Scavenging on a Carcass of Sika Deer by Introduced Raccoon Dogs (Nyctereutes procyonoides) in Spring: A Case Report in the World Heritage Site of Yakushima Island, Japan

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Rapid communication

Scavenging on a carcass of sika deer by introduced raccoon dogs (*Nyctereutes procyonoides*) in spring: a case report in the World Heritage Site of Yakushima Island, Japan

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Abstract. Understanding the behavior and ecology of non-native species is important to assess their impact on food webs and ecosystem functions and to facilitate the management of non-native species. The present study reports a case of scavenging on a deer carcass by mammals, especially introduced raccoon dogs and native Japanese weasels, in the World Heritage Site of Yakushima, Japan. A sensor camera was placed near the carcass from March to May 2022 to record scavenging behavior of mammals. Out of at least six species of mammals filmed, raccoon dogs and weasels fed on the carcass. Raccoon dogs almost monopolized the carcass, i.e., raccoon dogs were filmed around carrion more frequently and spent more time scavenging than weasels. Raccoon dogs and weasels were filmed around the carcass at similar times in a day, and no overt aggression was observed between the two species, but weasels were displaced by raccoon dogs. Japanese macaques and sika deer avoided and never fed on carrion. The present study suggests that raccoon dogs contribute to carrion decomposition in the World Heritage Site of Yakushima and that comprehensive studies of carrion availability and the scavenger community could help promote the management of introduced raccoon dogs in Yakushima.

Key words: alien species, camera trap, carnivores, carrion decomposition, wildlife management.

Assessing the impacts of non-native species on food webs and ecosystems is essential for understanding ecosystem functions and services and for the management of non-native species (Pyšek et al. 2020). The effects of non-native species vary from negative (e.g., competition with and predation of native species, damage to agriculture, forestry and fisheries, increased risk of disease and parasite infection) to positive (e.g., providing food resources to native species and promoting pollination and seed dispersal) (Goodenough 2010). In degraded anthropogenic habitats, non-native species sometimes plays important roles in maintaining ecological functions provided by declining native species (Dupuis-Desormeaux et al. 2022).

Invasion of non-native species can affect carrion decomposition (Wilson and Wolkovich 2011), which has recently received special attention as one of the important ecological processes in ecosystems. Scavengers not only facilitate material cycling and enhance the stability of food webs but also provide ecosystem services such as disease control (Olea et al. 2019). Frequent scavenging by (invasive) non-native species can alter the structure and stability of food webs in ecosystems by changing the community of native vertebrate and invertebrate scavengers (Brown et al. 2015; Sugiura and Hayashi 2018).

This report describes scavenging of a carcass of sika deer (*Cervus nippon yakushimae*) by mammals, especially introduced raccoon dogs (*Nyctereutes procyonoides*) and native Japanese weasels (*Mustela itatsi*), in the World Heritage Site of the western coastal forest of Yakushima Island, Japan. Although how raccoon dogs were introduced to Yakushima remains unknown, they were first sighted in the early 1990s, and they have been found across the island since the 2000s (Emergency Research Group on the Introduced Racoon-Dogs on Yakushima 2002). Raccoon dogs in Yakushima fed on fruit, invertebrates, and small mammals (Ministry of the Environment of Japan 2006; Tsujino and Agetsuma-Yanagihara 2006), as other populations in warm-temperate forests (Takatsuki et al. 2020). While they might act as seed dispersers, there are various concerns such as predation on

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and competition with native species, agricultural damage, and parasite and diseases transmission (Emergency Research Group on the Introduced Racoon-Dogs on Yakushima 2002; Ministry of the Environment of Japan 2006; Sato et al. 2006a, 2006b; Tsujino and Agetsuma-Yanagihara 2006). However, few ecological surveys on introduced raccoon dogs have been conducted yet. There are no reports on the diet of Japanese weasels in Yakushima, to the best of my knowledge.

Population growth and intensive population control of sika deer in Yakushima (Tsujino 2014) could increase carrion availability through natural mortality and hunting. Although no data are available for Yakushima, there have been cases reported in Japan where hunted wildlife was left abandoned in forests (Yamada 2018), which bring concerns about the impact of such carcasses on ecosystems (Inagaki et al. 2022). It is of great worth reporting scavenging behavior of raccoon dogs and Japanese weasels to encourage the management of non-native species and the proper disposal of carcasses of hunted deer in Yakushima.

