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Camera trap records of native and non-native mammalian carnivores in urban forests of southern Kyoto, central Japan

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Abstract. Information on urban mesocarnivores in densely populated urban areas of Asia remains limited. This study presents camera trap data collected in autumn and winter from urban forests in central Japan. The study was conducted in the Uji Campus of Kyoto University and riparian forest patches along the Uji River in southern Kyoto, central Japan. We confirmed the presence of six medium-sized carnivore species across five families, including three native species: Raccoon Dog *Nyctereutes procyonoides* (Gray, 1834), Red Fox *Vulpes vulpes* (Linnaeus, 1758), Japanese Marten *Martes melampus* (Wagner, 1841), and three non-native species: Raccoon *Procyon lotor* (Linnaeus, 1758), Masked Palm Civet *Paguma larvata* (Smith, 1827), and Stray Cat *Felis catus* (Linnaeus, 1758). The urban forests within the study area may provide habitat for mesocarnivores, presumably supporting their foraging and sheltering needs. Our data is valuable as baseline information on the mesocarnivore presence and utilisation of urban greenspaces in East Asia.

Key words. Domestic Cat, Japanese Marten, Masked Palm Civet, mesopredator, Raccoon Dog, Red Fox, urban green space

Hisano M, Tsunoda H, Peeva S, Aoyagi H, Yamamoto K, Ohte N, Komada N (2025) Camera trap records of native and non-native mammalian carnivores in urban forests of southern Kyoto, central Japan. Check List 21 (6): 1078–1091. https://doi.org/10.15560/21.6.1078

INTRODUCTION

With the growth of human populations, rapid urban development, and the decrease in natural habitats, understanding whether and how wildlife can adapt to human residential areas has become increasingly of concern. Increased overlap between wildlife habitats and human residences provides more frequent opportunities for human-wildlife interactions (Bateman and Fleming 2012; Soulsbury and White 2016), both in negative ways (e.g., conflicts such as property, crop, livestock damages, human injuries, or the spread of zoonotic diseases and parasites; Nyhus 2016) and positive ways (e.g., enhancing nature experiences, such as interactions with wildlife in close proximity to people; Cox and Gaston 2018). Therefore, accumulating information of urban wildlife adaptation is fundamental not only for species conservation but also for urban wildlife management, to maintain appropriate distance and enable co-existence (Bateman and Fleming 2012; Nyhus 2016).

Particularly, mesocarnivores are well adapted to urban areas with their flexible and generalist diets, often including anthropogenic food sources such as raw garbage (Jankowiak et al. 2016; Poessel et al. 2017), stray animals (Murray et al. 2015; Tsunoda et al. 2017), or planted fruits from human residence (Hisano et al. 2016, 2018; Gomes et al. 2019). Some species use urban areas as part of their home range, temporarily staying or passing through for foraging, etc., while their core territories or reproductive sites remain closer to natural habitats as rural areas (Gámez and Harris 2021). Others succeeded in reproducing in core urban areas, finding suitable and inconspicuous denning sites undisturbed by humans (Herr et al. 2010; Raymond and St. Clair 2023). Urban greenspaces, defined as a network of semi-natural spaces in both urban and rural settings that collectively support ecosystem health, while benefitting both biodiversity and people (Naumann et al. 2011; Godoi et al. 2025), serve as essential habitats providing corridors, shelters, or reproductive sites, whether used temporarily, or long-term (Lombardi et al. 2017; Łopucki et al. 2019; Parsons et al. 2019;

OPEN ACCESS

Academic editor: Krizler Tanalgo
Received: 4 April 2025
Accepted: 11 October 2025
Published: 11 November 2025

Gámez and Harris 2021). Therefore, assessing the role of urban greenspaces in mesocarnivore utilisation is crucial for understanding their urban ecology and informing conservation practices in urban biodiversity, as well as for managing human–wildlife conflicts. While the information on urban mesocarnivores is well documented in Europe and North America (Collins et al. 2021), studies in densely populated urban areas of Asia remain limited (Collins et al. 2021; Wierucka et al. 2023). Accumulating data from densely populated East Asia is particularly important, given that cities and greenspaces increasingly intersect with wildlife habitats, leading to potential interaction (Wierucka et al. 2023).

Here we investigated the occurrence of small urban greenspaces by mesocarnivores in southern Kyoto, central Japan, during the autumn and winter season. The study area is in a suburban region of the Keihanshin (Kyoto–Osaka–Kobe) Metropolitan Area, which has a population of more than 19 million people. Given the ongoing range expansion of invasive mammalian species in Japan, our study establishes monitoring of both, native and non-native species, along with domestic ones to assess the local mesocarnivore community. To highlight the regional novelty of our observations, we also report the distance of each sighting from the nearest historical record documented in citizen science portals.

STUDY AREA

The study was conducted in urban forests in the municipality section of Gokasho, Uji City, southern Kyoto, central Japan (Figure 1). Uji City had a population density of 2,656 people/km^2 as of 2020. The region belongs to the ecoregion of Taiheiyo evergreen forests, in the Temperate Broadleaf & Mixed Forests biome. The mean annual temperature and precipitation at the nearest meteorological observation site (Kyoto City, approximately 10 km north of the study area) between 2000 and 2023 were 16.4 °C and 1,535 mm, respectively (Japan Meteorological Agency 2025). The surroundings of the study sites were a human residential area and small patchy rice fields or green tea farms (Figure 1; see also Hisano 2023; Hisano et al. 2024). There was also a hilly forested area with elevations ranging between 200 and 400 m located approximately 1.5 km east of the study site. We set two sites in the study area, as described below.

