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Assessing The Javan Leopard Presence and Prey Abundance: Insights from Camera Trap Surveys in Meru Betiri National Park East Java Indonesia

Nur Kholiq[1,2], Hari Sulistyowati[1], Hariyo Tabah Wibisono[3], Asmoro Lelono[1], Retno Wimbaningrum[1], Sattya Arimurti[1], Arief Mohammad Siddiq[1], Adi Sucipto[2]
[1]Department of Biology, Faculty of Mathematics and Natural Sciences, University of Jember, Indonesia
[2]Meru Betiri National Park Office, Indonesia
[3]SINTAS Indonesia Foundation, Indonesia

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ABSTRACT
The use of incomplete or imbalanced data in ecological modelling and conservation planning can lead to inaccurate predictions due to limitations in detection methods. Therefore, obtaining comprehensive and precise empirical data on species presence and availability, particularly Javan leopard prey species is essential. This study aims to identify the presence of Javan leopards and their potential prey species, and to estimate the relative abundance indices (RAI) of each prey species. Using data from camera trap surveys carried out in the Meru Betiri National Park in 2024, we recorded 24 species, including the Javan leopard, and identified seven potential prey species. The RAI of the long-talied macaque was the highest (44.16), while the banteng was the lowest (0.23), appearing in only three independent images. The presence of Javan leopards highlights the ecological significance of this area and provides valuable data for biodiversity management, serving as a foundation for future research and conservation efforts.

Corresponding Author:
Nur Kholiq
Department of Biology, Faculty of Mathematics and Natural Sciences, University of Jember
Jl. Kalimantan 37, Tegalboto, Jember 68121, East Java, Indonesia
email: 231820401001@mail.unej.ac.id

1. INTRODUCTION

Meru Betiri National Park (MBNP, 526 km^2) is a nature conservation area in East Java Province with an intact ecosystem, managed using a zoning system and is used for research, scientific study, education, and supporting cultivation as well as the utilization of environmental services. MBNP has the potential for a high diversity of flora and fauna, with 602 species of flora and 473 species of fauna (MBNP, 2025), including the Javan leopard (Panthera pardus melas Cuvier, 1809). The management objective of MBNP is to protect the Javan leopard, the last big cat on the Indonesian island of Java (MBNP, 2017). The Javan leopard is one of the eight surviving leopard subspecies (Kitchener et al., 2017). This species is protected under Government Regulation Number 7 of 1999 of the Republic of Indonesia on the Preservation of Plant and Wildlife Species. According to the IUCN, the Javan leopard's status is Endangered (EN) (Wibisono et al., 2024).

As a priority management target, the Javan leopard and its prey are important study subjects for implementing conservation efforts. Wibisono et al. (2018) stated that MBNP is an important habitat for the survival of the Javan leopard population. Additionally, Wibisono et al. (2018) suggested employing prey species data to predict Javan leopard habitat suitability. As an apex predator, this endangered species plays a pivotal role in maintaining the ecological balance of forest ecosystems. Through the process of predation, the Javan leopard controls the growth of prey populations, thereby preventing overpopulation and maintaining biodiversity. Furthermore, the survival of wild predators, especially the Javan leopard, is contingent on the availability of sufficient prey resources. A recent study revealed that of the 473 potential fauna species in MBNP, nine of them are potential prey for the Javan leopard (Ariyanto et al., 2024a), including: banteng (*Bos javanicus*), barking deer (*Muntiacus muntjak*), Javan deer (*Rusa timorensis*), Javan mouse deer (*Tragulus javanicus*), wild boar (*Sus scrofa*), junglefowl (*Gallus spp*.), east Javan langur (*Trachypithecus auratus*), long-tailed macaque (*Macaca fascicularis*), and dhole (*Cuon alpinus*).

However, the availability of data and information regarding the presence, distribution, and availability of these Jacan leopards prey species remains limited due to the absence of comprehensive surveys and data analysis within the entire MBNP area. Limited data on species can have significant implications for scientific understanding and conservation efforts. Data limitations constrain effective conservation decision-making, as they prevent accurate assessments of species status, population trends, and habitat pressures (Moreno et al., 2023). Furthermore, without accurate information on the presence, distribution, and abundance of prey species, it is difficult to assess the health and viability of predator populations, especially for large carnivores that rely on specific prey densities to survive and reproduce (Karyakin and Knizhov, 2023; Fortuna et al., 2024). From a conservation standpoint, this data gap can result in poorly informed management decisions. For illustration, conservation areas could be designated without ensuring that they contain enough prey to support the intended species. Alternatively, critical habitats could be overlooked entirely in conservation plans. In some cases, human-induced prey depletion, such as overhunting or habitat degradation, goes unnoticed until predator populations begin to decline. The absence of comprehensive prey data also limits our ability to model predator-prey dynamics, understand ecosystem functioning, and predict responses to environmental changes (Hamilton et al., 2024). Moreover, data limitations can erode public trust and reduce funding opportunities, as stakeholders may be hesitant to invest in initiatives that lack clear evidence of impact. As one study put it, aligning data with decisions is essential to address the biodiversity crisis, yet many organizations face a data for decisions gap due to limited capacity and resources (Gerber and Iacona, 2024). This also hinders efforts to evaluate the effectiveness of conservation interventions, such as reintroductions or habitat restoration. In short, without robust prey data, we risk making decisions that may appear promising but fail to deliver tangible conservation outcomes (Gerber and Iacona, 2024).

