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Short communication

Winter diet of the raccoon dog (*Nyctereutes procyonoides*) in urban parks, central Tokyo

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Abstract. We studied the diet of the raccoon dogs (*Nyctereutes procyonoides*) in the two urban parks by fecal analysis in winter, when their nutritional condition is important for breeding. From December 2015 to March 2016, we collected 39 feces from 14 latrines for defecation of raccoon dogs in the Shinjuku Gyoen National Garden (n = 31) and the Toyama Park (n = 8), located in central Tokyo. The samples were analyzed by the hand sorting method, and the frequency of occurrence for each food item was calculated. As a result, seeds (97.4%), birds (48.7%), and earthworms (48.7%) were detected as main food items. Major seeds of fruits detected were *Hovenia dulcis* (56.4%), *Celtis sinensis* (35.9%), *Aphananthe aspera* (25.6%), and *Diospyros kaki* (20.5%). These were planted tree species for gardens and urban greening. Preyed birds consisted mainly of Passeriformes (20.5%), Podicipedidae (7.7%), and Phalacrocoracidae (7.7%). Compared with other studies, fruits were main food items in not only urban parks but also other urban environments and mountain areas in winter. On the other hand, birds were more consumed in urban environments than mountain area, and therefore the availability of animal food items may be different between urban and mountain areas in winter.

Key words: carnivore, fecal analysis, food habit, *Nyctereutes procyonoides*, urban ecology.

Urbanization is one of the major causes of the biodiversity loss (McKinney 2002), which effect is prominent in carnivores (Bateman and Fleming 2012). In central Tokyo, carnivores such as red foxes (*Vulpes vulpes japonica*) and Japanese badgers (*Meles anakuma*) probably began to disappear from around 1920s (Obara 1982). The population of raccoon dogs (*Nyctereutes procyonoides viverrinus*) also seemed locally disappeared from central Tokyo by the late 1950s (Obara 1982). However, raccoon dogs were found to distribute again in the central area of Tokyo since 1990s (Teduka and Endo 2005; Sako et al. 2008). At present, the raccoon dog is an only native Carnivora species inhabiting central Tokyo (Teduka and Endo 2005; Sako et al. 2008).

Food habits can help us to understand the ecology of mammals (Fukue et al. 2011). Raccoon dogs are opportunistic omnivores (Saeki 2015), and their food habits vary according to the locality (Sutor et al. 2010). In central Tokyo, the diet compositions of raccoon dogs were investigated in the Akasaka Imperial Grounds (Teduka and Endo 2005) and the Imperial Palace (Sako et al. 2008; Akihito et al. 2016), which were the residence of the royal family. These studies suggested that fruits and insects were predominant food items and that birds and chilopods also appeared frequently in both areas. However, in these areas, local people's entry is strongly limited because of security reasons, and therefore these areas may be regarded as unusual green spaces. On the contrary, urban parks are generally used by many people, and thus the difference in human use likely affects food resources or behavior of raccoon dogs. Thus, there is possibility that their food habits in urban parks differ from the Akasaka Imperial Grounds and the Imperial Palace. In order to understand the food habits of raccoon dogs in highly urbanized areas, surveys on their diet in urban parks are also necessary.

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In this study, we investigated the winter diet of the raccoon dogs in urban parks by fecal analysis, as a basis for the conservation and management of urban raccoon dogs. Because raccoon dogs mate and get pregnant from late winter to early spring (Saeki 2015), it is a season when the pregnancy of female is determined and the home range for pup-rearing is established. Therefore, nutritional conditions (e.g., food availability, food patch dispersion) of the habitat in winter seem to be important for reproduction of raccoon dogs.