Materials and methods

The study site is a warm-temperate evergreen broad-leaved forest that extends over the western coastal area of Yakushima Island, Kagoshima Prefecture, Japan (30°19'N–30°22'N, 130°22'E–130°24'E; ca. 0–300 m a.s.l.). A part of this area has been registered as a Natural World Heritage Site since 1993. The details of the study site are described in Tsujino and Yumoto (2007), Shibasaki (2017), and Kurihara and Aiba (2020).

Six species of medium and large-sized mammals are distributed there: Japanese macaques (*Macaca fuscata yakui*), sika deer, Japanese weasels, raccoon dogs, feral dogs (*Canis lupus familiaris*), and feral cats (*Felis catus*) (Morita 1984; Tsujino and Agetsuma-Yanagihara 2006). To reduce damage to agriculture and ecosystems owing to the increased deer density (21.9–32.7 individuals/km^2 in fiscal year [FY] 2022; Kagoshima Prefecture 2023), deer culling for the population management has been conducted intensively throughout the island since 2010, mainly in the lowlands (except for most of the area registered as a World Heritage site) (Ministry of the Environment of Japan 2023). Hunted deer are either buried in forests, transported to meat processing facilities, or consumed at home (Yakushima Town 2023).

On February 28, 2022, a dying deer (adult male; estimated to be > 6–7 years old based on the antler size and shape [Agetsuma-Yanagihara and Agetsuma personal communication]) was found on a forest road running through the study site. Road maintenance workers visited there and carried the deer into the forest. It could not be confirmed, but it was highly likely that the deer died on the day because there were flies swarming around the lying deer, and the deer was completely unresisting when carried by the humans. The cause of death was unknown, but no external wound was found on the body, and hunting is prohibited in the study area. The detailed description of the dying deer and the decomposition process of the deer carcass is provided in Supplementary materials S1–S3.

One sensor camera (BTC-4P, Browning) was placed near a deer carcass from 15:18 March 2 to 16:42 May 22, 2022, to take 10-second videos with a 1-second refractory period. On March 2 (2nd day after death), most of the body was still fresh and remained intact in appearance. Only the tail and rump of the carcass were lost, and the abdominal cavity was partially visible. I recorded species and the number of individuals of mammals and birds that were filmed around the carcass and the time (in seconds) that animals were feeding on the carcass. I regarded an animal feeding when its jaws or head was moving with its mouth on the carcass. If more than two individuals were foraging in a single video, the feeding time of each individual was measured separately. In the present study, I assumed that carrion was available between March 2 (the date of the camera deployment) and April 1 (the last date of scavenging recorded) and analyzed data collected during that period. The camera worked for 28.5 days in total, after excluding the period when the SD card was full (March 6) or the whole carcass was out of the detection area (March 7 and 8) (Supplementary material S1).

To examine whether mammals were attracted to or repelled by carrion, I compared the frequency that each species was filmed around the carcass with that around deadwood (regarded as control sites). I placed the same model of cameras in the same way in the study site for the purpose of monitoring deadwood (logs with > 10 cm diameter and ca. 1 m length). I used data in March (2020–2022) from the plots where the deadwood was heavily or completely decomposed and therefore it was unlikely to affect the frequency of mammals filmed ($N_{\text{camera}} = 12$). It would be reasonable to regard them as control data at least for the present study. I did not conduct this comparison for smaller animals (e.g., rodents, birds) that cannot be detected reliably by the camera.

Results

At least six species of mammals and two species of birds were filmed between March 2 and April 1, 2022. The number of videos taken for each species was 2616 for raccoon dogs, 106 for pale thrushes (*Turdus pallidus*), 35 for wood mice (*Apodemus* sp.), 33 for Japanese weasels, 18 for sika deer, 11 for Japanese macaques, four for varied tits (*Sittiparus varius*), and two for feral cats.

Raccoon dogs and Japanese weasels used the area around the carcass more frequently than control sites, while sika deer and Japanese macaques did less frequently. Feral cats were filmed only around the carcass (Fig. 1).

