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Original paper

Dietary habits of Japanese badgers (*Meles anakuma*) in northern Japan: relationship with food availability

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Abstract. We studied temporal (monthly and inter-yearly) variations in the dietary habits of wild Japanese badgers (*Meles anakuma*) inhabiting Ishinomaki City, northern Japan through fecal analyses, focusing on the relationship with the availability of main diets. The diets of the badgers in our study site were mainly composed of three items: fruits, arthropods, and earthworms, which were similar to those in other study sites in Japan. The degree of fruit and earthworm feeding by the badgers was higher throughout the year, whereas arthropod feeding was higher during spring and summer. Vertebrates were less detected in badger feces. During the fall of 2021, the percentage of fruits was greater than that in 2020, while that of arthropods and earthworms showed reverse trends, likely due to inter-yearly difference in fruit availability. For the three predominant food items, no significant correlation was found between feeding and availability. Our results imply that, similar to European badgers, the Japanese badger can be viewed as a generalist animal that uses profitable resources when available but shifts their preference to other food resources when availability of other primary food resources increases.

Key words: chaetae, feeding strategy, frugivory, mustelids.

In optimal foraging theory, animals should select appropriate choices based on their foraging behavior, such as length of searching, processing, and choice of feeding patches/food items (Stephens and Krebs 1987). Studying foraging strategies, thus, is useful for understanding the life history and fitness of target animals, especially predators, whose prey move freely. Conversely, in the applied field, food choice and environmental background are clues for considering conservation plans, especially for endangered species. In recent decades, studies on carnivorous mammals and meta-analyses orienting environmental determinants of their feeding have been conducted. For example, diets of Eurasian otters (*Lutra lutra*) were more diverse in the south as compared to the north (Clavero et al. 2003). Wildcats (*Felis sylvestris*) mainly feed on rabbits at lower latitudes and on rodents in boreal regions (Lozano et al. 2006). Martens (*Martes* spp.) prefer vegetable matter in the south, and mammals and birds in the north (Zhou et al. 2011). Finally, the red fox (*Vulpes vulpes*) feeds on lagomorph and invertebrates in the south, and on rodents and fruits in the north (Díaz-Ruiz et al. 2013). These examples imply that feeding strategy of carnivores is plastic and observed feeding behavior in each habitat would reflect food environment there.

Japanese badgers (*Meles anakuma*), an endemic mustelid in Japan, are distributed on three main islands: Honshu, Shikoku, and Kyushu (Kaneko 2009). Previous studies on their diet have emphasized a strong dependency on earthworms (e.g., Yamamoto 1991; Tanaka 2002; Kaneko et al. 2006; Hijikata et al. 2020), but case studies on the food habits of Japanese badgers in northern Japan, in which deciduous/conifer forests are dominant, are limited. In addition, previous studies have not examined the feeding strategy of badgers. In this study, we examined the food habits of Japanese badgers in northern Japan, focusing on their temporal variation and their relationship with the availability of the main diets. We then discuss the feeding strategy of Japanese badgers with reference to present and past studies.

Materials and methods

Study site

We conducted a field survey at the University Forest of Ishinomaki Senshu University and an adjacent hilly

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forest, Mt. Toyake Mori (north-south length: approximately 3 km, east-west length: approximately 1 km, maximum altitude: 173.6 m) located in Ishinomaki City, Miyagi Prefecture, northern Japan (38°27'N, 141°17'E). The west side of the study site is adjacent to the Kitakami River, and the northern and southern sides are surrounded by residential areas. The mean temperature and annual rainfall in Ishinomaki in 2020 (12.6°C and 1002.0 mm) and 2021 (12.7°C and 1073.5 mm) were similar and were not different from typical mean (temperature: 11.9°C [range: 4.8–27.0°C]; rainfall: 1091.3 mm, period: 1991–2020) (Japan Meteorological Agency, https://www.jma.go.jp/jma/index.html, Accessed 4 July 2023). Based on the mean temperature, the year can be classified into four seasons: spring (March–May), summer (June–August), fall (September–November), and winter (December–February). The dominant vegetation in the study area was a secondary forest composed of *Cryptomeria japonica*, *Pinus densiflora*, *Quercus serrata*, *Q. acutissima*, *Juglans mandshurica*, *Phyllostachys edulis*, and *P. bambusoides* (Ishizuka et al. 1994). A total of 23 animal species (12 mammals and 11 birds), including Japanese badgers, have been recorded in the forest (Furukawa et al. 2022). We conducted a preliminary survey in April 2020 and found badger latrines (n = 14) along the ridge of the forest.

Fecal sample collection and its analysis

Fecal sampling was conducted every month between June 2020 and December 2021, except for winter and early spring (between January and March 2021) when the badgers were hibernating (Tanaka 2006). The collected fecal samples were sieved through 0.5-mm meshed sieve with 1 L of tap water. After washing, the residue was retrieved from the sieve and stored in a plastic bottle with 70% ethanol until analysis. The tap water used for washing feces was used to analyze earthworm availability (see a later section).