Materials and methods

Study area

We surveyed the food habits of raccoon dogs living in urban parks in Shinjuku, central Tokyo. Tokyo with a population of 37 million in 2015 is the most populous urban agglomeration in the world (United Nations, Department of Economic and Social Affairs, Population Division 2018), and Shinjuku is one of the highest human density (the daytime population is 411 people/ha in 2010, Shinjuku City 2018) areas in Tokyo where many business districts and houses exist. This study was conducted in the Shinjuku Gyoen National Garden (SGNG, 35°41'N, 139°42'E) and the Toyama Park (35°42'N, 139°42'E) (Fig. 1). These are particularly large parks in Shinjuku. SGNG covers 0.58 km^2 surrounded by many offices, stores, and apartments. In this park, the raccoon dog was recorded in 2005 (Yoshino 2006). The Toyama Park covers 0.19 km^2 surrounded by many apartments and some schools. Both study areas belong to temperate humid climate. The average annual temperature was 16.4°C, and the annual precipitation was 1782 mm in 2015 (Japan Meteorological Agency, http://www.jma.go.jp/jma/index.html, Accessed 8 December 2016).

Sample collection and diet analysis

From December 2015 to March 2016, we collected feces from latrines for defecation of raccoon dogs in the study area. In order to confirm that the sample was the feces of the raccoon dog, we conducted the observation by camera-traps and used the form and smell of feces as a cue. We analyzed feces following the hand sorting method (Fukue et al. 2011). Each feces were washed in a sieve (mesh size 1.0 mm) with 1 L of water. The remains were classified into seven categories: mammals, birds, insects, myriapods, seeds, leaves, and other plant materials. Further, insects whose bodies were not broken apart were excluded from analyses because the individual probably entered the feces after defecation. The fragments of mammals and birds were identified to the family or order level according to Murai et al. (2011). Seeds were identified to the species, genus, or family level by the form of seeds according to Suzuki et al. (2012) and specimens collected by authors. In addition, a sample of the wash water (15 mL) was taken and examined for the occurrence of earthworm chaetae under a microscope (×20) as described by Kaneko et al. (2006). We calculated the frequency of occurrence (FO) of each food item according to Fukue et al. (2011).

Comparison with other studies

We compared the FO of main food items with other previous studies. In addition, we investigated the appearance of the fruit species which occurred in the other studies. The conditions of the previous studies used for comparison were as follows: 1) study in Kanto region, 2) fecal analysis in winter, and 3) analysis based on FO. We selected four studies in three study sites to compare them with the present study (Fig. 1): the Imperial Palace (IP, Sako et al. 2008; Akihito et al. 2016), the Akasaka Imperial Grounds (AIG, Teduka and Endo 2005), and Fudakake in Kanagawa prefecture (Sasaki and Kawabata 1994). The IP is a large green space covering 1.15 km^2 located at the center of Tokyo and mainly dominated by evergreen and deciduous broad leaf tree (Sako et al. 2008). The AIG is also a large green space located at the center of Tokyo with an area of 0.51 km^2. In the AIG, there are various environments such as buildings, forests, bamboo grove, grasslands, and ponds (Teduka and Endo 2005). Fudakake is located in the western part of the Tanzawa Mountains in Kanagawa prefecture. The study area covered 1.40 km^2 and has an altitude of 500–1000 m above sea level. The area consisted of patches of primeval forests, secondary mixed forests, and coniferous forests (Sasaki and Kawabata 1994).

Results and discussion

Winter diet composition in the urban parks

A total of 39 raccoon dog feces were collected from 14 latrines: 31 in SGNG and 8 in the Toyama Park. In total, animal matter occurred in 61.5% of feces, and plant matter in 97.4% (Table 1). Seeds (FO: 97.4%), other plants (FO: 94.9%), earthworms (FO: 48.7%), and birds (FO: 48.7%) were predominant. Insects (FO: 33.3%), myriapods (FO: 15.4%), mammals (FO: 7.7%), and leaves (FO: 23.1%) were also detected from the feces. In