Uji Campus site. This study site was a small forest patch (4,845 m^2) located on the Uji Campus of Kyoto University (34°54′33″N, 135°47′52″E). It was covered by a secondary forest, and the area is occasionally subject to selective logging as a result of campus management activities. With regards to the vegetation, the dominant overstorey tree species in this patch were *Pinus densiflora* Siebold & Zucc. (Pinaceae), *Mallotus japonicus* (L.f.) Müll.Arg. (Euphorbiaceae), and *Aphananthe aspera* (Thunb.) Planch. (Cannabaceae) (Hisano et al. 2024). The understory layer was dominated by herbaceous species including *Vinca major* L. (Apocynaceae), *Pleioblastus chino* (Franch. et Savat.) Makino var. *viridis* (Makino) Sad.Suzuki (Poaceae). There is also an open area of small grassland, comprised of *Pueraria lobata* (Willd.) Ohwi subsp. *lobata* (Fabaceae), and *Miscanthus sinensis* Andersson (Poaceae), and *Erigeron annuus* (L.) Pers. (Asteraceae), adjacent to the forest patch.

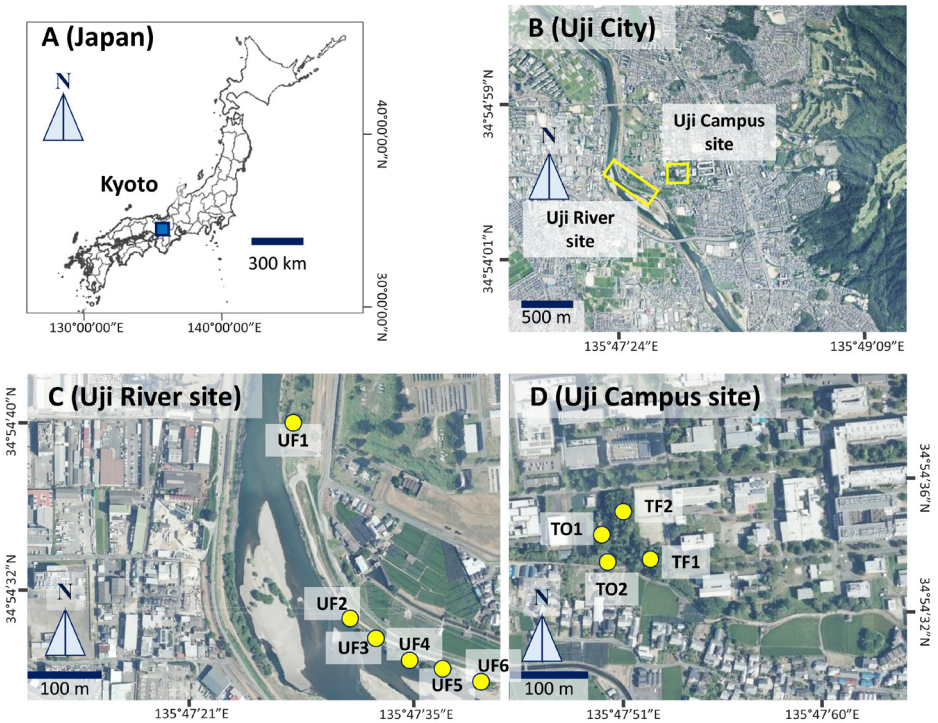

Figure 1. Maps showing the study area and sites in southern Kyoto, central Japan. **A.** The Japanese archipelago, in which the blue square indicates the location of Kyoto Prefecture. **B.** Study area of Uji City, in which the yellow squares show the location of the Uji Campus site (Kyoto University) and the Uji River site. **C.** The Uji River site, with yellow spots indicating the locations of camera stations (UF1–UF6 along the riparian forests). **D.** The Uji Campus site, with yellow spots showing the locations of camera stations (TF1 and TF2 at the inner forest; TO1 at the forest edge; TO2 at the open space). Materials are based on maps and aerial photos of the Geospatial Information Authority of Japan (https://www.gsi.go.jp/; the aerial photos are as of 2020).

Uji River site. The other site comprised two riparian forest patches along the Uji River (34°54′33″N, 135°47′29″E, approximately 600 m apart from the Uji Campus site; Table 1, Figure 1). Within the Uji River site, we investigated two riparian forest areas of 2,432 m^2 and 3,127 m^2, respectively, approximately 300 m apart from each other. These riparian forest patches were also secondary, with dominant overstorey species of *Aphananthe aspera* (Cannabaceae) and *Salix* sp. (Salicaceae). The riparian forest patches were dominated by *Miscanthus sacchariflorus* (Maxim.) Benth. et Hook.f. ex Franch. (Poaceae) and *Pueraria lobata* (Fabaceae).

Table 1. Summary of the camera trap locations in southern Kyoto, central Japan. Elevation information was obtained by the elevation function in the *rgbif* package (Chamberlain et al. 2017).

Site ID	Station ID	Environment	Decimal latitude	Decimal longitude	Elevation (m)	Year
Uji Campus	TF1	Forest patch	34.9092	135.7979	16	2023–2024
Uji Campus	TF2	Forest patch	34.9097	135.7975	19	2023–2024
Uji Campus	TO1	Forest edge	34.9095	135.7974	16	2023–2024
Uji Campus	TO2	Open area	34.9091	135.7975	16	2023–2024
Uji River	UF1	Forest patch	34.9112	135.7903	10	2024
Uji River	UF2	Forest patch	34.9082	135.7921	9	2024
Uji River	UF3	Forest patch	34.9080	135.7925	18	2024
Uji River	UF4	Forest patch	34.9078	135.7931	11	2024
Uji River	UF5	Forest patch	34.9077	135.7934	11	2024
Uji River	UF6	Forest patch	34.9077	135.7938	11	2024