Predator-prey relationships are intricate, with close interaction and reciprocal influence (Davis et al., 2021). This dynamic relationship indicates that the availability of prey data can serve as a predictor of various ecological phenomena, such as predator distribution, habitat suitability, and density (Erfanian et al., 2013; Perez et al., 2022; Choi et al., 2023; Ariyanto et al., 2024b). This predictive capacity extends to the study of home range dynamics (Gray and Start, 2013) and even the density of predators, such as leopards (Khorozyan et al., 2008). The utilization of species datasets that are uneven or incomplete due to inadequate detection will yield minimalist and less reliable predictions (Khorozyan et al., 2008). Consequently, it is imperative to compile a comprehensive empirical database that encompasses the presence, distribution, and availability of species, particularly prey animals. Camera traps have been employed with great efficacy in determining the presence of elusive, frequently nocturnal, mammalian species (O'Brien, 2011; Karanth et al., 2017; Bruce et al., 2018; Turot et al., 2024), including the Javan leopard and its prey (Santoso and Restanto, 2021; Ario et al., 2022; Bashir et al., 2023; Kholiq and Sucipto, 2024). The objective of this study is to ascertain the presence of Javan leopards and their potential prey species through the analysis of camera trap data from MBNP, and to estimate the abundance of each prey species.

2. RESEARCH METHOD

This study used camera trap data collected by the MBNP survey conducted in 2024, covering 128 km^2 which includes the core and wilderness zones. Fourteen camera stations were located in the core zone, and 19 were located in the wilderness zone. The study area is situated in the western region of MBNP, ranging in elevation from sea level up to 920 meters. The landscape is predominantly covered by dryland forest, accounting for 86.31% of the area, followed by dryland agriculture (9.15%), shrubs (4.12%), and a small proportion of other land types such as savanna, mangrove, residential zones, and open land (0.41%). This diverse land cover gives rise to seven distinct ecosystem types, including lowland (pamah) ecosystem (90.42%), artificial ecosystem (9.22%), river ecosystem (0.15%), savanna (0.13%), coastal ecosystem (0.05%), riparian ecosystem (0.02%), and mangrove ecosystem (0.01%). This survey area is part of the MBNP that had never been surveyed using camera traps (Figure 1). The survey used a Panthera Version 7 camera trap made in the United States owned by the SINTAS Indonesia.

A survey site was established with 33 stations (grids), with a density of one station (one camera trap) per 2 x 2 km^2. The use of a 2×2 km grid for camera trap installation is based on established ecological survey protocols, spatial modeling principles, as well as extant literature (Wilianto et al., 2020; Hongo et al., 2020; Noor et al., 2020; Jayasekara et al., 2021; Ario et al., 2022; Salvatori et al., 2023; Ahmad et al., 2024). The grid size of 4 km² was adopted from the smallest home range size of adult female Javan leopards (Wilianto et al., 2020; Ario et al., 2022). In addition, this grid size strikes a balance between spatial resolution and logistical feasibility, ensuring adequate coverage of the landscape while maintaining manageable fieldwork demands.

The position of the stations optimized to capture the densities and area coverage, and each station is considered as one sampling unit covering an area of four-square kilometres. The camera trap was configured to record events of 30 seconds in length with a 2-second delay between events, with the date and time of each event recorded. The cameras remained active 24 hours a day. Camera trap data processing carried out with the following steps: (1) calculated the survey effort, (2) identify all animal species and sorting them by species by grouping photos/videos into folders, (3) tabulated all species, date and time recorded and rated them as a dependent or independent event, (4) classify all species based on their protection and conservation status, (5) determine the potential prey species for Javan leopards, (6) calculated two relative abundance indices. We calculated the effort of camera trap survey based on the number of days each camera trap unit is active in a survey period (Wilianto et al., 2020). Following O'Brien et al. (2003), we defined an independent event as photos showing different individuals or the same species with at least a 30-minute interval between shots and not taken one after another. When processing a photo of a wild boar at 6:00 p.m., followed by another wild boar at 6:45 p.m. Since more than 30 minutes passed, the two events are considered independent. Using the Protected Wildlife Species Identification Guidebook: Mammals, Aves, Reptiles Series (available at: https://ksdae.menlhk.go.id/publikasi-buku.html), we identified all wildlife species captured in the photos/videos and sorting them by species by grouping photos/videos into folders named after the species recorded in the photos/videos.

