. melas* exhibits a polygynous mating system in which one male's territory overlaps with those of several females. Consequently, males must traverse broader areas not only to secure food but also to locate and access receptive females while defending their range from rival males. In contrast, females tend to occupy smaller, resource-rich territories that are more stable over time, optimized for raising offspring and minimizing energetic costs (Lekagul & McNeely, 1977).

According to a previous study, long-tailed monkeys (*Macaca fascicularis*), Javan langurs (*Trachypithecus auratus*), wild boars (*Sus scrofa*), and barking deer (*Muntiacus muntjak*) are among the main prey species of *P. p. melas* (Gunawan et al., 2012). According to research conducted at Bromo Tengger Semeru National Park (TNBTS) by (Firmansyah et al., 2023), the primary prey also included the Javan porcupine (*Hystrix javanica*), Javan pangolin (*Manis javanica*), and civet (*Viverricula malaccensis*). Moreover, according to camera trap results in the research by (Rustiadi & Prihatini) 2015 reported possible prey such as Javan mouse deer (*Tragulus javanicus*), civet (*Paradoxurus*

hermaphroditus), partridge (*Gallus gallus*), mountain squirrel (*Tupaia montana*), and forest cat (P*rionailurus bengalensis*). TNBTS is one of the most crucial ecosystems for *P. p. melas* and its prey, with an area of 50,276.3 hectares. The area is made up of two zones: the core zone and the jungle zone, which belong to the principal places of activity for this species. There were 11 individuals *P. p. melas* and 13 indivduals melanistic (panther) were discovered during observation in 2021. There were 3 *P. p. melas* individuals with different pigmentations were detected in two Management Resort (RPTN), Jabung and Candipuro (Firmansyah et al., 2022).

Nevertheless, there exists no scientific evidence of the presence of possible *P. p. melas* prey animals in TNBTS. In reality, carnivorous predators like *P. p. melas* rely heavily on food availability for survival. This research aims to identify possible prey animals of *P. p. melas* in the Bromo Tengger Semeru National Park region. The outcomes of this research will provide benefit to *P. p. melas* efforts to conserve holistically with habitat-based techniques and predator-prey ecology.

MATERIALS AND METHOD

Time and location of research

This research was conducted at five Management Resort locations (RPTN), namely Jabung, Tengger Lautan Pasir, Ranu Darungan, Candipuro, and Pasrujambe. The selection of locations aims to represent variations in habitat and tracks of potential prey animals *Panthera pardus melas* in the Bromo Tengger Semeru National Park area. The selection of this location considered the diversity of topography, vegetation types, and the record of the presence of Javan leopards and their prey animals based on previous monitoring data. The data analysis process was carried out in the Ecology Laboratory, Department of Biology, ITS.