METHODS

Camera trap survey

Uji Campus site. We installed a total of four trail cameras (Bushnell 119932C) between 25 October 2023 and 10 March 2024 in the Uji Campus site (Tables 1, 2). These months overlapped with a period when young individuals of most medium-sized carnivores might show increased movement as they continue dispersing after gaining independence in summer and autumn (Tatara 1994; Yamamoto et al. 1994; Uraguchi 2018), which may potentially increase their detectability. Of these, two cameras were deployed within the forest patch: one installed on a tree trunk at a height of 1.3 m above the ground (Station ID of TF1 in Table 1; Figure 1), and the other at the base of a tree trunk (Station ID: TF2), 30 cm above ground level. As the study was in its preliminary stage, this arrangement was oriented to capture animals from various positions and angles. The remaining two cameras were placed outside the forest, with one deployed at the forest edge, attached to a shrub at 1.3 m height (Station ID: TO1), and the other in the adjacent open grassland, attached to a pole at a height of 1.3 m (Station ID: TO2). The grassland was a managed area covered with *Zoysia* spp. (Poaceae). The camera stations were spaced approximately 30 m apart.

All cameras were set to capture consecutive sequences of three photographs at a 1-minute delay after triggering (Meek et al. 2014). This setup was used during three periods: 25–28 October (First Session, three camera trap days; hereafter, CTD), 12 November–9 December (Third Session, 27 CTD), and 9–28 December (Fourth Session, 19 CTD; Table 2). Additionally, the cameras were programmed to record 1-minute videos at 1-minute intervals during two periods: 28 October–12 November (Second Session, 15 CTD) and 28 December–10 March (Fifth Session, 73 CTD; Table 2). Note that a session refers to a distinct period after the memory cards were replaced. The camera-trap batteries lasted until the end of the study period.

Two different baits were used to attract animals (Ferreira–Rodríguez and Pombal 2019). On the first day of the study (25 October 2023), we applied pilchard oil (Robley et al. 2010) to the forest floor and the base of tree trunks, with 10–15 spray pumps per application (each pump releasing approximately 1.2 ml). In addition, we also placed 200 cm^3 of dry cat food ("Neko-Gourmet", tuna-, chicken-, and bonito-flavoured, manufactured by DCM, Japan) in a plastic container at each station. These containers were buried in the forest floor and covered with *P. densiflora* litter. These baits were not re-sprayed or refilled during the study period.

Uji River site. We placed a total of six camera traps within two riparian forest patches at the Uji River site (Table 1; Figure 1), between 5 January and 9 March 2024 (Table 2). One camera trap was positioned in one of the forest patches, while the remaining five were placed in the other patch, spaced 20–30 m apart within the forest (Figure 1). We set all the cameras to capture consecutive three pictures at 1-minute intervals (Meek et al. 2014), but did not set them to record any videos at this site. Unlike the Uji Campus site, no baits were used at the camera stations in the Uji River site. We did not change the SD cards or encounter battery depletion during the study period.

Table 2. Summary of camera trap setting and duration deployed in southern Kyoto, central Japan. Station IDs of TF1–2 and TO1–2 were located in the Uji Campus site, and those of UF1–6 were in the Uji River site (see Table 1). (CTD, camera trap days).

Session	Station ID	Start date (year/month/date)	End date (year/month/date)	CTD	Camera setting
First	TF1	2023/10/25	2023/10/28	3	Photo: 3 shots, 1 min interval
	TF2	2023/10/25	2023/10/28	3	Photo: 3 shots, 1 min interval
	TO1	2023/10/25	2023/10/28	3	Photo: 3 shots, 1 min interval
	TO2	2023/10/25	2023/10/28	3	Photo: 3 shots, 1 min interval
Second	TF1	2023/10/28	2023/11/12	15	Video: 60 sec recording, 1 min interval
	TF2	2023/10/28	2023/11/12	15	Video: 60 sec recording, 1 min interval
	TO1	2023/10/28	2023/11/12	15	Video: 60 sec recording, 1 min interval
	TO2	2023/10/28	2023/11/12	15	Video: 60 sec recording, 1 min interval
Third	TF1	2023/11/12	2023/12/9	27	Photo: 3 shots, 1 min interval
	TF2	2023/11/12	2023/12/9	27	Photo: 3 shots, 1 min interval
	TO1	2023/11/12	2023/12/9	27	Photo: 3 shots, 1 min interval
	TO2	2023/11/12	2023/12/9	27	Photo: 3 shots, 1 min interval
Forth	TF1	2023/12/9	2023/12/28	19	Photo: 3 shots, 1 min interval
	TF2	2023/12/9	2023/12/28	19	Photo: 3 shots, 1 min interval
	TO1	2023/12/9	2023/12/28	19	Photo: 3 shots, 1 min interval
	TO2	2023/12/9	2023/12/28	19	Photo: 3 shots, 1 min interval
Fifth	TF1	2023/12/28	2024/3/10	73	Video: 60 sec recording, 1 min interval
	TF2	2023/12/28	2024/3/10	73	Video: 60 sec recording, 1 min interval
	TO1	2023/12/28	2024/3/10	73	Video: 60 sec recording, 1 min interval
	TO2	2023/12/28	2024/3/10	73	Video: 60 sec recording, 1 min interval
NA	UF1	2024/1/5	2024/3/9	64	Photo: 3 shots, 1 min interval
	UF2	2024/1/5	2024/3/9	64	Photo: 3 shots, 1 min interval
	UF3	2024/1/5	2024/3/9	64	Photo: 3 shots, 1 min interval
	UF4	2024/1/5	2024/3/9	64	Photo: 3 shots, 1 min interval
	UF5	2024/1/5	2024/3/9	64	Photo: 3 shots, 1 min interval
	UF6	2024/1/5	2024/3/9	64	Photo: 3 shots, 1 min interval

Data presentation

For both study sites, we defined independent records as instances in which at least one of the camera traps placed within a study site captured images more than 30 minutes apart (Tsunoda 2021; Hisano et al. 2025), following the typical practices employed by the majority of studies (Peral et al. 2022). That is, if the same species were recorded at the same camera trap station within a time interval of <30 minutes, it was not considered an independent observation and was therefore excluded from the data (Appendix 1).