We evaluated the dietary composition of each fecal sample using two methods: 1) the point-frame method (Stewart 1967; Takatsuki et al. 2007) and 2) frequency of occurrence (*FO*).

Point-frame method: A tap water was spread over a glass slide fit with a 20 × 50 mm metal frame and covered with a 1 mm grid, and the residue was spread onto the glass slide (Hijikata et al. 2020). Using an optical microscope (Nikon Eclipse E*i*, Tokyo), the points of the grids covered by the fragments were counted. A total of 200 points were counted, and the proportions in the fecal composition (%) of the food categories were calculated. Food items were visually categorized into eight types: 1) fruits (including seeds), 2) herbaceous plants, 3) woody leaves, 4) arthropods (mainly insects), 5) insect larvae, 6) mammals and birds, 7) reptiles, and 8) unknowns. For fruits, before analyzing we identified plant species in whole samples based on the size and shape of the detected seeds with reference to Nakayama et al. (2000) and Kominami et al. (2016). By the point-frame method, we evaluated the temporal change in the feeding of target food items by showing monthly and yearly changes in their proportions.

*Frequency of occurrence (*FO*):* To compare the dietary composition of Japanese badgers in Ishinomaki with those in other study sites, we calculated *FO* for each item, calculated as follows:

$$FO = \text{(number of fecal samples containing a target food item)} / \text{(number of total fecal samples)} \times 100$$

It is difficult to detect earthworm remnants in feces because they are broken into small pieces during mastication (Battisti et al. 2019; Tsukada et al. 2021). Therefore, we employed a different method to evaluate earthworm feeding by the badgers, modified from Seki et al. (2015): we kept water used for washing fecal samples for 15 min, and picked up its sediments (approximately 1 ml) using a dropper. We then placed a piece of the sediment on a slide-glass with 1 mm aperture grids. Under the optical microscope, we counted the number of earthworm chaetae within a 1 cm^2 area (representing 100 grid cells). We checked 10 areas for each sample (i.e., 10 cm^2 in total) and represented the number of earthworm chaetae as the degree of feeding.

Evaluation of food availability

We evaluated the availability of three main diets for Japanese badgers: fruits, arthropods, and earthworms.

Fruits: We established three 50 m × 2 m line transects covering typical vegetation types at the study site. Between April and December 2021 (nine times), we randomly set five 0.4 × 0.4 m quadrates along each transect (i.e., 15 quadrates in total), and collected fallen fruits (both berries and nuts) within them. We then counted the number of fruits that are included in diet of Japanese badgers in other study sites (Koike and Masaki 2008).

Arthropods: Between April and December 2021 (nine times), we set ten pitfall traps made of plastic (open area: 64 cm^2, volume: 600 ml) along the ridge of the study site in the afternoon of the first day. Chrysalis powder (5 g wet weight) was used as bait for the traps. The distance between neighboring traps was approximately 50 m. On the morning of the second day, we collected ground-prowling insects (such as Carabidae and Harpalidae) inside the traps and represented the number of insects as arthropod availability in each month.

Earthworms: Between April and November 2021 (eight times), we dug a 0.4 × 0.4 × 0.1 m hole along with each transect (i.e., three holes in total), and collected earthworms in them. The number of earthworms per square meter was considered as the availability in each month.

Statistical analyses

To test the effects of 1) month, 2) year, and 3) their interaction on the badger diet, we conducted generalized linear models (GLMs), in which the response variables were the number of counts of target food items in the point-frame method. The response variable for earthworms was the number of earthworm chaetae. We assumed that the error structure of the response variable follows a Poisson distribution (exception: normal distribution was assumed for case of earthworm).

To test the monthly variation in food availability in 2021, we conducted a GLM, setting month as an explanatory variable. We assumed that the error structure of the response variable followed a normal distribution. If we obtained significant differences in availability among months, we performed *post-hoc* tests (Bonferroni) to specify the month(s) with greater (or lesser) food availability.

To evaluate the relationship between feeding of the main diets (fruits, arthropods, and earthworms) and their availability, we conducted Spearman's rank correlation tests. For the analyses, the statistical standard (α) was set to 0.05. All analyses were performed using the R Statistical Software ver. 4.05 (R Core Team 2021).

Results

During the study period, we collected 169 fresh fecal samples (n = 84 in 2020 and 85 in 2021). The dietary composition (in terms of *FO*) of Japanese badgers in Ishinomaki during the study period is shown in Table 1 and Appendix 1. Among the eight food items, four showed a higher *FO* (> 50%): fruits, arthropods (mainly insects), earthworms, and woody leaves. We detected the seeds of 14 different plant species in badger feces (Appendix 2).

Conversely, food items with higher proportions in point-frame methods were fruits (average in the study period: 71.9%) and arthropods (13.7%). The percentage of woody leaves (9.8%) was lower for their *FO*. Therefore, we conducted detailed analyses of three food items, fruits, arthropods, and earthworms, whose chaetae were detected throughout the year (annual mean: 3.1/10 cm^2).