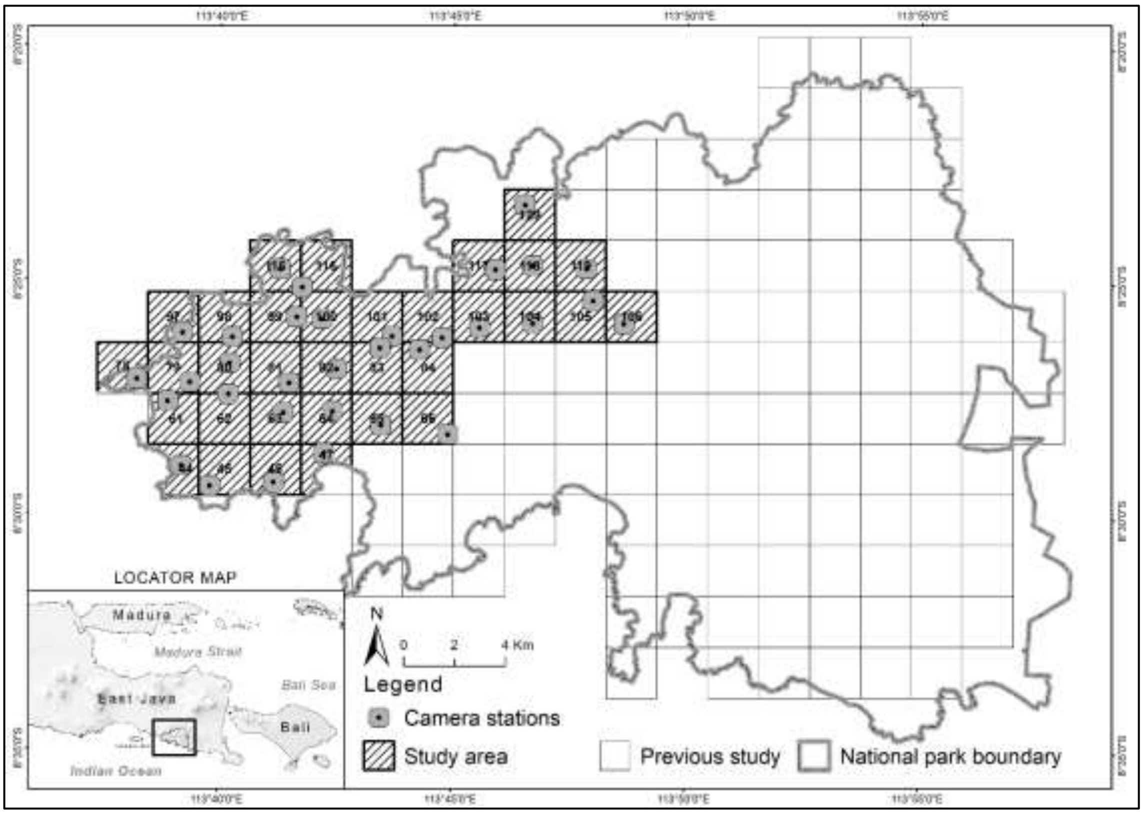

Figure 1. The distribution of camera trap stations and survey grid

Furthermore, we extract the photo/video metadata information especially date and time recorded using Renamer software (Sanderson and Harris, 2013, available at https://www.den4b.com) and tabulated all species, date and time recorded and rated each photos/videos as a dependent or independent event by following the method described by O'Brien et al. (2003). We analysed protection and conservation status for all identified species based on Indonesian government regulations and the IUCN Red List. We selected the potential prey species for Javan leopard base on the list of nine prospective prey species proposed by Ariyanto et al. (2024a). Furthermore, following O'Brien et al. (2003), we used the number of independent events for each species as an index of species abundance. The relative abundance indices (RAI) calculated using the formula (O'Brien et al., 2003): $RAIi = (Ni/\Sigma TD) \times 100$, where Ni: the number of individuals of each species from the independent photos/videos and ΣTD: the number of trap-days.