Review in citizen-science portals

To identify the distance from observations to the nearest historical records of each species, we consulted GBIF (Global Biodiversity Information Facility 2025), a widely used international biodiversity database. GBIF was preferred because it hosts large, publicly accessible datasets covering a broad range of taxa, with spatially explicit occurrence records that are regularly updated. The database also incorporates most research-grade records from the iNaturalist platform (iNaturalist 2025) while including additional sources such as museum collections, academic surveys, and government monitoring programs (Global Biodiversity Information Facility 2025).

RESULTS

Uji Campus site. We collected a total of 397 images for all captures (including failure detections of any animals) and 65 effective images (independent observations) for focal animal species from 548 camera days. Our study recorded a total of six mesocarnivore species from five families at the Uji Campus site (Table 3). Here the most frequently captured species was the Japanese Red Fox [*Vulpes vulpes* (Linnaeus, 1758)] with 29

independent observations, followed by the Raccoon Dog [*Nyctereutes procyonoides* (Gray, 1834), 11 independent observations] and the Raccoon [*Procyon lotor* (Linnaeus, 1758), 10 independent observations]. The Stray Cat [*Felis catus* (Linnaeus, 1758), seven independent observations], the Japanese Marten [*Martes melampus* (Wagner, 1841), four independent observations], and the Masked Palm Civet [*Paguma larvata* (Smith, 1827), three independent observations] were occasionally recorded. Red Foxes and Raccoon Dogs were detected at all camera stations on this site. Raccoons were primarily found at stations within the inner forest patch, with only two observations at the forest edge, while Stray Cats were mostly observed in an open environment and at the forest edge, with just one observation in the inner forest. Japanese Martens and Masked Palm Civets were observed exclusively at the inner forest stations (Table 3).

Uji River site. A total of 1,487 images for all captures including failed detections, with 83 effective images (independent observations) of focal mesocarnivores were obtained over 384 camera-days. We recorded a total of four species from three families at the Uji River site (Table 3). The Red Fox and the Stray Cat were the two most frequently recorded species (39 and 32 independent observations, respectively) in this site. We also had occasional records of Raccoon Dogs (five independent observations) and Masked Palm Civets (one independent observation; Table 3).

These observation sites were 9 km from the nearest historical GBIF records for Japanese Marten, Raccoon Dog, Masked Palm Civet, and Red Fox, and <1 km from those for Domestic Cat and Raccoon (Table 4).

Annotated list

Order Carnivora Bowdich, 1821
Family Canidae Fischer de Waldheim, 1817

Nyctereutes procyonoides (Gray, 1834)

Observations. JAPAN – Kyoto • Uji, Gokasho; 34°54′33″N, 135°47′52″E and 34°54′33″N, 135°47′29″E; 10–19 m alt.; first capture on 27.X.2023; Masumi Hisano obs.; secondary evergreen needle-leaved and deciduous broadleaved forests of the Taiheiyo evergreen forests ecoregion; photo and video; camera stations TF1, TF2, TO1, TO2, UF1, UF3 (forest patch, edge, open grassland).

Identification. The Raccoon Dog has a stocky body (but thinner than the Raccoon), a short, pointed muzzle, and small, rounded ears. Its tail is less than one-third of its body length. The face has a raccoon-like black mask extending beneath the muzzle, with a broad white band above the eyes and to the ears (Ward and Wurster–Hill 1990) (Figure 2A). Body length = 50–60 cm; tail length = 15 cm; weight = 3–5 kg (Yoneda 2008a).

Vulpes vulpes (Linnaeus, 1758)

Observations. JAPAN – Kyoto • Uji, Gokasho; 34°54′33″N, 135°47′52″E and 34°54′33″N, 135°47′29″E; 9–19 m alt.; first capture on 28.X.2023; Masumi Hisano obs.; secondary evergreen needle-leaved and deciduous broadleaved forests of the Taiheiyo evergreen forests ecoregion; photo and video; camera stations TF1, TF2, TO1, TO2, UF2, UF3, UF4, UF5, UF6 (forest patch, edge, open grassland).

Identification. The Red Fox is a slender canid with an elongated muzzle, large, pointed ears, and a round, bushy tail that is usually as long as the head and body (Larivière and Pasitschniak-Arts 1996) (Figure 2B).

Table 3. The list of species captured by camera trap survey in southern Kyoto, central Japan, during the study period (October 2023–March 2024 for the Uji Campus site, January–March 2024 for the Uji River site). Those captured after an interval greater than 30 minutes were defined as independent observations. That is, when the same species were recorded at different camera trap stations but within the time interval of 30 minutes, they were considered as one observation. TF1 and TF2 stations were located inside the forest patch at Uji Campus, while TO1 at its edge and TO2 at the open grassland adjacent to the forest patch. UF1–6 were located on riparian forests at the Uji River site. (*Non-native species, from Taiwan (Masuda et al. 2010); **Non-native species, from North America; CTD, camera trap days; "✓" indicates the presence of the species; "-" stands for its non-observation)

Species	Uji Campus site (137 CTD)					Uji River site (64 CTD)						
	Independent records per site	Forest		Edge	Open	Independent records per site	Riparian forest					
		TF1	TF2	TO1	TO2		UF1	UF2	UF3	UF4	UF5	UF6
Felis catus	7	-	✓	✓	✓	32	✓	✓	✓	✓	✓	✓
Martes melampus	4	-	✓	-	-	0	-	-	-	-	-	-
Nyctereutes procyonoides	11	✓	✓	✓	✓	5	✓	-	✓	-	-	-
Paguma larvata*	3	✓	✓	-	-	1	-	-	-	✓	-	✓
Procyon lotor**	10	✓	-	✓	✓	0	-	-	-	-	-	-
Vulpes vulpes	29	✓	✓	✓	✓	39	-	✓	✓	✓	✓	✓

Table 4. Global Biodiversity Information Facility (GBIF) records of mesocarnivores observed in this study and their nearest distance from our observations in the study area (Uji City, Kyoto, central Japan).