Figure 1 shows monthly changes in the feeding of a) fruits, b) arthropods, and c) earthworms (in terms of number of chaetae). For each food item, we found significant effects of month, year, and the month × year interaction ($P < 0.05$) (summarized in Appendix 3). The percentage of fruits was consistently high (> 50%), and it increased in fall, especially in 2021 (Fig. 1a). The percentage of arthropods was higher during summer and lower in fall. The decrease during fall was much greater in 2021 (Fig. 1b). There was a significant negative correlation between the proportion of arthropods and fruits in feces (Spearman's rank correlation test: $r_s = -0.818$, $P < 0.001$). Earthworms were detected every month, but

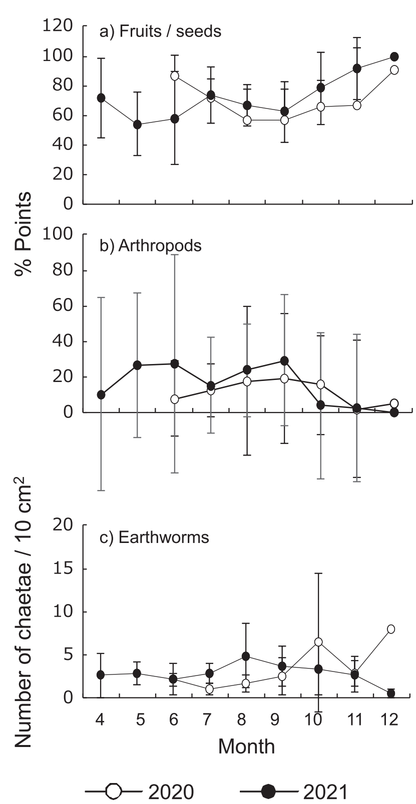

Fig. 1. Monthly change in a) mean (± *SD*) percentages of fruits (including seeds), b) mean (± *SD*) percentages of arthropods, and c) mean (± *SD*) number of earthworm chaetae (Number / 10 cm^2). Open circles and filled circles represent 2020 and 2021, respectively.

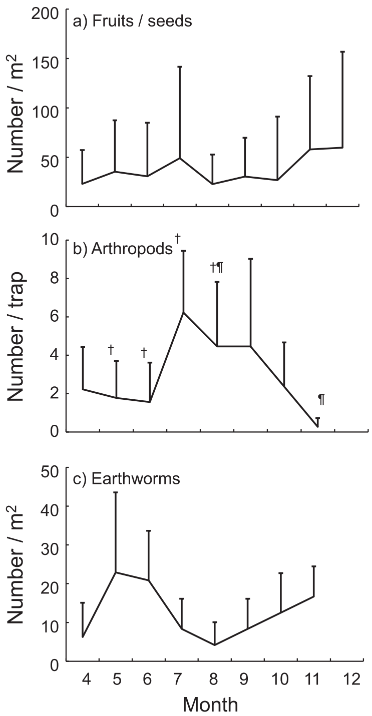

Fig. 2. Monthly changes in mean (+ *SD*) availability of a) fruits (including seeds), b) arthropods (represented by ground prowling insects), and c) earthworms. The same symbol represents significant differences between months (Bonferroni *post-hoc* tests).

the degree of feeding varied between years; during summer in 2021, the number of earthworm chaetae was greater, whereas during fall, an opposite trend was found (Fig. 1c). We found no significant correlations between earthworm feeding and the proportions of the other two main diets (fruits: r_s = –0.032, P = 0.905; arthropods: r_s = 0.139, P = 0.609).

Figure 2 shows the monthly changes in food availability for 2021. The availability of fruits was greater during summer and fall (Fig. 2a), whereas that of insects was the highest during summer (Fig. 2b). Finally, the availability of earthworms had two peaks: spring and fall (Fig. 2c).

The results of the correlation analyses between food availability and the degree of feeding are summarized in Fig. 3. None of the combinations showed significant correlations (P > 0.05).

Discussion

Through fecal analyses, we found that Japanese badgers in Ishinomaki mainly fed on fruits, arthropods, and earthworms. This composition was similar to that of Japanese badgers in other study sites (Mt. Nyugasa:

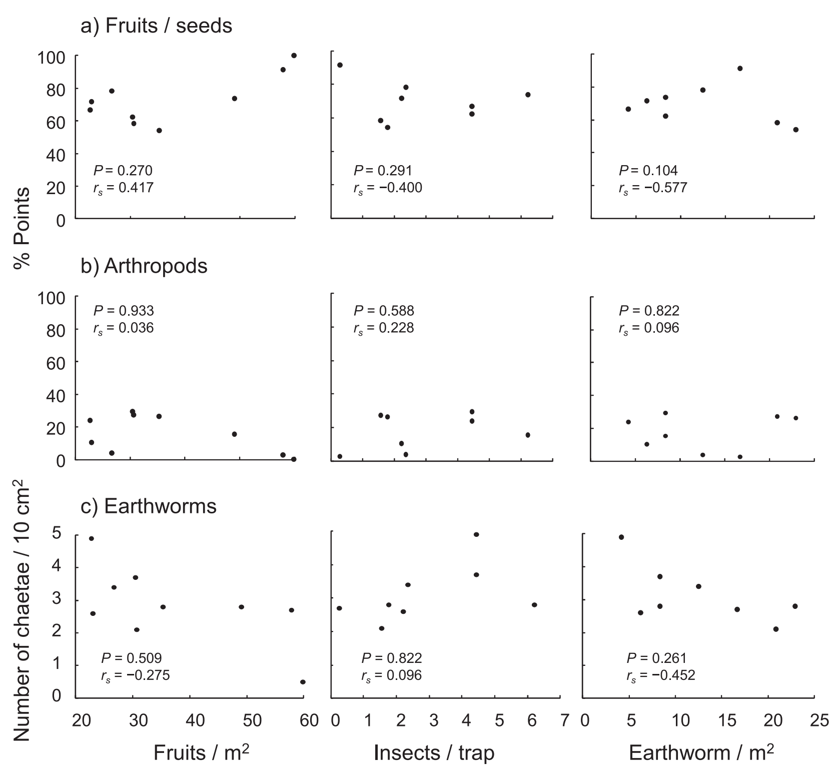

Fig. 3. Results of the Spearman's correlation analyses: relationships between availability (fruits [left], ground prowling insects [center], and earthworms [right]) and feeding: a) % points of fruits (including seeds), b) % points of arthropods, and c) earthworm chaetae in feces.

Table 1. Diet composition (in terms of frequency of occurrence, *FO*) of Japanese badgers (*Meles anakuma*) in five study sites

Study site	Ishinomaki	Hinode	Kozu	Yamaguchi	Mt. Nyugasa
Number of samples	169	82	84	146	231
Animal					
Insect (adult)	67.5		92.9	87.0	92.6
Insect (larva)	8.9		39.3	43.2	
Other arthropod		4.9		8.2	
Earthworm (chaetae)	95.0	63.4	91.7	97.3	96.1
Mollusk				7.5	
Mammal	8.9	3.7	13.1		13.4
Bird		8.5			0.4
Reptile	6.5				
Amphibia		1.2			
Unknown	2.4	2.4	2.4		
Vegetable matter					
Fruits / seeds	98.8	59.8	81.0	38.3	32.6
Herbaceous plant	4.7	39.0			
Woody leaves	67.5	14.6			
Fiber			73.8		
Root		6.1	39.3		
Others				8.9	100.0
Artificial matter		34.1		4.1	18.6
Unknown	7.1	8.5	19.0		
Source	This study	Kaneko et al. (2006)	Hijikata et al. (2020)	Tanaka (2002)	Yamamoto (1991)

Yamamoto 1991; Yamaguchi: Tanaka 2002; Hinode: Kaneko et al. 2006; Kozu: Hijikata et al. 2020, see details in Table 1), which shows that the badgers are omnivorous. In addition to this similarity, we found several regional variations in feeding; badgers in Ishinomaki, Hinode, and Kozu frequently fed on woody leaves, herbaceous plants, and fibers, respectively (Table 1). The reason why specific population relied on specific types of food is unclear, but it may be attributed to differences in fauna, flora and/or soil characteristics among the study sites. Therefore, the food environment can affect food choices of Japanese badgers.

Woody leaves and herbaceous plants were detected in fecal samples of the badgers throughout seasons, but nutritional implication of the non-fruit plant materials for the badgers is unknown (Cleary et al. 2009). The badgers might ingest them inadvertently while foraging for prey in soil (Neal et al. 1988).

This study demonstrated that dietary composition, in terms of *FO*, of Japanese badgers to be common among study sites. In the case of European badgers, earthworms and vegetable matter were the dominant food types, but the relative importance of the former was greater at higher latitudes (Goszczyński et al. 2000). Studying such geographical food patterns would be necessary to understand the feeding strategy of Japanese badgers.

Previous studies have emphasized earthworm feeding by Japanese badgers (e.g., Yamamoto 1991), but we should also pay attention to their frugivorous nature: we found seeds of 14 different plant species. From the seed dispersal background, defecation in latrines implies that ingested seeds are gathered in small areas. This would affect the initial stage of seed fitness differently than seeds dispersed by sympatric frugivores such as bears (Koike et al. 2011), martens (Tsuji et al. 2016), raccoon dogs (Sakamoto and Takatsuki 2015), and macaques (Tsuji and Su 2018).

The badgers in Ishinomaki fed mainly on arthropods during the summer, and fruits and earthworms throughout the year. Considering inter-yearly difference in diets, in 2021, percentage of fruits in fall increased, while that of earthworms and insects in this season decreased. These results imply that the main food items of the badgers are fixed, but their relative contribution can be changed inter-yearly, likely due to inter-year differences in food availability.