3. RESULT AND DISCUSSION

Camera trap accomplishment

Of all the camera traps used in this study, 29 (85.29%) performed well and produced useful results. However, one camera trap was misplaced (CT 63) and the remaining four camera stations (CT 99, CT 100, CT 102, and CT 117) were insufficient to record data because they did not function properly. Preliminary findings, as showed by the results of data processing and tabulation, indicate that the number of trap days was 1281.59 trap days with a mean of 45.77 (±XX) trap days (Table 1). The total photos and videos recorded was 5046 images, comprising of 3202 animals (63.46 %), 1337 empty (25.50 %), 496 human (9.83 %), and 11 unidentified (0.22 %). Among the 28 camera stations that detected wildlife presence, CT 46 and CT 84 documented the highest species counts, regarding 12 and 11 species, respectively (Figure 2).

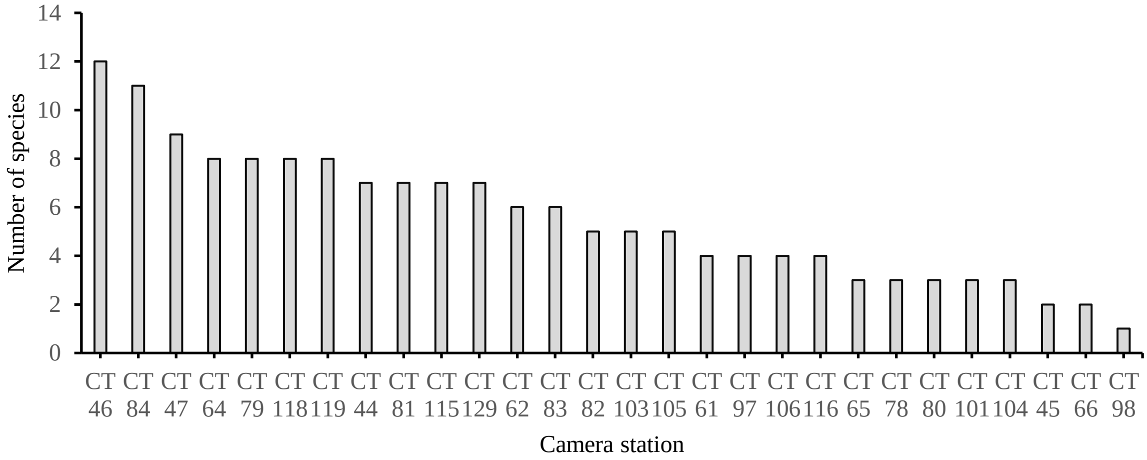

Figure 2. Number of species captured by each camera trap stations

Table 1. Sampling effort measured by the number of trap days

Camera stations	Start time	Start date	End time	End date	Trap days
CT 44	15:00	20/09/2024	11:06	07/11/2024	47.84
CT 45	10:47	20/09/2024	9:17	07/11/2024	47.94
CT 46	11:16	26/09/2024	8:28	08/11/2024	42.88
CT 47	10:21	20/09/2024	12:30	08/11/2024	49.09
CT 61	16:40	21/09/2024	9:29	10/11/2024	49.70
CT 62	14:25	25/09/2024	10:26	10/11/2024	45.83
CT 64	13:43	25/09/2024	12:51	06/11/2024	41.96
CT 65	9:57	20/09/2024	7:02	09/11/2024	49.88
CT 66	15:30	20/09/2024	7:28	09/11/2024	49.67
CT 78	4:22	24/09/2024	13:51	04/11/2024	41.40
CT 79	14:25	25/09/2024	10:26	10/11/2024	45.83
CT 80	12:39	24/09/2024	8:26	10/11/2024	46.82
CT 81	12:11	24/09/2024	9:42	06/11/2024	42.90
CT 82	10:25	25/09/2024	5:14	07/11/2024	42.78
CT 83	13:58	22/09/2024	9:54	06/11/2024	44.83
CT 84	16:38	21/09/2024	12:16	06/11/2024	45.82
CT 97	12:43	24/09/2024	8:20	14/11/2024	50.82
CT 98	11:16	24/09/2024	9:53	09/11/2024	45.94
CT 101	14:36	22/09/2024	9:25	06/11/2024	44.78
CT 103	13:07	21/09/2024	10:54	06/11/2024	45.91
CT 104	12:08	21/09/2024	13:54	06/11/2024	46.07
CT 105	17:30	20/09/2024	10:20	07/11/2024	47.70
CT 106	14:15	20/09/2024	12:26	07/11/2024	47.92
CT 115	17:01	23/09/2024	9:26	07/11/2024	44.68
CT 116	15:19	22/09/2024	13:26	07/11/2024	45.92
CT 118	11:39	20/09/2024	8:25	07/11/2024	47.87
CT 119	15:28	19/09/2024	9:08	07/11/2024	48.74
CT 129	13:43	08/10/2024	15:08	07/11/2024	30.06
		Total			**1281.59**