Species	Location (geographic coordinates)	Distance (km)	Date (yyyy/mm/dd)	Reference via GBIF*
Felis catus	Uji City, Kyoto (34°54′41.6″N, 135°48′09.8″E)	0.5	2024/04/25	iNaturalist contributors (2025a)
Martes melampus	Oyamazaki Town, Kyoto (34°54′00.0″N, 135°42′00.0″E)	9 .0	2012/05/19	Biodiversity Center of Japan (2018a)
Nyctereutes procyonoides	Oyamazaki Town, Kyoto (34°54′00.0″N, 135°42′00.0″E)	9 .0	2011/09/27	Biodiversity Center of Japan (2018b)
Paguma larvata	Oyamazaki Town, Kyoto (34°54′00.0″N, 135°42′00.0″E)	9 .0	2012/05/18	Biodiversity Center of Japan (2018c)
Procyon lotor	Uji City, Kyoto (34°54′34.0″N, 135°48′08.0″E)	0.3	2025/02/17	iNaturalist contributors (2025b)**
Vulpes vulpes	Oyamazaki Town, Kyoto (34°54′00.0″N, 135°42′00.0″E)	9.0	2012/06/17	Biodiversity Center of Japan (2018d)

*Reference data were accessed via GBIF: The Global Biodiversity Information Facility (2025), with formatting following their recommended style.
**Viewer discretion is advised.

Body length excluding the tail (hereafter, body length) = 60–75 cm; tail length = 40 cm; weight = 4–7 kg (Yoneda 2008b).

Family Felidae Fischer de Waldheim, 1817

Felis catus (Linnaeus, 1758)

Observations. JAPAN – Kyoto • Uji, Gokasho; 34°54′33″N, 135°47′52″E and 34°54′33″N, 135°47′29″E; 9–19 m alt.; first capture on 26.X.2023; Masumi Hisano obs.; secondary evergreen needle leaved and deciduous broadleaved forests of the Taiheiyo evergreen forests ecoregion; photo and video; camera stations TF2, TO1, TO2, UF1, UF2, UF3, UF4, UF5, UF6 (forest patch, edge, open grassland).

Identification. The Stray Cat shows a wide variety of fur colours and patterns, including solid, tabby, tortoiseshell, and bicolour. It has a rounded face with forward-facing eyes. Ears are triangular and upright. We observed individuals with orange (Figure 2C), white, black, and/or brown fur.

Family Mustelidae Fischer de Waldheim, 1817

Martes melampus (Wagner, 1841)

Observations. JAPAN – Kyoto • Uji, Gokasho; 34°54′33″N, 135°47′52″E; 19 m alt.; first capture on 31.X.2023; Masumi Hisano obs.; secondary evergreen needle-leaved and deciduous broadleaved forests of the Taiheiyo evergreen forests ecoregion; photo and video; camera station TF2 (forest patch).

Identification. In the central region of Japan, the Japanese Marten fur colour varies from yellowish brown to dark brown in summer, while in winter, it typically appears bright yellow with a distinctive white face (Masuda 2009). Body length = 45 cm; tail length = 19 cm; weight = 1.1–1.5 kg (Yoneda 2008c). Although we could not determine the yellowish body colour due to the black-and-white pictures taken at night, we identified the species based on its overall whitish face and characteristic elongated body typical of Mustelidae (Figure 2D) (Hisano et al. 2025), with a substantially larger and thicker body than weasels [*Mustela* spp. (Linnaeus, 1758)]. For comparison, weasels of potential occurrence, Japanese Weasel [*M. itatsi* (Temminck, 1844)] and Siberian Weasel [*M. sibirica* (Pallas, 1773)], range in body length from 16 to 39 cm, tail length from 7 to 21 cm, and weight from 0.3 to 0.8 kg, respectively (Yoneda 2008d, 2008e). Unlike the marten, both weasels typically exhibit black colouration on their face.

Family Procyonidae (Gray, 1825)

Procyon lotor (Linnaeus, 1758)

Observations. JAPAN – Kyoto • Uji, Gokasho; 34°54′33″N, 135°47′52″E and 34°54′33″N, 135°47′29″E; 9–19 m alt.; first capture on 29.X.2023; Masumi Hisano obs.; secondary evergreen needle-leaved and deciduous broadleaved forests of the Taiheiyo evergreen forests ecoregion; photo and video; camera stations TF1, TF2, TO1 (forest patch, edge).

Figure 2. Native and non-native mesocarnivores recorded by camera traps deployed in southern Kyoto, central Japan. **A.** *Nyctereutes procyonoides* (6 November 2023, at TF1). **B.** *Vulpes vulpes* (12 January 2024, at UF3). **C.** *Felis catus* (16 November 2023, at TO1). **D.** *Martes melampus* (14 November 2023, at TF2; adopted from (Hisano et al. 2025). **E.** *Procyon lotor* (19 October 2023, at TF1). **F.** *Paguma larvata* (25 February 2024, at TF1).