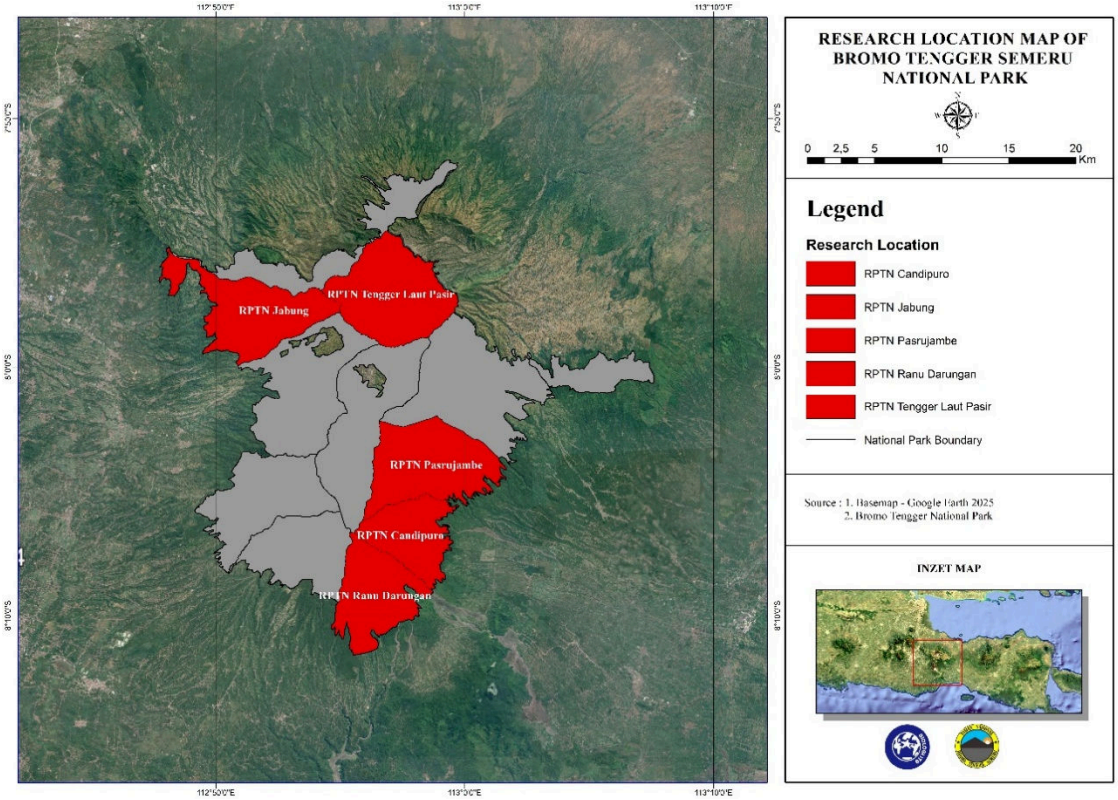


Figure 1. Location of research map

Materials and tools

This research used materials, including alcohol and distilled water. In addition, several tools were used, including a shovel, 750 ml sample box, ziplock plastic, 50 ml sample tube, latex gloves, sample storage container box, tweezers, compound microscope, stereo microscope, object glass, and object glass cover.

Method

This study was conducted through field observations to detect and collect traces of potential prey animals *Panthera pardus melas* in five locations of the National Park Management Resort (RPTN) in the Bromo Tengger Semeru National Park (TNBTS) area, namely Jabung, Tengger Lautan Pasir, Ranu Darungan, Candipuro, and Pasrujambe. Observations aimed to look for various types of potential prey traces, including feces, skin derivatives (hair, thorns, scales), footprints, feeding traces, nests, and burrows. All findings were documented visually, with environmental conditions recorded and morphological measurements taken whenever possible. Collected tracks were categorized into two types: (1) feces and (2) skin derivatives. Feces were collected from six potential prey species based on previous studies, namely Long tailed monkey (*Macaca fascicularis*), wild boar (*Sus scrofa*), barking deer (*Muntiacus muntjak*), civet (*Viverricula malaccensis*), Javan pangolin (*Manis javanica*), and Javan porcupine (*Hystrix javanicus*). Feces of potential prey species were collected using a sterile shovel, stored in a closed container, and preserved with 70% alcohol. Skin derivative samples were collected using sterile tweezers and preserved in 70% alcohol. Footprints, nests and burrows were only visually documented without sampling. All samples were then analyzed at the Ecology Laboratory, Department of Biology, Sepuluh Nopember Institute of Technology (ITS) for species identification based on morphological characteristics and relevant literature references.

Data analysis

Observation data were analyzed descriptively to determine the types and traces of potential prey animals of *Panthera pardus melas* in 5 RPTNs in the TNBTS area. Species identification was carried out based on the morphological characteristics of feces samples and skin derivatives, with reference to scientific literature. Visual traces such as footprints, nests and wallows were matched with morphological characters from reference sources to support species identification. The results were entered into Microsoft Excel and analyzed descriptively.