Species list and composition

We identified 24 species, including the Javan leopard, 24 genus, 20 families, 12 orders, and three classes (Table 2). The following taxonomic categories were identified: the Mammal class comprises of 19 species, Aves comprises of four species, and one species of Reptiles. Our analysis revealed that the species accumulation curve reached a steady state after eight weeks (Figure 3). This suggests that further investigation at the same locations may not yield the discovery of additional species. Furthermore, insights into the ecological and conservation status of all these species can be obtained through the consideration of management priorities, protection status, and IUCN Red List categories.

Table 2. The species list and composition, with their potential rate as prey for the Javan leopard

Species	∑ Camera station[1]	∑ Images	∑Inde-pendent images	%	∑ Indi-vidual	%	P106 status	IUCN Red List status	Potential rate[2]
Arctictis binturong	3	3	3	0.36	3	0.30	Protected	VU	-
Bos javanicus	1	6	3	0.36	3	0.30	Protected	CR	Potential
Canis familiaris	5	41	10	1.20	11	1.11	-	NE	-
Chalcophaps indica	1	2	1	0.12	1	0.10	-	LC	-
Gallus gallus	9	35	22	2.64	25	2.52	-	LC	Potential
Herpestes javanicus	1	10	1	0.12	1	0.10	-	LC	-
Hydrornis guajanus	1	2	2	0.24	2	0.20	Protected	LC	-
Hystrix javanica	11	30	18	2.16	18	1.81	Protected	LC	-
Macaca fascicularis	27	2088	474	56.83	564	56.85	-	EN	Potential
Manis javanica	2	3	3	0.36	3	0.30	Protected	CR	-
Martes flavigula	4	22	7	0.84	11	1.11	-	LC	-
Muntiacus muntjak	17	179	53	6.35	55	5.54	Protected	LC	Potential
Nisaetus bartelsi	1	7	1	0.12	1	0.10	Protected	EN	-
Panthera pardus melas	3	26	10	1.20	10	1.01	Protected	EN	-
Paradoxurus hermaphroditus	14	69	52	6.24	52	5.24	-	LC	-
Prionailurus bengalensis	5	9	7	0.84	7	0.71	Protected	LC	-
Pteropus vampyrus	2	3	3	0.36	3	0.30	-	NT	-
Rattus argentiventer	5	10	9	1.08	9	0.91	-	LC	-
Sus scrofa	18	506	105	12.59	159	16.03	-	LC	Potential
Trachypithecus auratus	11	72	20	2.40	23	2.32	Protected	VU	Potential
Tragulus javanicus	4	43	14	1.68	15	1.51	Protected	DD	Potential
Tupaia javanica	6	14	8	0.96	8	0.81	-	LC	-
Varanus salvator	2	13	3	0.36	3	0.30	-	LC	-
Viverricula indica	3	9	5	0.60	5	0.50	-	LC	-
Total		**3208**	**836**	**100**	**994**	**100**			

Note: ∑Camera station1: number of camera station that capture the species, Potential rate2: Potential rate as prey species for Javan leopard base on Ariyanto et al. (2024), CR: Critically Endangered, EN: Endangered, VU: Vulnerable, NT: Near Threatened, LC: Least Concern, DD: Data Deficient, NE: Not Evaluated.

Of the 24 species, three species have been identified as priority species in MBNP, including the Javan leopard, banteng, and Javan hawk-eagle. A total of 13 species are protected (Table 2) based on the Minister of Environment and Forestry Regulation Number P.106/MENLHK/SETJEN/ KUM.1/12/2018 of 2018 concerning the Second Amendment to the Minister of Environment and Forestry Regulation Number P.20/MENLHK/SETJEN/KUM.1/6/2018 concerning Protected Plant and Animal Species. This assertion is further substantiated by the IUCN Red list category (Table 2), which designates two species as critically endangered (CR), including the Sunda pangolin (Manis javanica) and banteng (*Bos javanicus*). A total of three species have been categorized as endangered (EN) including the Javan leopard (*Panthera pardus melas*), Javan hawk-eagle (*Nisaetus bartelsi*), and the long-tailed macaque (Macaca fascicularis). Two species have been classified as vulnerable (VU), including Javan langur (*Trachypithecus auratus*) and binturong (*Arctictis binturong*). Fourteen species have been designated as low risk or least concern (LC). We found that the Javan mouse deer (*Tragulus javanicus*) is categorized as data deficient (DD), and one remains unevaluated (NE).