Identification. The Raccoon has a distinct brown-black "bandit" facial mask, sharply contrasting with adjacent whitish hair, and a tail featuring five to seven brown-black rings alternating with lighter hairs (Lotze and Anderson 1979) (Figure 2E). Body length = 42–60 cm; tail length = 20–41 cm; weight = 4–10 kg, substantially larger and fatter than the Raccoon Dog. The Raccoon is native to North America, but it was introduced to Japan as a pet and has been rapidly expanding its range since the late 1980s (Hayama et al. 2006).

Family Viverridae (Linnaeus, 1758)

Paguma larvata (Smith, 1827)

Observations. JAPAN – Kyoto • Uji, Gokasho; 34°54′33″N, 135°47′52″E and 34°54′33″N, 135°47′29″E; 9–19 m alt.; first capture on 11.XI.2023; Masumi Hisano obs.; secondary evergreen needle-leaved and deciduous broadleaved forests of the Taiheiyo evergreen forests ecoregion; photo and video; camera stations TF1, TF2, UF4, UF6 (forest patch).

Identification. The body colour of the Masked Palm Civet is greyish brown, with dark brown markings on the face and limbs. A distinctive white stripe runs from the lower forehead to the centre of the nose (Figure 2F), easily distinguishable from other species. Body length = 61–66 cm; tail length = 40 cm; weight = 3 kg (Yoneda 2008f). The Masked Palm Civet is considered non-native, as genetic research (Masuda et al. 2010) revealed that populations in Japan likely originated from Taiwan.

DISCUSSION

In this study, we observed six out of the 10 mesocarnivore species reported in Kyoto Prefecture (Kyoto Prefecture 2015). The distribution and density of medium-sized carnivores in urban areas can be shaped by the amount and structure of greenspaces that provide food resources or function as shelters (Lombardi et al. 2017; Łopucki et al. 2019; Parsons et al. 2019; Gámez and Harris 2021). The occurrence of the six species in our sites may reflect their tolerance to human disturbance and ability to exploit urban resources. Domestic Cats, Raccoon Dogs, Masked Palm Civets, and Raccoons are well known to inhabit highly populated urban areas and exhibit great urban adaptability (e.g., Bateman and Fleming 2012; Tsunoda et al. 2019; Seki et al.

2024). Although Red Foxes in central Japan are not often urban adaptive unlike those in Europe, they are tolerant to habitat fragmentation and human presence (e.g., Kaneko et al. 2001). Food availability for these species could also be a key driver. Domestic Cats, Raccoons, and Raccoon Dogs are known to scavenge garbage (e.g., Széles et al. 2018; Xu et al. 2024). Raccoon Dogs and Masked Palm Civets consume seasonally abundant fruits and invertebrates (e.g., Iwama et al. 2017; Xu et al. 2024). As for Red Foxes and Japanese Martens, although both species rely on small mammals as a key source of protein, they show clear seasonal shifts in diet composition, with fruits and invertebrates becoming more prevalent during periods when these resources are abundant [Hisano et al. 2017, 2019, 2022; see also Zhou et al. (2011) and Tsunoda et al. (in press a)]. These patterns suggest that the urban forests in our study area may provide habitat structure and seasonal food resources that facilitate the persistence of urban adaptive or tolerant mesocarnivores within the urbanised landscape. Therefore, our faunal data suggest that the urban forests within the study area may provide habitat structure and seasonal food resources that facilitate the occurrence of urban adaptive or tolerant mesocarnivores.

Compared to previous studies conducted in Japan, urbanised landscapes in eastern Japan, surveyed year-round, typically record only three or four species and often lack foxes and martens (Saito and Koike 2015). For example, a camera trap study in an urban greenspace on a campus in western Tokyo (Nagamitsu and Kaneko 2017) recorded four species: two native species, the Raccoon Dog and the Japanese Badger [*Meles anakuma* Temminck, 1844], Mustelidae, along with two non-native species, the Masked Palm Civet and the Stray Cat. Similarly, another campus study in western Tokyo (Kamito et al. 2019) recorded the same four species while also reporting the presence of the non-native Raccoon. In suburban areas, a camera trap study conducted on a campus surrounded by larger forests in western Japan reported a more complete mesocarnivore fauna, including the Siberian Weasel, Japanese Marten, and the Red Fox (Hemmi et al. 2018), although a similar suburban campus in eastern Japan lacked martens and foxes (Iwasaki et al. 2021).

Out of the 10 species listed in the Kyoto Prefecture Red List (Kyoto Prefecture 2015) as potentially present, the following species were not confirmed: the native Japanese Weasel, the Japanese Badger, the non-native Siberian Weasel, and the Stray Dog [*Canis familiaris* (Linnaeus, 1758), Canidae]. Since badgers experience overwintering [so-called "winter lethargy" (McClune et al. 2015)] during the core winter season (likely December–February) (Tanaka 2006), the effective effort was even smaller compared to other species due to the seasonal bias, even if they were present. Weasels (*Mustela* spp.) in Japan are typically found in agricultural lands and riverbanks (Tsunoda et al. in press b), and so we expected to record them in our study, especially in the area of the Uji River site. Although not captured by camera trap survey, a *Mustela* sp. was sighted within the residential area of the municipal section Gokasho (1.0 km north of the Uji campus site or 800 m northeast of the Uji River site) during the study period, on the night of 2 March 2024 (Masumi Hisano, personal obs.). Therefore, we assume that weasels should be present in the area. Weasels are active and move swiftly, which may have hindered adequate detection depending on the camera's trigger speed (Glen et al. 2013). To address these issues, the application of bait has been proposed (Mos and Hofmeester 2020; Barros et al. 2024; Ebel and White 2024). While baiting was implemented at the Uji campus site, it was not applied at the Uji River site, which is necessary to improve the detection rate of *Mustela* species, particularly in riparian habitats.

In summary, despite the shorter survey period in the present study, the relatively diverse range of species recorded suggests that the Uji City area, southern Kyoto, may benefit from greenspaces that enhance habitat availability and connectivity with larger areas of surrounding forests.