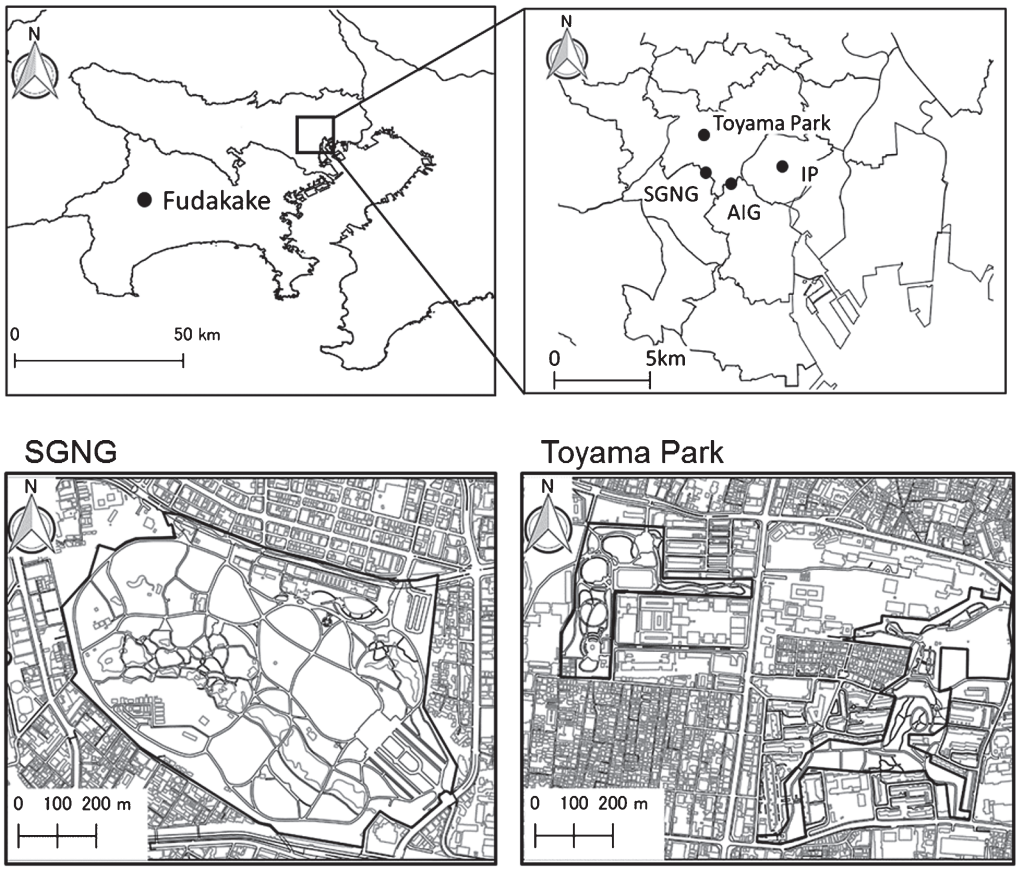

Fig. 1. Locations of the study area; the Shinjuku Gyoen National Garden (SGNG), the Toyama Park, and other studies compared (AIG: Akasaka Imperial Grounds, IP: Imperial Palace, and Fudakake).

winter, raccoon dogs in urban parks used mainly fruits, birds, and earthworms.

Major species of detected seeds were *Hovenia dulcis* (FO: 56.4%), *Celtis sinensis* (FO: 35.9%), *Aphananthe aspera* (FO: 25.6%), and *Diospyros kaki* (FO: 20.5%). In these species, *H. dulcis*, *C. sinensis*, and *A. aspera* were recorded on the guideline of planting for urban greening for the purpose of improving biodiversity including native animals (Natural Environment Division, Bureau of Environment, Tokyo Metropolitan Government 2014) and used as trees for parks, gardens, and landscapes (Iijima and Anbiru 1974). Furthermore, these species were observed in the previous studies in urban areas of central Tokyo (Teduka and Endo 2005; Sako et al. 2008; Akihito et al. 2016). Contrary to this, these fruits did not appear from feces in Fudakake located in the mountain areas (Sasaki and Kawabata 1994). It suggests that planted trees may play an important role as a winter food source of urban raccoon dogs.