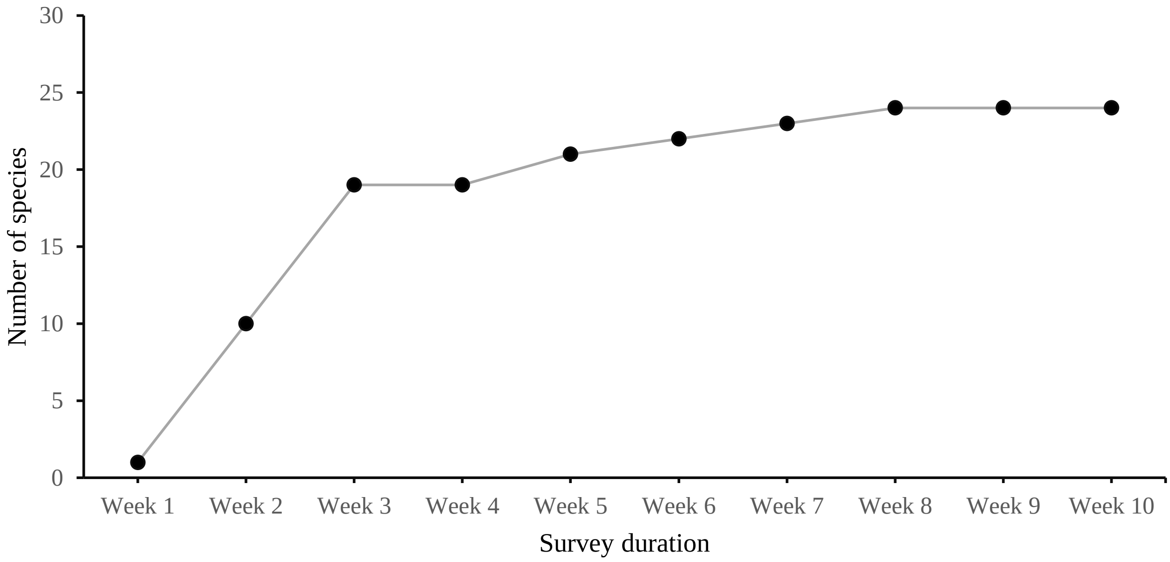

Figure 3. Cumulative number of potential prey species captured by camera trap.

Compared to previous camera trap surveys conducted in several locations within MBNP, the number of species recorded in this study area was not significantly different to the number recorded in 2023. MBNP (2023) recorded 26 species in the northern part of MBNP, while this study recorded 24 species in the western part of MBNP. We found that the number of Javan leopards captured in this study was lower than that reported in a previous survey conducted in different region of MBNP. Among the 33 camera stations, only three captured the Javan leopards, including camera station CT 105, CT 106, and CT 119. These stations located in the northeastern part of the study area and the northwestern part of MBNP. From a total of 1281.59 trap days, we obtained only 26 images of Javan leopards (22 images showed single animals, four pairs). We identified three individual leopards from the image of their right and left flanks, including two females and one melanistic male. The result indicated that the sex ratio between adult males and adult females was 1:2, which is considered to be the ideal sex ratio for leopards (Samarasinghe et al., 2022). Compared to the previous camera trap surveys, the number of leopards identified in this study area was significantly different from the results of previous studies conducted in several different locations within MBNP. According to MBNP (2023), the number of individual leopards captured in the camera trap survey from 2017 to 2023 was 6, 15, 12, 16, 17, 7, and 8, respectively.

The Relative Abundance Indices (RAI) of potential prey species

The result of the RAI analysis (Table 3) revealed that the most abundant prey species in the study area were the long-tailed macaque with the number of independent images of 474 and the RAI value of 44.16 independent events per 100 trap-days. This was followed by wild boars and muntjacs, with RAI values of 12.41 independent events per 100 trap-days and 4.29 independent events per 100 trap-days, respectively. Banteng was the rarest species, appearing only three independent images with an RAI value of 0.23 independent events per 100 trap-days.