Only raccoon dogs and Japanese weasels fed on the carcass. Raccoon dogs were observed feeding in 1708 videos (62.9% of the total number of videos), with a total feeding time of 15 363.8 seconds. This accounted for 99.9% of the time spent by mammals feeding on the carcass. Raccoon dogs were observed foraging in 29

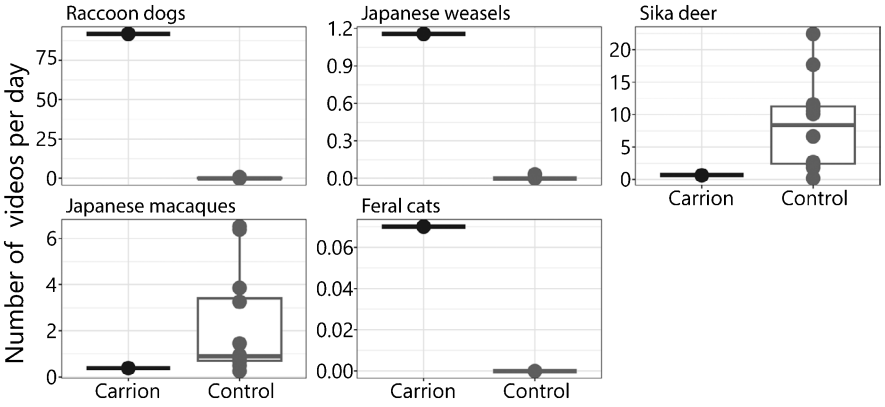

Fig. 1. Attraction to and avoidance of carrion by mammals. Frequency of mammals filmed around carrion (the deer carcass; $N_{camera} = 1$) and control sites (deadwood; $N_{camera} = 12$) during March 2–April 1 is shown. The horizontal line in the box indicates the median. The lower and upper hinges indicate the first and third quartiles, respectively.

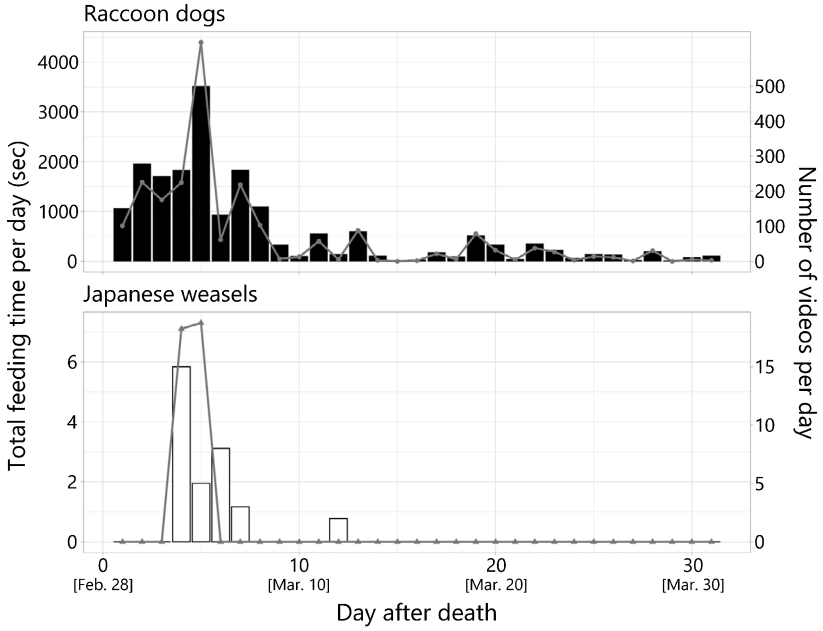

Fig. 2. Utilization of carrion by raccoon dogs and Japanese weasels. The number of videos per day (bar graph, right Y axis) and the total feeding time per day in seconds (line graph, left Y axis) during March 2–April 1 are shown. The date of death was February 28, and the camera was placed on March 2 (2nd day after death). Missing data occurred on March 6, 7, and 8.

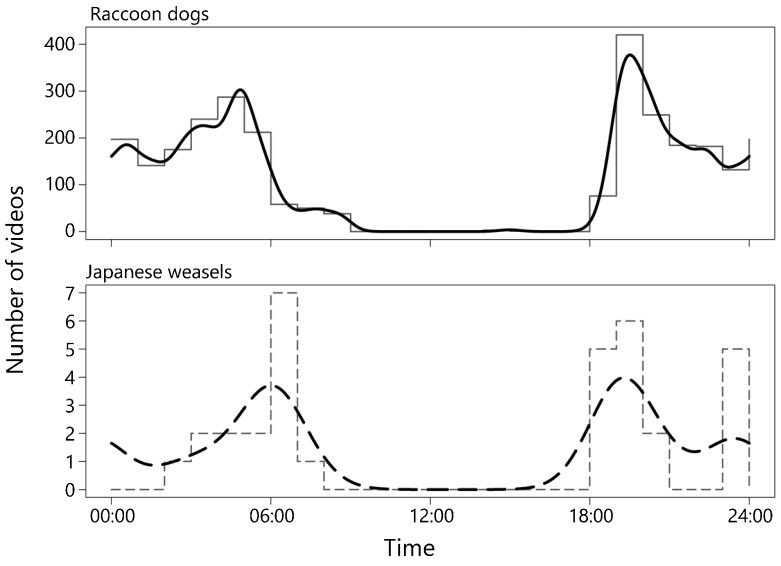

Fig. 3. Times when raccoon dogs and Japanese weasels were filmed around the deer carcass. Bars (thin lines) and curves (thick lines) indicate the number of videos and the kernel density estimates (using the *activity* package [Rowcliffe 2022] in statistical software R ver 4.1.1 [R Core Team 2022]), respectively.