Birds mainly consisted of Passeriformes (FO: 20.5%), Podicipedidae (FO: 7.7%), and Phalacrocoracidae (FO: 7.7%). We sometimes found scattered feathers of birds above grounds in field surveys at the SGNG. Because it may be hard for raccoon dogs to hunt these waterfowls such as Podicipedidae and Phalacrocoracidae that almost live on the water, raccoon dogs might consume carcasses, injured or debility individuals, and young birds (Kauhala and Auniola 2001; Drygala et al. 2013).

It is noteworthy that earthworms were one of the major food items in this study. However, there were a few studies examining earthworms in fecal analysis of raccoon dogs. The previous study based on stomach samples of raccoon dogs in suburban areas by Yamamoto and Kinoshita (1994) reported that earthworms occurred more frequently in summer than in winter (summer: about 40%, winter: about 10%, FO). Same tendency was observed in the case in mountain area (Yamamoto 1994). In this study, however, the FO of earthworms was quite higher (48.7%, FO) than that of other studies. It is necessary to investigate the diet of raccoon dogs throughout the year and the importance of earthworms for the source of protein in urban environments.

Table 1. The number and frequency of occurrence (FO, %) of food items in raccoon dog feces collected in Shinjuku Gyoen National Garden (SGNG) and Toyama Park from December 2015 to March 2016

Food item	SGNG (n = 31)	Toyama Park (n = 8)	Total (n = 39)
Animal matter	23 (74.2)	1 (12.5)	24 (61.5)
Mammals	3 (9.7)	0 (0.0)	3 (7.7)
Mogera imaizumii	2 (6.5)	0 (0.0)	2 (5.1)
Unidentified	1 (3.2)	0 (0.0)	1 (2.6)
Birds	18 (58.1)	1 (12.5)	19 (48.7)
Passeriformes	8 (25.8)	0 (0.0)	8 (20.5)
Podicipedidae	3 (9.7)	0 (0.0)	3 (7.7)
Phalacrocoracidae	3 (9.7)	0 (0.0)	3 (7.7)
Unidentified	4 (12.9)	1 (12.5)	5 (12.8)
Insects	13 (41.9)	0 (0.0)	13 (33.3)
Coleoptera	9 (29.0)	0 (0.0)	9 (23.1)
Mantodea	2 (6.5)	0 (0.0)	2 (5.1)
Hymenoptera	1 (3.2)	0 (0.0)	1 (2.5)
Unidentified larvae	10 (32.3)	0 (0.0)	10 (25.6)
Myriapods	6 (19.4)	0 (0.0)	6 (15.4)
Chilopoda	6 (19.4)	0 (0.0)	6 (15.4)
Earthworms	18 (58.1)	1 (12.5)	19 (48.7)
Plant matter	30 (96.8)	8 (100.0)	38 (97.4)
Fruits	30 (96.8)	8 (100.0)	38 (97.4)
Hovenia dulcis	22 (71.0)	0 (0.0)	22 (56.4)
Celtis sinensis	6 (19.4)	8 (100.0)	14 (35.9)
Aphananthe aspera	9 (29.0)	1 (12.5)	10 (25.6)
Diospyros kaki	2 (6.5)	6 (75.0)	8 (20.5)
Ilex sp.	0 (0.0)	4 (50.0)	4 (10.3)
Carex sp.	1 (3.2)	0 (0.0)	1 (2.6)
Fagaceae	1 (3.2)	0 (0.0)	1 (2.6)
Unidentified	10 (32.3)	0 (0.0)	10 (25.6)
Leaves	9 (29.0)	0 (0.0)	9 (23.1)
Monocotyledoneae	9 (29.0)	0 (0.0)	9 (23.1)
Other plants	29 (93.5)	8 (100.0)	37 (94.9)

There were some similarities and differences between SGNG and the Toyama Park, although we could not compare them precisely due to the small sample size from the Toyama Park. Plant matter was predominant in both study areas (SGNG: 96.8%, Toyama Park: 100.0%, FO). *Celtis sinensis*, *A. aspera*, and *D. kaki* appeared in both parks in common. In SGNG, animal matter occurred in 74.2% of feces and five categories (mammals, birds, insects, myriapods, and earthworms) appeared. On the other hand, FO of animal matter in the Toyama Park was 12.5%, which is lower than that of SGNG. The number of categories in animal matter of the Toyama Park was only two (birds and earthworms).