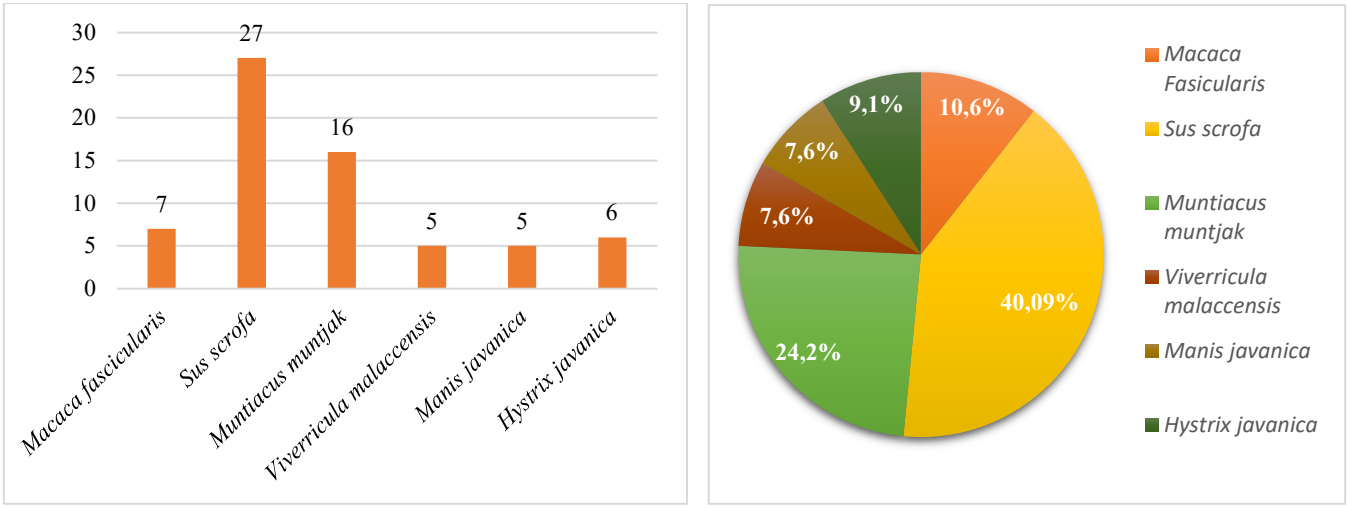
RESULTS

This study successfully identified six potential prey animals, namely *Macaca fascicularis*, *Sus scrofa*, *Muntiacus muntjak*, *Viverricula malaccensis*, *Manis javanica*, and *Hystrix javanicus* from trace findings including feces, skin derivates, footprints, feeding traces, nests, wallows, and direct sightings. The potential prey items of *Panthera pardus melas* and the types of tracks found are summarized in Table 1.

This bar chart (Figure 2) shows the number of field detections for each potential prey species within the study area. *Sus scrofa* was the most identified species with a total of 27 findings (40.9%), followed by *Muntiacus muntjak* with 16 findings (24.2%) and *Macaca fascicularis* with 7 findings (10.6%). *Hystrix javanica* was recorded with 6 findings (9.1%), *Viverricula malaccensis* and *Manis javanica* had five findings (7.6%) each.

Table 1. Types of potential prey traces of *Panthera pardus melas*

Potential Prey Identified	Types of Tracks							Total
	Feces	Skin Derivates	Footprints	Feeding Traces	Burrow	Wallows	Direct Sightings	
Macaca fascicularis	-	-	-	3	-	-	4	7
Sus scrofa	-	-	25	2	-	-	-	27
Muntiacus muntjak	-	-	16	-	-	-	-	16
Viverricula malaccensis	5	-	-	-	-	-	-	5
Manis javanica	-	-	-	-	5	-	-	5
Hystrix javanica	-	-	-	6	-	-	-	6
Total								66



(a) (b)

Figure 2. Potential prey trace findings in Bromo Tengger Semeru National Park (a) Frequency; and (b) Percentage

This stacked bar chart (Figure 3) illustrates the types of tracks found in each species. The *Macaca fascicularis* had three feeding traces and four direct encounters. In *Sus scrofa* and *Muntiacus muntjak*, 25 and 16 footprints were found respectively. In *Viverricula malaccensis*, five feces were found. *Manis javanica* found five burrows. While the *Hystrix javanicus* found six feeding traces. Based on these findings, it is known that *Sus scrofa* and *Muntiacus muntjak* footprints were the most dominating findings.

DISCUSSION

Sus Scrofa traces

Sus scrofa tracks dominated the field findings, representing 41% of all tracks found. The high frequency of boar footprints was related to its adaptive ecological characteristics, including its wide range and flexibility in activity timing. *Sus scrofa* is active mainly in the morning and evening (crepuscular) but can also be nocturnal to avoid predators (Lekagul & McNeely, 1977). The wide distribution of tracks at various observation points reflects intensive foraging behavior, such as digging the soil for tubers, roots, invertebrates, and snails (Istiqomah et al., 2017). A total of 25 footprints were found in the study site, with 1 meter of decomposed soil, indicating soil digging activity by *Sus scrofa*.