The three main diets were constantly consumed across seasons, and we found no relationships between fruit availability and feeding on the main diets. Similarly, Roper (1994) reported that European badgers' diet contained a constant proportion of any food over the study period and did not make a functional response. These findings imply that badgers should be viewed as either generalist or opportunistic feeders. This is different from other mustelids, such as martens, whose diet composition promptly changes in response to temporal fluctuations in fruit/vertebrate availability (e.g., Jędrzejewski et al. 1993).

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References

Battisti, A., Giuliano, D. and Balestrieri, A. 2019. Detection of earthworm *chaetae* in mammal feces: methodological implications. Folia Zoologica 68: 43–47.

Clavero, M., Prenda, J. and Delibes, M. 2003. Trophic diversity of the otter (*Lutra lutra* L.) in temperate and Mediterranean freshwater habitats. Journal of Biogeography 30: 761–769.

Cleary, G. P., Corner, L. A. L., O'Keeffe, J. and Marples, N. M. 2009. The diet of the badger *Meles meles* in the Republic of Ireland. Mammalian Biology 74: 438–447.

Díaz-Ruiz, F., Delibes-Mateos, M., García-Moreno, J. L., López-Martín, J. M., Ferreira, C. and Ferreras, P. 2013. Biogeographical patterns in the diet of an opportunistic predator: the red fox *Vulpes vulpes* in the Iberian Peninsula. Mammal Review 43: 59–70.

Furukawa, M., Yoda, K. and Tsuji, Y. 2022. A survey of mammalian and avian fauna in University Forest of the Ishinomaki Senshu University, Miyagi Prefecture, using sensor cameras. Human and Nature 32: 133–140.

Goszczyński, J., Jedrzejewska, B. and Jedrzejewski, W. 2000. Diet composition of badgers (*Meles meles*) in a pristine forest and rural habitats of Poland compared to other European populations. Journal of Zoology 250: 495–505.

Hijikata, K., Minami, M. and Tsukada, H. 2020. Food habits and habitat utilization of the Japanese badger (*Meles anakuma*) in a grassland/forest mosaic. Mammal Study 45: 229–242.

Ishizuka, K., Sasaki, Y., Nemoto, T., Saito, K. and Hirose, K. 1994. Studies on the university forest of the Ishinomaki Senshu University, Mt. Toyake-mori I. Community-types and flora. Bulletin of Ishinomaki Senshu University 5: 1–44 (in Japanese with English abstract).

Jędrzejewski, W., Zalewski, A. and Jędrzejewska, B. 1993. Foraging by pine marten *Martes martes* in relation to food resources in Białowieża National Park, Poland. Acta Theriologica 38: 405–426.

Kaneko, Y. 2009. *Meles anakuma* Temminck, 1844. In (Ohdachi, S. D., Ishibashi, Y., Iwasa, M. A. and Saitoh, T., eds.) The Wild Mammals of Japan, pp. 258–260. Shoukadoh, Kyoto.

Kaneko, Y., Maruyama, N. and Macdonald, D. W. 2006. Food habits and habitat selection of suburban badgers (*Meles meles*) in Japan. Journal of Zoology 270: 78–89.

Koike, S. and Masaki, T. 2008. Frugivory of carnivora in central and southern parts of Japan analyzed by literature search. Journal of the Japan Forest Society 90: 26–35 (in Japanese with English abstract).

Koike, S., Masaki, T., Nemoto, Y., Kozakai, C., Yamazaki, K., Kasai, S., Nakajima, A. and Kaji, K. 2011. Estimate of the seed shadow created by the Asiatic black bear *Ursus thibetanus* and its characteristics as a seed disperser in Japanese cool-temperate forest. Oikos 120: 280–290.

Kominami, Y., Tanouchi, H. and Yagihashi, T. 2016. Search Picture Book of Woody Seeds. Bun-Ichi Cp, Ltd., Tokyo, 304 pp.

Lozano, J., Moleón, M. and Virgós, E. 2006. Biogeographical patterns in the diet of the wildcat, *Felis silvestris* Schreber, in Eurasia: factors affecting the trophic diversity. Journal of Biogeography 33: 1076–1085.

Nakayama, S., Inokuchi, M. and Minamitani, T. 2000. Seeds of Wild Plants in Japan. Tohoku University Press, Sendai, 696 pp.

Neal, E. 1988. The stomach contents of badgers *Meles meles*. Journal of Zoology 215: 367–369.

R Core Team. 2021. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. Available at https://www.r-project.org/(Accessed 30 April 2021).

Roper, T. J. 1994. The European badger *Meles meles*: food specialist or generalist? Journal of Zoology 234: 437–452.

Sakamoto, Y. and Takatsuki, S. 2015. Seeds recovered from the droppings at latrines of the raccoon dog (*Nyctereutes procyonoides viverrinus*): the possibility of seed dispersal. Zoological Science 32: 157–162.

Seki, Y., Enari, H., Kodera, Y. and Tsuji, Y. 2015. Field Survey Methods for Wildlife Management: from the Identification of Field Signs of Mammals to Data Analysis. Kyoto University Press, Kyoto, 448 pp. (in Japanese).