days, reaching a peak on March 6 (4395.9 sec/day), when the carcass was heavily damaged. Weasels were observed feeding in four videos (0.2% of the total number of videos), with a total feeding time of 14.4 seconds. Scavenging by weasels was observed only on March 5 and 6 (Fig. 2).

Raccoon dogs sometimes fed on the carcass with multiple individuals while Japanese weasels always did solitarily. The average number of raccoon dogs per video was 1.48 individuals (median: 1, range: 1–4), and the average number of scavenging individuals was 1.14 (median: 1, range: 1–3). Overt aggression (e.g., lunge and bite) over carrion among raccoon dogs occurred in six videos (one video on March 5, two on March 6, and three on March 7; Supplementary material S4).

Raccoon dogs and Japanese weasels were filmed around the carcass in similar times in a day, with peaks in the number of videos taken around 5:00–6:00 and 19:00 (Fig. 3). In five videos on March 5, raccoon dogs and weasels were filmed at the same time (Supplementary material S5). No overt aggression was observed between the two species; however, the weasels were displaced by the raccoon dogs, and the weasels never arrived later than the raccoon dogs. In a series of the videos, the weasel stared at the approaching raccoon dog while the raccoon dog started scavenging in close proximity to the weasel without vigilance.

Discussion

Raccoon dogs used the area around the deer carcass most frequently and fed on it for the longest time among mammals. In particular, the raccoon dog was the only species that could open the intact carcass in Yakushima and almost monopolized the carcass. Raccoon dogs have been known as the main facultative scavenger in other parts of Japan, including an introduced population on Chiburijima Island in Oki (Sugiura et al. 2013; Sugiura and Hayashi 2018; Inagaki et al. 2020; Enari and Enari 2021; Gerke et al. 2022). Aggression over carrion among raccoon dogs, observed in the present study, implied that carrion was a preferred resource for them, even in the warm-temperate forest of Yakushima. Carrion is not only an important food during winter in cool-temperate forests but also a preferred food in warm-temperate forests, where the availability of fruit and insects is high (Takatsuki et al. 2020). The lack of reports in Yakushima may be due to the insufficient sample size or study duration (stomach content analysis: N_{sample} = 8 collected in October–November 2004 [Ministry of the Environment of Japan 2006]; fecal content analysis: N_{sample} = 6 collected in August 2003–March 2004 [Tsujino and Agetsuma-Yanagihara 2006]) or general characteristics of carrion, a food resource that is ephemeral and spatially clumped (Moleón et al. 2019).

Japanese weasels were attracted to carrion but only

fed on it for a short time after raccoon dogs opened it. Similarly, scavenging by weasels has been rarely observed in other regions of Japan (Sugiura et al. 2013; Inagaki et al. 2020; Enari and Enari 2021; Gerke et al. 2022). On the three islands in Oki, where potential mammalian scavengers are only weasels, the contribution of invertebrates to the removal of experimentally-placed mouse carcasses was greater than that of weasels (Sugiura and Hayashi 2018). Further studies are needed to determine if access to carrion by weasels is constrained by competition with raccoon dogs in Yakushima. Weasels were displaced by raccoon dogs around the deer carcass, which could result from the interspecies differences in the number of individuals filmed around the carcass (raccoon dogs: 1.48 individuals; weasels: one individual) and body size (raccoon dogs: 4.13 kg [Saeki 2015]; weasels: ca. 0.45 kg for males and ca. 0.15 kg for females [Masuda and Watanabe 2015]) (Monterroso et al. 2020). Temporal niche segregation might not have occurred between the two species in the present study. Avoiding competition over unpredictable and ephemeral resources (i.e., carrion) could be insufficient to cause a shift in the activity pattern of weasels, unlike factors which consistently affect the activity pattern (e.g., activity patterns of staple prey, thermal environment, human activity [Kronfeld-Schor and Dayan 2003; Ikeda et al. 2022]).