Table 3. The relative abundance index values (RAI) of each potential prey species for the Javan leopard

Common name	Scientific name	∑ Camera station	∑ Images	∑ Independent events	Number of individuals	RAI
Banteng	*Bos javanicus*	1	6	3	3	0.23
Red junglefowl	*Gallus gallus*	9	35	22	25	1.95
Long-tailed macaque	*Macaca fascicularis*	26	2088	474	566	44.16
Muntjac	*Muntiacus muntjak*	16	179	53	55	4.29
Wild boar	*Sus scrofa*	5	506	105	159	12.41
East Javan langur	*Trachypithecus auratus*	18	72	20	23	1.79
Java mouse deer	*Tragulus javanicus*	11	43	14	15	1.17

Note : Images: photos or videos recorded by camera trap during survey period

Based on the RAI (Table 3), long-tailed macaque (*Macaca fascicularis*) is the most frequently detected species, with an RAI of 44.16. This suggests that it is likely a key prey resource for the Javan leopard. Wild boar (*Sus scrofa*) also exhibits a notable presence, with an RAI of 12.41, indicating its potential significance in the leopard's diet. The availability of muntjac deer (*Muntiacus muntjak*) is moderate (RAI: 4.29). Meanwhile, red junglefowl (Gallus gallus) and East Javan langur (*Trachypithecus auratus*) demonstrate a more limited yet noteworthy presence, with RAI values of 1.95 and 1.79, respectively. Meanwhile, Java mouse deer (*Tragulus javanicus*) has a relatively low RAI of 1.17, indicating its infrequent detection. Lastly, banteng (*Bos javanicus*) has the lowest RAI value of 0.23, which may reflect low population density, elusive behavior, or habitat avoidance within the study area. These findings suggest that the Javan leopard's prey availability is dominated by primate species, particularly *Macaca fascicularis*, which had the highest RAI of all recorded species. The high relative abundance of *M. fascicularis* likely makes it reliable and energetically efficient prey. The presence of *Sus scrofa* and *Muntiacus muntjak* at moderate RAI values indicates that these ungulates may also play a significant role in the leopard's diet depending on the local habitat and seasonal factors. Meanwhile, species such as *Gallus gallus*, *Trachypithecus auratus*, and *Tragulus javanicus* offer less consistent prey opportunities. The low detection rate of *Bos javanicus* implies that it may be infrequent in the leopard's diet, potentially due to behavioral avoidance or lower population density.

Potential disturbance

The presence of humans in the defined survey area implies a potential disruption to the survey activities as well as disruption of wildlife and their habitats. In addition, rampant illegal activities have caused damage and loss of camera trap. According to the documentation, 28 camera traps were damaged and misplaced during the previous survey (MBNP, 2023). In this study, human subjects was documented at 21 out of the 33 camera stations, including CT 44, CT 45, CT 47, CT 62, CT 64, CT 65, CT 66, CT 78, CT 79, CT 81, CT 82, CT 83, CT 97, CT 100, CT 101, CT 102, CT 105, CT 115, CT 116, CT 118, CT 129. Base on the number of human presence images at each camera station during 2024 survey, we found that CT 65, CT 81 and CT 115 is the most frequently documented human presence (Figure 4). Compared to the surveys during 2017-2023, the number of stations recording human presence in 2024 has the highest number in the last eight-year period (Figure 5).

Illegal encroachment into MBNP, including poaching, logging, and land conversion, can harms both biodiversity and local communities (Kleinschroth and Healey 2017: Liu et al. 2019; Cole et al. 2023; Cole et al. 2024; Gunawan et al. 2024; MoEF 2024). A decrease in the population of prey species such as deer, wild boar, and langurs has the potential to disrupt the survival of the Javan leopard. Furthermore, it has been acknowledged that the Javan leopard is active during both diurnal and nocturnal periods (Kholiq and Sucipto, 2024). Consequently, human-leopard encounters may occur, leading to potential conflicts that could be detrimental to both parties involved. As previously mentioned, the limited number of Javan leopards recorded, in conjunction with the reduced number of camera trap stations that documented their presence, compared to earlier surveys, may be indicative of the impact of anthropogenic disturbances within the study area. It is therefore imperative that future studies be conducted to explore this phenomenon.