Stephens, D. W. and Krebs, J. R. 1987. Foraging Theory. Princeton University Press, Princeton, 262 pp.

Stewart, D. R. M. 1967. Analysis of plant epidermis in faeces: a technique for studying the food preferences of grazing herbivores. Journal of Applied Ecology 4: 83–111.

Takatsuki, S., Hirasawa, M. and Kanda, E. 2007. A comparison of the point-frame method with the frequency method in fecal analysis of an omnivorous mammal, the raccoon dog. Mammal Study 32: 1–5.

Tanaka, H. 2002. Ecology and Social System of the Japanese Badger, *Meles Meles Anakuma* (Carnivora; Mustelidae) in Yamaguchi, Japan. Ph.D. Thesis. Yamaguchi University, Yamaguchi, 117 pp.

Tanaka, H. 2006. Winter hibernation and body temperature fluctuation in the Japanese badger, *Meles meles anakuma*. Zoological Science 23: 991–997.

Tsuji, Y., Okumura, T., Kitahara, M. and Jiang, Z. 2016. Estimated seed shadow generated by Japanese martens (*Martes melampus*): comparison with forest-dwelling animals in Japan. Zoological Science 33: 352–357.

Tsuji, Y. and Su, H. H. 2018. Macaques as seed dispersal agents in Asian forests: a review. International Journal of Primatology 39: 356–376.

Tsukada, H., Nishikawa, Y., Shimada, H., Hijikata, K. and Minami, M. 2021. A refined method for estimating the number of earthworm chaetae in carnivore feces. Ecological Research 36: 617–628.

Yamamoto, Y. 1991. Food habits of *Meles meles anakuma* in Mt. Nyugasa, Nagano pref., Japan. Nature Environment Science Research 4: 73–83.

Zhou, Y. B., Newman, C., Xu, W. T., Buesching, C. D., Zalewski, A., Kaneko, Y., Macdonald, D. W. and Xie, Z. Q. 2011. Biogeographical variation in the diet of Holarctic martens (genus *Martes*, Mammalia: carnivora: Mustelidae): adaptive foraging in generalists. Journal of Biogeography 38: 137–147.

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Appendix 1.

Monthly change in diet composition of Japanese badgers (*Meles anakuma*) in the University Forest of Ishinomaki Senshu University, Ishinomaki City, Miyagi Prefecture, northern Japan

Month	April		May		June			
Year	2021		2021		2020		2021	
Number of samples	$n = 9$		$n = 10$		$n = 24$		$n = 10$	
Fruits / seeds	71.6 ± 27.1	(9)	54.1 ± 21.3	(6)	86.8 ± 13.5	(24)	58.3 ± 31.6	(10)
Woody leaves	9.5 ± 17.9	(6)	19.0 ± 26.7	(10)	4.7 ± 11.5	(15)	11.0 ± 27.1	(6)
Herbaceous plants	0.0 ± 0.0	(0)	0.0 ± 0.0	(0)	0.0 ± 0.0	(0)	0.0 ± 0.0	(0)
Arthropods	10.4 ± 54.1	(6)	26.3 ± 40.6	(10)	7.9 ± 21.1	(14)	27.3 ± 61.1	(8)
Mammals / Birds	0.0 ± 0.0	(0)	0.0 ± 0.0	(0)	0.0 ± 0.0	(0)	0.1 ± 0.3	(1)
Reptiles	0.2 ± 0.9	(1)	0.1 ± 0.3	(1)	0.0 ± 0.0	(0)	0.0 ± 0.0	(0)
Others	8.3 ± 0.0	(0)	0.6 ± 0.0	(0)	0.3 ± 2.2	(2)	3.4 ± 0.9	(1)
Earthworms	2.6 ± 2.5	(8)	2.8 ± 1.3	(10)	2.2 ± 1.8	(22)	2.1 ± 0.8	(10)