This activity aims to find food in the form of invertebrates, such as earthworms, snails, and maggots (Istiqomah et al, 2017). In addition, there were also findings of food traces in the form of young bamboo or bamboo shoots, indicating the diversity of food sources consumed by wild boars. Previous research (Fauzi et al, 2023) found soil scouring in the form of foot and snout marks and food waste in the form of cassava flakes.

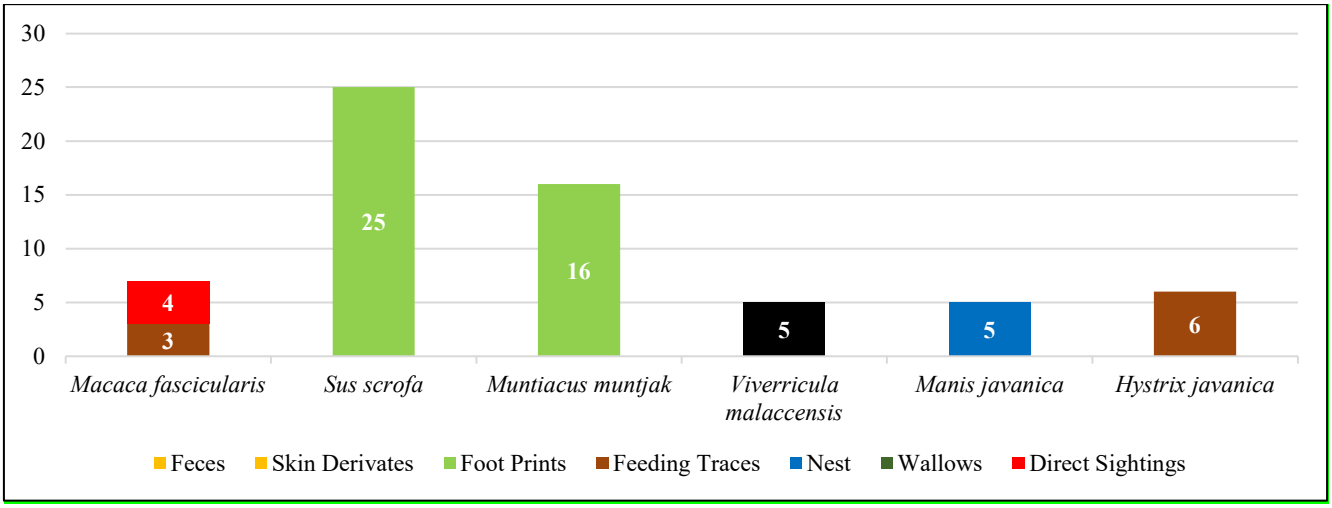


Figure 3. Frequency of trace types per potential prey species in Bromo Tengger Semeru National Park

Sus scrofa has a diverse ecological role, not only as a fruit eater and plant destroyer, but also functions as a seed disperser (Genov, 1981; Geisser & Reyer, 2004). Their broad ecological roles demonstrate the ability of wild boars to adapt to a wide range of natural resources. They can prey on small vertebrates such as mammals, birds, reptiles and amphibians, as well as insects and microorganisms (Thomson & Challies, 1988; Baubet et al, 2004; Wilcox & Van Vuren, 2009). The diversity of food types consumed by wild boars also reflects their adaptation to various environmental conditions, especially in areas with dense vegetation and moist soils, such as those found in Bromo Tengger Semeru National Park.

(a) (b)

Figure 4. *Sus scrofa* traces (a) footprints and soil excavations; (b) food traces

Muntiacus muntjak traces

There were 16 *Muntiacus muntjak* traces found, accounting for about 24% of the total footprints found, making it the species with the second highest number of traces. The footprints found were about 4.47 cm long. *M. muntjak* footprints were found in a location with primary forest vegetation with a gentle

slope (8-15%) (Anggrita et al., 2017; Ekanasty et al., 2014). The sloping condition of the observation path is likely to be a factor supporting the high number of traces found, because it facilitates the mobility of *M. muntjak* in daily activities, especially in searching for food.

M. muntjak tends to utilize seedling and sapling stands to reach young leaves as food (Anggrita et al., 2017). In addition, *M. muntjak* footprints were also found on steep hillsides. Previous research (Firmansyah et al., 2022) also recorded findings of *M. muntjak* feces at Candipuro RPTN in the Gunung Papak block, which has a steep slope. Field observations showed that no feeding traces of *M. muntjak* were found during the observation period. However, two *M. muntjak* carcasses were found in the flat slope savanna land cover of the Tengger Lautan Pasir RPTN, indicating that although *M. muntjak* are more active in primary forests, they can also venture into open areas in search of foraging food.