Table 2. Comparison of frequency of occurrence (FO, %) of food items in raccoon dog feces collected in Shinjuku Gyoen National Garden (SGNG) with other studies during winter

Study site	SGNG	IP[a)]	IP[b)]	AIG[c)]	Fudakake[d)]
Habitat type	Urban	Urban	Urban	Urban	Mountain
Number of feces	31	43	40	51	177
Food item					
Small mammals	10	7	0	10	21
Birds	58	40	63	67	16
Insects	42	91	100	92	94
Myriapods	19	63	65	37	0
Crustaceans	0	2	0	2	16
Gastropods	0	7	13	2	4
Fish	0	0	0	0	14
Fruits	97	93	100	94	99
Artificial materials	0	21	18	18	28
Earthworms	58	n.d.	n.d.	n.d.	n.d.

[a)] Imperial Palace; Sako et al. (2008)
[b)] Imperial Palace; Akihito et al. (2016)
[c)] Akasaka Imperial Grounds; Teduka and Endo (2005)
[d)] Sasaki and Kawabata (1994)

Comparison with other studies

Only feces collected in SGNG were used to compare with previous studies because of sufficient sample size. Fruits frequently appeared in the present and previous studies (FO: 93–100%, Table 2). Fruits were one of the main food items in not only urban parks but also other urban environments and mountain areas in winter. For raccoon dogs, the availability of fruits with high sugar content may be important for maintaining the body fat and passing the winter (Helle and Kauhala 1995; Saeki 2008).

In SGNG, insects appeared form 42% of feces. However, those appeared more frequently in the other studies areas including other urban environments (FO: 91–100%, Table 2). In urban parks, the abundance of terrestrial insects is low in places where human activities are intensive or where vegetation is sparse (Shimada 1984; Shimada et al. 1990). The SGNG and the Toyama Park have managed open spaces such as lawn field or sparse vegetation, which possibly influence the abundance of insects. In the future, it is necessary to clarify whether the amount of insect resources will be affected by the management and maintenance methods of the urban parks in order to evaluate the suitability of urban parks as a feeding site of racoon dogs.

Moreover, the FO of small mammals, fish, crustaceans, and birds were different between the urban areas (SGNG,

IP, and AIG) and the mountain area (Fudakake) (Table 2). Small mammals appeared more frequently in the mountain area than the urban areas (Table 2). The FOs of fish and crustaceans showed the same tendency as small mammals (Table 2). Differences in animal food items in the urban and mountain areas may reflect differences in the amount of food resources and the easiness of obtaining food. On the other hand, an opposite tendency was observed in the FO of birds (Table 2). Because birds were frequently consumed in urban environments (Table 2), the availability of birds in this study areas may be higher than mountain area. It suggests that birds may be an important source of protein in the urban environment in winter. The FOs of myriapods and gastropods varied among studies.

Artificial materials did not appear in this study, although they appeared in other studies in urban environment (Table 2) and the previous study based on stomach contents in suburban area (FO: 72.3%, Yamamoto and Kinoshita 1994). In SGNG, the garbage collection point was surrounded by fences, which prevent animals from scattering garbage (personal observation by T. Enomoto, March 2016). This may contribute to the low use of artificial materials by raccoon dogs. Because depending on artificial materials by wildlife may cause the human-wildlife conflict, managing the garbage properly will reduce the conflict between human and raccoon dogs.

Although we focused on winter diet especially, for further research, it is necessary to investigate diet analysis in other seasons and to conduct comprehensive discussion considering the seasonality of food habits. It will deepen our understanding of racoon dogs' adaptation to urban environments. Further, it is expected to contribute to conservation and management for this species.

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