Month	July				August				September			
Year	2020		2021		2020		2021		2020		2021	
Number of samples	$n = 12$		$n = 10$		$n = 12$		$n = 10$		$n = 17$		$n = 10$	
Fruits / seeds	71.6 ± 12.7	(12)	73.7 ± 18.5	(10)	54.6 ± 21.3	(12)	66.7 ± 14.2	(10)	57.2 ± 20.8	(17)	62.3 ± 20.6	(10)
Woody leaves	14.5 ± 14.8	(12)	10.6 ± 23.7	(7)	16.1 ± 26.8	(10)	8.5 ± 17.9	(6)	19.7 ± 20.4	(17)	8.4 ± 19.3	(8)
Herbaceous plants	0.7 ± 1.6	(2)	0.0 ± 0.0	(0)	0.0 ± 0.0	(1)	0.1 ± 0.2	(1)	0.0 ± 0.0	(0)	0.0 ± 0.0	(0)
Arthropods	12.3 ± 14.8	(12)	15.4 ± 27.2	(8)	17.7 ± 41.7	(10)	23.9 ± 26.2	(10)	18.9 ± 36.7	(16)	29.4 ± 37.1	(8)
Mammals / Birds	0.0 ± 0.0	(0)	0.0 ± 0.0	(0)	0.0 ± 0.0	(0)	0.0 ± 0.0	(0)	0.4 ± 2.8	(1)	0.0 ± 0.0	(0)
Reptiles	0.0 ± 0.0	(0)	0.0 ± 0.0	(0)	0.2 ± 0.9	(2)	0.4 ± 1.8	(2)	0.2 ± 0.8	(3)	0.0 ± 0.0	(0)
Others	0.9 ± 0.0	(0)	0.0 ± 1.5	(2)	3.4 ± 26.2	(4)	0.0 ± 3.0	(1)	3.5 ± 1.4	(2)	0.0 ± 0.0	(0)
Earthworm	1.0 ± 0.7	(9)	2.8 ± 1.2	(10)	1.6 ± 1.0	(11)	4.9 ± 3.8	(10)	2.5 ± 2.1	(17)	3.7 ± 2.3	(10)

Month	October				November				December			
Year	2020		2021		2020		2021		2020		2021	
Number of samples	$n = 8$		$n = 10$		$n = 10$		$n = 10$		$n = 1$		$n = 6$	
Fruits / seeds	65.4 ± 18.4	(8)	78.2 ± 24.7	(10)	67.1 ± 38.2	(8)	91.3 ± 20.7	(10)	90.5 ± 0.0	(1)	100.0 ± 0.0	(6)
Woody leaves	15.7 ± 24.1	(8)	2.7 ± 12.0	(3)	11.4 ± 59.3	(3)	0.1 ± 0.6	(1)	4.5 ± 0.0	(1)	0.0 ± 0.0	(0)
Herbaceous plants	0.1 ± 0.2	(1)	8.8 ± 19.1	(2)	0.0 ± 0.0	(0)	0.4 ± 1.1	(1)	0.0 ± 0.0	(0)	0.0 ± 0.0	(0)
Arthropods	15.5 ± 27.5	(7)	3.9 ± 41.0	(7)	2.2 ± 38.3	(5)	2.7 ± 41.5	(3)	5.0 ± 0.0	(1)	0.0 ± 0.0	(0)
Mammals / Birds	2.5 ± 13.2	(1)	0.0 ± 0.0	(0)	2.6 ± 15.6	(1)	0.0 ± 0.0	(0)	0.0 ± 0.0	(0)	0.0 ± 0.0	(0)
Reptiles	0.1 ± 0.3	(1)	0.0 ± 0.0	(0)	4.9 ± 29.1	(1)	0.0 ± 0.0	(0)	0.0 ± 0.0	(0)	0.0 ± 0.0	(0)
Others	0.0 ± 4.3	(1)	6.5 ± 0.0	(0)	11.9 ± 0.0	(0)	5.6 ± 0.0	(0)	0.0 ± 0.0	(0)	0.0 ± 0.0	(0)
Earthworm	6.4 ± 8.1	(8)	3.4 ± 3.1	(10)	2.8 ± 1.5	(10)	2.7 ± 2.1	(10)	8.0 ± 0.0	(1)	0.5 ± 0.5	(3)

Month	All year				Grand mean	
Year	2020		2021			
Number of samples	$n = 84$		$n = 85$		$n = 169$	
Fruits / seeds	69.9 ± 24.1	(82)	71.6 ± 25.8	(81)	70.8 ± 25.0	(163)
Woody leaves	12.6 ± 14.7	(66)	8.1 ± 11.1	(47)	10.3 ± 13.2	(113)
Herbaceous plants	0.1 ± 0.6	(4)	1.1 ± 7.1	(4)	0.6 ± 5.1	(8)
Arthropods	15.0 ± 16.2	(65)	19.0 ± 22.5	(80)	17.0 ± 19.7	(145)
Mammals / Birds	0.6 ± 3.6	(3)	0.0 ± 0.1	(1)	0.3 ± 2.5	(4)
Reptiles	0.6 ± 5.3	(7)	0.1 ± 0.4	(4)	0.4 ± 3.7	(11)
Others	1.1 ± 5.5	(9)	0.1 ± 0.6	(4)	0.6 ± 3.9	(13)
Earthworm	2.6 ± 3.4	(78)	2.9 ± 2.5	(81)	2.8 ± 3.0	(159)

Values in parentheses represent number of fecal samples containing target food category.

Appendix 2.