(a) (b)

Figure 5. *Muntiacus muntjak* traces (a) footprints; (b) carcass (Ariyanto, 2019)

Macaca fascicularis traces

Macaca fascicularis was identified from seven traces, which included three feeding traces and four direct sightings, representing approximately 11% of the total findings. Feeding traces were found in RPTN Ranu Darungan, in the form of young stem remains such as pith and water guava fruit (*Syzygium aqueum*). *M. fascicularis* is known to favor pith due to its water and carbohydrate content that can provide energy (Hasanudin et al., 2017). As an opportunistic animal, the monkey utilizes a variety of resources available in its habitat, including fruits, invertebrates, fungi, leaves, flowers, seeds and tubers (Fittinghoff & Lindburg, 1980; Hill, 1991; Hadi, 2005).

Direct encounters with *M. fascicularis* were recorded in several locations, such as RPTN Ranu Darungan, RPTN Candipuro, RPTN Jabung, and the border area of RPTN Tengger Lautan Pasir with RPTN Gunung Penanjakan. At Ranu Darungan, this animal was seen eating water guava fruit. At Gunung Penanjakan, individuals of *M. fascicularis* approached tourists around the viewpoint of Mount Bromo. At Jabung and Candipuro, although sightings occurred, documentation was not possible due to distance, rainy conditions and steep terrain. All these sightings suggest that *M. fascicularis* is arboreal, primarily for feeding, sleeping, mating and locomotion (Supriyatin et al., 2019). The dense canopy vegetation in the TNBTS area strongly supports this arboreal activity, which is relevant to the presence of *Panthera pardus melas*, another arboreal animal that has the ability to climb trees (Gunawan, 2009). Predation interactions between the two, both on the ground and in the trees, are likely to occur.

(a) (b)

Figure 6. *Macaca fascicularis* traces (a) on rose apple; (b) on plant pith

(a) (b)

Figure 7. *Macaca fascicularis* direct sightings (a) RPTN Tengger Lautan Pasir; (b) RPTN Ranu Darungan

Hystrix javanica traces

Hystrix javanica showed a relatively low frequency of findings, with five findings representing approximately 7% of the total findings. This low number of findings was likely influenced by its solitary, nocturnal ecological characteristics, as well as its habit of not always leaving easily recognizable tracks in the field. Feeding traces of *H. javanica* were found in Ranu Darungan, in the form of the remains of bamboo shoots, young bamboo, and young stems of salak *(Salacca zalacca*) trees. Feeding traces are characterized by damage to the lower part of the plant, which is sometimes severe enough to cause the plant to collapse. As an animal of the Rodentia order, *H. javanica* feeds on the outer parts of plants by gnawing, especially on species from the families Anacardiaceae, Moraceae, Poaceae, Araceae, Fabaceae, Euphorbiaceae, Rhamnaceae, and Oleaceae. Sap-containing plants are also favored, as they aid in the production of rib gel stones in their body. Interestingly, *H. javanica* can consume poisonous plants without being poisoned (Farida, 2015).

Most of *H. javanica* feeding tracks were found in primary forest vegetation types with dense canopy cover. This condition causes the soil to be damp due to the lack of sunlight penetrating the forest floor. Humidity, the presence of weathered dead plants, and an understory structure rich in shrubs and grasses favor *H. javanica* activity. This habitat type is in line with hedgehog habitat preferences as reported by (Woods, 1973), namely areas with lots of shrubs and grasses, and by (Mustikasari et al. 2019), which mentions hedgehog (genus Erethizon) habitats including grasslands, shrubs and riverbanks. Therefore, the primary forest vegetation type in Ranu Darungan supports the presence of *H. javanica*.

(a) (b)

Figure 8. Feeding traces of *Hystrix javanica* (a) feeding on bamboo shoots; and (b) feeding on young bamboo.