Red Foxes. At the Uji River site, foxes were often observed during the two-month survey period even without the use of bait, suggesting that the habitat of grasslands in the riverbank might be favourable for them in terms of food resources. Additionally, the area around the Uji Campus features small-scale farmland and expansive managed grasslands adjacent to the Japan Ground Self-Defence Force Camp Uji. These areas likely provide additional food resources for foxes, while the small woodlands on campus may function as shelter. Foxes are listed as a "Species of Concern" in the Red List of Kyoto Prefecture (Kyoto Prefecture 2015). The prefectural report emphasises the decline in riverbank habitats, attributing it to the reduction of rodents, and habitat destruction due to urban development (Kyoto Prefecture 2015). Although an unofficial online description reported the species from surrounding mountains connected to large forests in the region (Wild Bird Society of Japan Kyoto 2024), we confirmed for the first time the presence of foxes in a small, isolated forest patches within the urban matrix of Uji City. Particularly, we recorded a video of a fox urine marking in an open area of the station TO1 at the Uji Campus site (presented as Appendix 2), which may suggest occasional territorial use of the habitat (e.g., defending food resources; Monclús et al. 2009). Therefore, our study provides valuable information for the conservation and management of urban greenspaces within Kyoto Prefecture.

Raccoon Dog. The Raccoon Dog inhabits not only rural green areas but also the core urban of Tokyo (Mitsuhashi et al. 2018; Tsunoda et al. 2019). Therefore, the presence of Raccoon Dogs in our study area is not surprising. On 4th November 2023, we also confirmed Raccoon Dogs' latrine containing seeds of

persimmon (*Diospyros kaki* Thunb.) on the Uji Campus (Figure S1). Its large, strongly scented fleshy fruits fall to the ground sooner after ripening, making them highly accessible to animals that rely on their sense of smell for foraging (Takatsuki et al. 2018). Since persimmon trees are present both on the campus and in nearby residential areas, the Raccoon Dogs likely utilise these fruits during the autumn season. A study conducted along an urban-forest gradient in eastern Japan showed that Raccoon Dogs were most frequently photographed in landscapes where urban and forest areas are moderately mixed (Saito and Koike 2013). Environments like those around Uji Campus, where lands are shared with forest patches and urban areas, likely provide Raccoon Dogs with food resources and shelter.

Japanese Marten. The Japanese Marten was recorded from only one station of the forested environment at the Uji Campus site, but not from the edge or open area. The previous study in eastern Japan (Saito and Koike 2013) suggested that martens typically occur only in more forest-dominated landscapes. However, their presence in urban greenspaces as observed in regions in more central to western Japan (Takasaki 2022), may be a distinctive feature of this part of Japan. A meta-analysis of the Japanese Marten diet at the national scale showed that martens in colder regions in Japan (cool-temperate/subalpine zones) consume mammals more frequently (predicted as >50% by relative frequency of occurrence, RFO). In contrast, in warm-temperate zones, which our study area in southern Kyoto belongs to, mammals account for less than RFO of 30% of their diet, while fruits comprise more than 80% (Hisano et al. 2019). Therefore, martens may be able to thrive in environments with fewer mammalian prey (e.g., rodents and hares), which could partly explain their occurrence in lowland urban and suburban areas of central to western Japan, characterised by generally evergreen landscapes (Takasaki 2022). Martens consume not only wild fruits but also various anthropogenic fruits (Hisano and Deguchi 2018). Indeed, marten faeces found around the study area confirm that martens consumed human-subsidised persimmon fruits (Hisano et al. 2025), similar to the Raccoon Dogs mentioned above. Given the limited observations, however, it remains unclear whether martens are consistently utilising the campus forest or if they are transient visitors from nearby larger forest areas (Hisano et al. 2025). This uncertainty aligns with personal reports describing martens inhabiting human residential areas near larger forests, including an anecdotal observation from Myojocho, Uji City (located 2 km from our study site) in 2020 (S. Watanabe, personal communications).

Masked Palm Civet. Masked Palm Civet were observed in forest patch environments at the Uji Campus site and were also recorded in riparian forests along the Uji River. In their native range in south-central China, they are known to utilise open forests and managed woodlands (Zhou et al. 2014), which aligns with their preference for the early-successional forests at Uji Campus, where thinning of pine trees is operated. As their diet includes fruits, insects, and small mammals (Zhou et al. 2008; Iwama et al. 2017), their typical omnivorous and flexible diet likely enables them to adapt easily to both urban greenspaces of the campus environment and the nearby agricultural and residential areas along the Uji River. A sighting was also reported outside the survey period, on the evening of June 2023 (Shiwei Gong, personal obs.), suggesting that they may use the campus not only during the autumn-winter period but also in summer.

Raccoon. Raccoons occurred both in open and forested stations at the Uji Campus site, but they were not recorded in the Uji River site. They exhibit higher detection rates in areas closer to urban centres in their native range of North America (Rodriguez et al. 2021), often utilising urban matrices (Gross et al. 2012). As an invasive species in Japan, Raccoons are estimated to have higher detection rates in moderately forested urban landscapes (Saito and Koike 2013). By 2008, Raccoons had already been confirmed in every municipality within Kyoto Prefecture (Kyoto Prefecture 2008). In Kyoto City, around 10 km north of the study area, there has been a gradual increase in their population over the past decade (Kawamichi et al. 2016). Beyond our study period, an additional GBIF record of a Raccoon at Uji Campus in February 2025 (Table 4) suggests their persistent occurrence. Therefore, our camera trap evidence is important for monitoring their population growth and range expansion, providing valuable information to the City of Uji, which has formulated the Uji City Raccoon Control Implementation Plan, calling for "planned measures to prevent agricultural damage caused by feral raccoons" (Uji City Comprehensive Planning Council 2021), as well as surrounding municipalities of southern Kyoto (Kyoto Prefecture 2008).