Japanese macaques and sika deer avoided carrion and never fed on it. Despite the close proximity of Japanese macaques to deer in Yakushima (Agetsuma et al. 2011), behavioral observations also showed that Japanese macaques were vigilant toward the dying deer and did not even touch it in the present study (Supplementary material S1). These two species rarely feed on vertebrates (including carrion) (Agetsuma et al. 2011; Tsuji et al. 2012) and may prioritize reducing the risk of parasite and disease transmission by avoiding foraging plants around the carcass (Moleón and Sánchez-Zapata 2021). It was unclear whether feral cats were attracted to carrion because they were filmed only twice.

Roles of avian and invertebrate scavengers should be investigated in future studies because they can contribute substantially to carrion decomposition in temperate forests (Selva et al. 2003; Sugiura and Hayashi 2018). No avian scavengers were recorded in the present study. The forest canopy was closed where the carcass was located, which could prevent birds from finding and visiting it (Selva et al. 2003). Potential avian scavengers in Yakushima are black kite (*Milvus migrans*), Japanese sparrowhawk (*Accipiter gularis*), Eurasian sparrowhawk (*Accipiter nisus*), common buzzard (*Buteo buteo*), grey-faced buzzard (*Butastur indicus*), peregrine falcon (*Falco peregrinus*), Sunda scops owl (*Otus lempiji*), brown boobook (*Ninox scutulata*), tiger shrike (*Lanius tigrinus*), bull-headed shrike (*Lanius bucephalus*), brown shrike (*Lanius cristatus*), Eurasian jay (*Garrulus glandarius*), carrion crow (*Corvus corone*), and large-billed crow (*Corvus macrorhynchos*), which are known to feed on mammals and birds (Hanawa 1984; Takagawa et al. 2011). Although I did not conduct systematic sampling of invertebrate scavengers, I found several species of flies around the carcass throughout the study period (species identification was not possible). Avian and invertebrate scavengers could play crucial roles in carrion decomposition in Yakushima, where mammalian scavengers had been almost absent for a long time.

The raccoon dog, a non-native species, was the primary and dominant mammalian scavenger in the World Heritage Site of the coastal forest of Yakushima, suggesting that it contributes substantially to carrion decomposition. Despite the limited sample size and study duration of the present study, the results warrant further investigation on scavenging dynamics in Yakushima. In particular, it is worth considering, from the viewpoint of wildlife management, the possibility that the increased number of sika deer hunted in recent years (Tsujino 2014) has increased the supply of carrion, promoting the colonization success of raccoon dogs (Wilson and Wolkovich 2011). A carcass of adult deer could fill stomachs of a minimum of 24 raccoon dogs, given that the body weight of adult females is 19–25 kg (Agetsuma et al. 2011), the percentage of bone weight in the total body weight of sika deer is 19.82% (Ishida et al. 1996), the wet weight of daily food intake of captive raccoon dogs is 639.7 g (Korhonen and Harri 1986), and competition with other scavengers and decomposers is negligible (i.e., $19\,000 * (1 - 0.1982)/639.7 \approx 24$).

Island-wide surveys of the feeding ecology and population dynamics of raccoon dogs and Japanese weasels, carrion availability, and the community of avian and invertebrate scavengers across seasons and landscapes would contribute to the management of non-native species as well as understanding of detrital food webs and dynamics of material cycling. For example, it can be predicted that carrion use by raccoon dogs would decrease in summer, when competition with invertebrate scavengers (e.g., flies, beetles) would be more intense, and in urban landscapes, where other vertebrates (e.g., crows, feral cats and dogs) would be potential competitors (Shizukuda

and Saito 2023). Alternatively, raccoon dogs could limit carrion acquisition by other scavengers (Brown et al. 2015). In particular, population declines of necrophagous beetles (Silphinae) could possibly occur owing to decreased availability of carrion in areas with high densities of raccoon dogs. Further studies will also provide useful insight into whether current procedures of carrion disposal are sufficient and appropriate from the perspective of the management of introduced raccoon dogs in Yakushima.

Supplementary data

Supplementary data are available at *Mammal Study* Online.
Supplementary material S1. Detailed description of the dying deer and the decomposition process of the deer carcass.
Supplementary material S2. The dying deer lying on a road.
Supplementary material S3. Chronology of the decay of the deer carcass.
Supplementary material S4. Aggression over carrion in raccoon dogs.
Supplementary material S5. Interspecies encounters around the deer carcass between raccoon dogs and Japanese weasels.

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