List of plant species whose seeds were detected from feces of Japanese badgers in Isinomaki, northern Japan

Family	Scientific name	Months
Moraceae	*Morus australis*	May (4), Jun (24), Jul (7), Aug (4)
Rosaceae	*Cerasus leveilleana*	Jun (2), Jul (2), Aug (1)
Rhamnaceae	*Berchemia racemosa*	Aug (4)
Cornaceae	*Cornus kousa*	Aug (1), Sep (2)
Ulmaceae	*Zelkova serrata*	Sep (1)
Betulaceae	*Carpinus* sp.	Sep (1)
Fagaceae	*Quercus serrata*	Sep (1)
Cornaceae	*Cornus macrophylla*	Sep (1), Oct (1)
Actinidiaceae	*Actinidia argua*	Sep (1), Oct (1), Nov (1)
Rhamnaceae	*Hovenia dulcis*	Sep (1), Oct (4), Nov (11), Dec (4)
Solanaceae	*Physalis alkekengi var. franchetii*	Oct (1),
Ginkgoaceae	*Ginkgo biloba*	Oct (1), Nov (2)
Ebenaceae	*Diospyros kaki*	Nov (1)
Cannabaceae	*Celtis sinensis*	Dec (2)

Numbers in parentheses represent number of fecal samples containing seeds.

Appendix 3.

Summary of the generalized linear models (GLMs) for temporal variation in fecal contents of Japanese badgers in Ishinomaki, Miyagi Prefecture, northern Japan: a) fruits (including seeds), b) arthropods, and c) earthworm chaetae

Variables	Estimate ± *SE*	*z*	*P*
a) Fruits /seeds			
Intercept	–0.42 ± 0.05	–9.17	**< 0.001**
Month (April)[a]			
August	–0.15 ± 0.05	–2.87	**0.004**
December	0.32 ± 0.09	3.66	**< 0.001**
July	0.09 ± 0.05	1.66	0.097
June	0.28 ± 0.05	5.75	**< 0.001**
May	–0.28 ± 0.04	–6.80	**< 0.001**
November	0.02 ± 0.05	0.38	0.701
October	–0.01 ± 0.06	–0.10	0.920
September	–0.14 ± 0.04	–3.53	**0.004**
Year (2020)[b]	0.09 ± 0.04	2.36	**0.015**
Month × Year (April × 2020)[c]			
August × 2021	0.08 ± 0.05	1.53	0.126
December × 2021	0.01 ± 0.09	0.16	0.870
July × 2021	–0.06 ± 0.05	–1.12	0.262
June × 2021	–0.48 ± 0.05	–9.85	**< 0.001**
May × 2021	NA	NA	NA
November × 2021	0.22 ± 0.05	4.35	**< 0.001**
October × 2021	0.09 ± 0.05	1.73	0.083
September × 2021	NA	NA	NA
b) Arthropods			
Intercept	–2.70 ± 0.09	–29.13	**< 0.001**
Month (April)			
August	0.97 ± 0.10	9.25	**< 0.001**
December	–0.29 ± 0.33	–0.89	0.373
July	0.61 ± 0.11	5.54	**< 0.001**
June	0.17 ± 0.11	1.57	0.117
May	0.93 ± 0.09	10.91	**< 0.001**
November	–1.14 ± 0.18	–6.37	**< 0.001**
October	0.84 ± 0.11	7.46	**< 0.001**
September	1.04 ± 0.08	12.37	**< 0.001**
Year (2020)	0.44 ± 0.06	7.68	**< 0.001**
Month × Year (April × 2020)			
August × 2021	–0.14 ± 0.09	–1.55	0.122
December × 2021	–16.04 ± 191.60	–0.08	0.933
July × 2021	–0.21 ± 0.10	–2.14	**0.033**
June × 2021	0.80 ± 0.09	9.08	**< 0.001**
May × 2021	NA	NA	NA
November × 2021	–0.21 ± 0.21	–0.99	0.322
October × 2021	–1.83 ± 0.14	–12.86	**< 0.001**
September × 2021	NA	NA	NA

Variables	Estimate ± *SE*	*z*	*P*
c) Earthworms (chaetae)			
Intercept	1.43 ± 1.42	1.00	0.317
Month (April)			
August	0.15 ± 1.64	0.09	0.925
December	6.57 ± 3.14	2.09	**0.038**
July	–0.43 ± 1.64	–0.26	0.793
June	0.77 ± 1.60	0.48	0.630
May	0.20 ± 1.25	0.16	0.873
November	1.37 ± 1.68	0.82	0.415
October	4.95 ± 1.73	2.85	**0.005**
September	1.10 ± 1.25	0.88	0.381
Year (2020)	1.17 ± 1.11	1.05	0.295
Month × Year (April × 2020)			
August × 2021	2.15 ± 1.64	1.31	0.192
December × 2021	–8.67 ± 3.22	–2.69	**0.008**
July × 2021	0.63 ± 1.64	0.39	0.701
June × 2021	–1.27 ± 1.60	–0.80	0.427
May × 2021	NA	NA	NA
November × 2021	–1.27 ± 1.68	–0.76	0.450
October × 2021	–4.15 ± 1.73	–2.39	**0.018**
September × 2021	NA	NA	NA

P values of significant effects (< 0.05) were indicated by bold. NA: not available.
[a] Intercept in April was set to zero. [b] Intercept in 2020 was set to zero. [c] Intercept in April 2020 was set to zero.