Stray Cat. On the Uji campus, Stray Cats were recorded once in the forested areas. The Stray Cat is commonly observed in global urban areas. Unlike other carnivores, which were mostly captured on cameras at night, they were mostly photographed during the daytime (Appendix 1). As statistical analyses were not applicable in our preliminary investigation using bait, further investigation is needed to confirm the potential temporal niche differentiation compared to other species.

Methodological limitations. Since this was a preliminary study aimed at inventorying the mesocarnivore fauna in urban greenspaces, we employed various methods to explore which camera trapping techniques (e.g., different angles, positioning, with or without bait) and recording media (photos or videos) would be most effective. Consequently, we did not follow a consistent or systematic methodological framework (Meek et al. 2014). The use of bait can increase the detectability of target species by emitting olfactory

cues that attract animals from greater distances (Ferreras et al. 2018). Variations in camera height can also affect detection rates, as cameras placed too high may reduce the likelihood of capturing smaller-bodied species (Swann et al. 2004). Furthermore, differences in camera angle may influence detectability by altering the directionality and range of the field of view, as well as how animals perceive the trap in terms of illumination or sound (Meek et al. 2014).These methodological inconsistencies prevented the calculation of standard metrics, such as relative abundance indices, limiting spatial and temporal comparisons of species occurrences across study sites and periods.

Furthermore, we could not obtain any evidence of denning for each species, preventing us from concluding whether these mesocarnivores were temporarily using the urban greenspaces as corridors/foraging sites or inhabiting them for reproductive activities. Nonetheless, our study provides baseline data on the mesocarnivore presence and utilisation of urban greenspaces in southern Kyoto.

Conclusion. We observed a greater number of mesocarnivore species in the small woodland in the more urbanised part of the overall study area (Uji Campus) than in the more natural part (Uji River), suggesting the importance of well-managed urban forests as a habitat for both native and invasive species. This emphasises the proximity of forested landscapes around the city, where humans and mesocarnivores inhabit overlapping spaces. Our study contributes to the understanding of urban mesocarnivores presence in Japan on a fine scale by describing the local fauna in southern Kyoto. The diverse mesocarnivore species observed here suggest that green spaces in the study area may provide wildlife with habitat and connectivity to surrounding forests. While carnivores are often used as umbrella species (Roberge and Angelstam 2004), incorporating small carnivores into this concept is important (Caro 2003), as they can be effective indicators of ecosystem health (Zielinski 1997) and well-planned urban greenspaces (Łopucki et al. 2019). Future studies with a systematic research design would enable a formal analysis of spatial and temporal patterns of mesocarnivore utilisation in relation to urban forest size, shape, and distribution.

ACKNOWLEDGEMENTS

We appreciate S. Gong for providing the preliminary sighting information of the Masked Palm Civet on the Uji Campus, which motivated the research and aided in the data collection process. The study was supported by the Research Institute for Humanity and Nature and Hiroshima University (funding details below).

ADDITIONAL INFORMATION

Conflict of interest

The authors declare no conflict of interest.

Ethical statement

No ethical statement is reported.

Funding

The study was financially supported by the Research Institute for Humanity and Nature's Feasibility Study: "The Value of Forests—a Vision of the Future for People and Society Living in Harmony with Forests" (RIHN-FS) led by Nobuhito Ohte. Our work was also facilitated by the "Start-up Funding for Young Researchers" from Hiroshima University to Masumi Hisano (HU-SFYR_MH) and Natsuki Komada (HU-SFYR_NK).

Author contributions

Conceptualisation: MH, HT. Data collection: MH, KY. Data curation: MH, HA. Formal analysis: MH. Funding acquisition: NO (for RIHN-FS), MH (for HU-SFYR_MH), NK (for HU-SFYR_NK). Investigation: MH, KY (fauna), NK (flora). Methodology: MH, KY, HT. Resources: MH, NO, NK. Project administration: MH, NO. Validation: MH, HT, SP, NK. Visualisation: MH, NK. Writing – original draft: MH. Writing – review and editing: MH, HT, SP, HA, KY, NO, NK.

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Data availability

The datasets generated during the present study are provided in the *figshare* (Appendix 1: https://doi.org/10.6084/m9.figshare.28666511.v1; and Appendix 2: https://doi.org/10.6084/m9.figshare.29877104.v1). Ad-

ditional data that are not essential for replicating the present study—e.g., original camera trap pictures/movies of other taxa (Hisano et al. 2024), pictures of each habitat/camera station—are all available upon request to the corresponding author (Masumi Hisano). Original photographs of *M. meleampus*, associated with (Hisano et al. 2025), are also available from figshare, https://doi.org/10.6084/m9.figshare.27000433.v1.

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APPENDICES

Appendix 1. Camera trap records data of mesocarnivores in southern Kyoto, central Japan. Only the data on effective images (65 independent observations from the Uji Campus site and 83 from the Uji River site) of mesocarnivore species are presented, excluding failed detections of any animals. Independent observations were defined as images of the same species taken at the same camera station within a 30-minute interval, counted as a single observation. *Baits were applied at the Uji Campus site (stations TF1–2 and TO1–2), but not at the Uji River site (stations UF1–6) (see *Methods*). The dataset is archived in figshare, https://doi.org/10.6084/m9.figshare.28666511.v1.

Appendix 2. Video recording of urine marking behaviour of a Red Fox (*Vulpes vulpes*) at the Uji Campus site (station TO1) in southern Kyoto, central Japan (3:34 am, 7 November 2023). The media is archived in figshare, https://doi.org/10.6084/m9.figshare.29877104.v1.