Manis javanica traces

Manis javanica shows a relatively low frequency of encounters, with only five records, accounting for approximately 7% of the total findings. These include two active burrows and one carcass found in the RPTN Ranu Darungan area.The burrows of *M. javanica* were found in the form of small caves among rocks with a soil base. The soil beneath the rocks appeared to be excavated, forming a protective space. According to (Withaningsih et al. 2018), *M. javanica* constructs three types of burrows: among rocks, in the soil, and in dead trees. Soil burrows are usually dug for resting as well as foraging, particularly for ants and termites. In addition to digging, *M. javanica* also tears into dead tree trunks to find termites. The size of soil burrows varies, typically ranging from 8–100 cm in length, 15–73 cm in width, and 50 cm to 3 m in depth. Meanwhile, rock burrows measure between 16–170 cm in length, 8–98 cm in width, and 77 cm to 3 m in depth.

The two burrows found were located in areas with primary forest vegetation characterized by dense canopy cover and high humidity due to limited sunlight penetration. These conditions align with the natural habitat preferences of *M. javanica*, which can survive in both primary and secondary forests, as well as in rubber and oil palm plantations or open areas near human settlements (Lekagul & McNeely, 1977; Davies & Payne, 1982; Nowak, 1999). The primary forests of RPTN Darungan provide dense vegetation and moist microclimates, meeting the habitat requirements necessary for predator avoidance (Manshur & Kartono, 2015). In addition to the burrows, a carcass of *M. javanica* was also found in the RPTN Darungan area, indicating that the region forms part of the species' natural home range.

(a) (b)

Figure 9. *Manis javanica* traces (a) Burrow; and (b) carcass

***Viverricula malaccensis* traces**

Viverricula malaccensis showed a relatively low frequency of track findings, with 6 findings for *V. malaccensis*, representing approximately 9%. This low number of findings is likely influenced by its ecological characteristics, which tend to be solitary, nocturnal, and do not always leave easily recognizable tracks in the field. *V. malaccensis* showed feces-dominated trace findings, found in several study sites. All feces found contained seeds, which are incompletely digested food residues. This suggests that the main diet of *V. malaccensis* is fruit. According to Mudappa et al (2010), civets are more appropriately referred to as frugivores than carnivores, because within the limits of their feeding behavior, these animals will choose fruit as their main food source as long as fruit is available. However, when fruit scarcity occurs, civets will switch to preying on small vertebrates, reptiles or insects.

(a) (b)

Figure 10. *Viverricula malaccensis* feces (a) on RPTN Pasrujambe; and (b) on RPTN Candipuro

V. malaccensis is a nocturnal animal, with its main activity occurring at night, particularly between after dusk and before dawn (Colón, 2002). This nocturnal activity helps civets avoid competition with other fruit-eaters such as scorpions, rodents, insects of the order Blattodea, and Chilopoda (Colón, 1999). This nocturnal activity is consistent with the activity pattern of Panthera pardus melas, the apex predator in the TNBTS area. *V. malaccensis* is also known as an arboreal animal, spending most of its life in trees. However, when mobilizing to forage or move, *V. malaccensis* often descends to the forest floor and passes understanding trees (Vaughan et al., 2000). This movement pattern supports its flexibility in foraging in diverse habitats, both above and below the forest canopy.

The results of this study provide important information on the composition and distribution of potential prey animals in TNBTS. This information not only reflects the availability of food for *P. p. melas* but also serves as an ecological indicator of the pattern of space use by prey animals in their habitat. However, this study has several limitations, especially in terms of the relatively limited scope of data collection time and the limitations of detection methods for nocturnal and solitary animals. However, these findings provide an important basis for conservation strategies of key animals in TNBTS, especially *P. p. melas*. For future research, additional approaches such as camera traps, environmental DNA (eDNA) surveys, and GPS tracking are recommended to obtain more comprehensive information on spatial interactions and food availability within the natural habitat of the Javan leopard.

CONCLUSION

Tracks of potential prey animals of the Javan leopard (*Panthera pardus melas*), namely *Macaca fascicularis*, *Sus scrofa, Muntiacus muntjak, Viverricula malaccensis, Manis javanica,* and *Hystrix javanicus*. Each species provides different types of tracks, including footprints, feeding tracks, feces, nests, and direct encounters. *S. scrofa* was the species with the highest number of tracks, followed by *M. muntjak* and *M. fascicularis*. The other three species had lower frequencies of findings. The variety of prey species and types of tracks found reflects the high diversity of prey communities in TNBTS. These findings provide an important basis for understanding the availability of natural food, community structure, and supporting conservation and habitat management efforts for *P. p. melas* in the area.

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