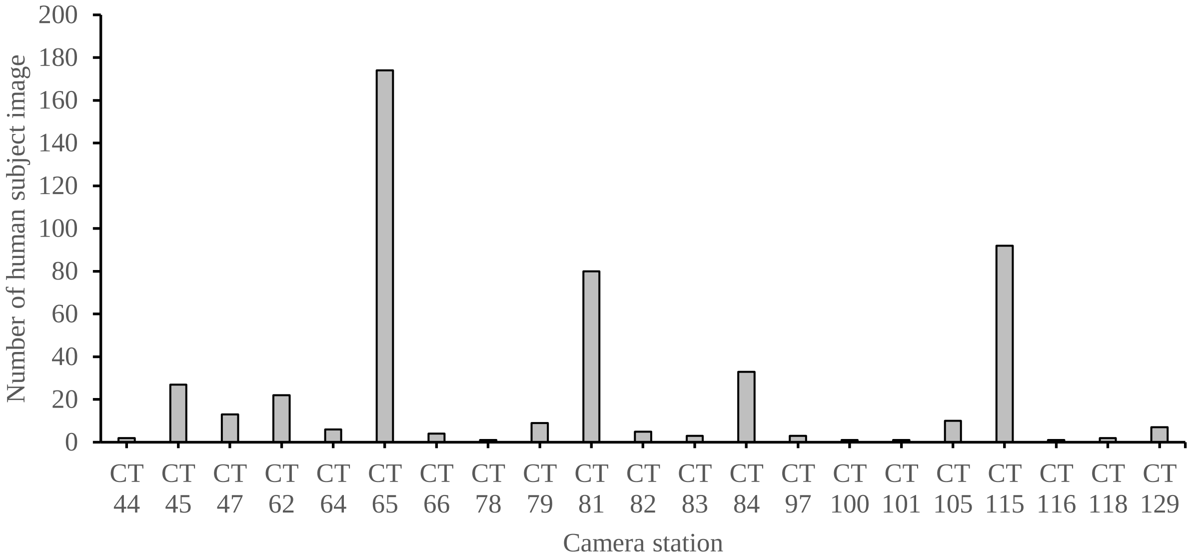

Figure 4. Number of human presence images at each camera station during 2024 survey.

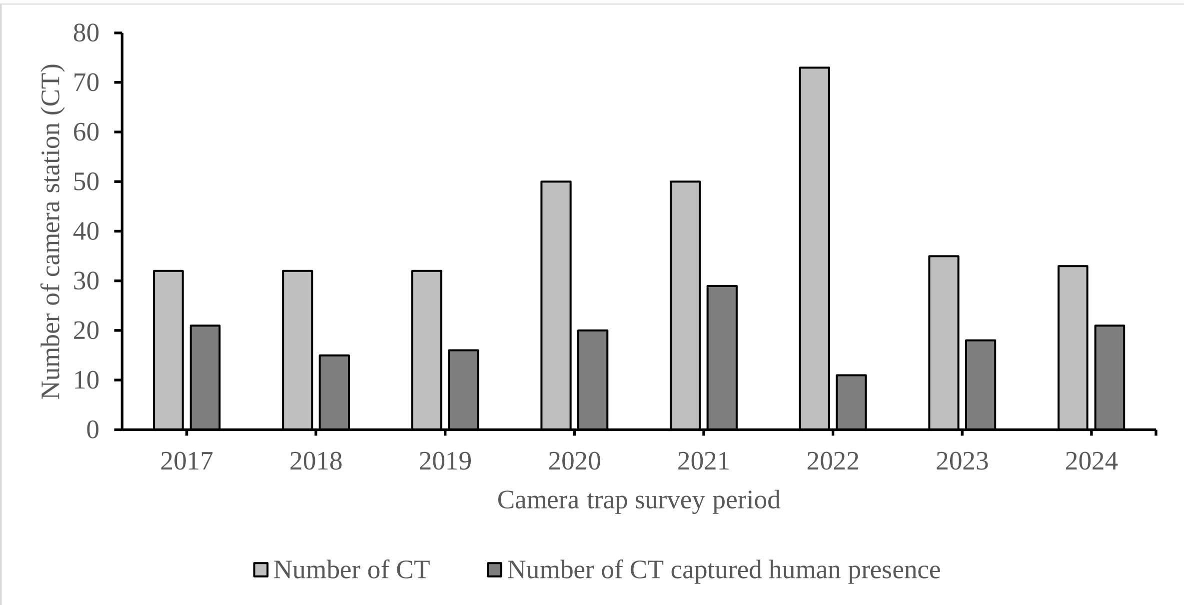

Figure 5. The total number of camera stations that recorded human presence during the designated survey period (2017-2024).

4. CONCLUSION

Using the camera trap data, we found the presence of Javan leopard and their potential prey species in the study area. Three adult Javan leopard individuals were recorded, with a sex ratio of one melanistic male to two females (1:2). All observed individuals belonged to a single age class, consisting exclusively of adults. The result of this study identified 24 species and selected seven potential prey species for Javan leopard, including banteng, muntjac, Javan mousedeer, wild boar, junglefowl, Javan langur, and long-tailed macaque. RAI analysis showed that the most abundant prey species was the long-tailed macaque (44.16 independent events per 100 trap-days), followed by wild boars (12.41 independent events per 100 trap-days) and muntjacs (4.29 independent events per 100 trap-days). Banteng was the rarest prey species, with an RAI value of 0.23 independent events per 100 trap-days. The presence of charismatic flagship species such as Javan leopards in this study area highlights its ecological significance and provides a foundation for improving biodiversity data and guiding future conservation efforts, as well as providing a fundamental basis for future study.

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