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Invasion of the raccoon *Procyon lotor* into the remote mountainous area of the Chichibu region, Saitama Prefecture, Japan

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埼玉県奥秩父山域へのアライグマ *Procyon lotor* の侵入

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1. Introduction

The raccoon *Procyon lotor* is an invasive carnivore that has been introduced and become naturalized in multiple countries and regions across the world (Timm *et al*., 2016). Raccoons are known to invade urban and agricultural spaces, frequently causing nuisances such as breaking into the attics of homes, scavenging through garbage, and damaging crops in the field (Ikeda *et al*., 2004). However, their preferred habitats are forest edges and aqueous plots such as marshes (Barding and Nelson 2008), and they have also been found to prey on a wide range of native species (Ikeda *et al*., 2004) including eggs of lower-nesting forest-dwelling birds (Schmidt, 2003). In addition, their diet and habitat preference may overlap with native mesocarnivore species, leading to adverse impacts on the native species' behaviors and population sizes.

The raccoon was introduced into Japan in the mid-late 20th century and has since expanded to inhabit most of its prefectures (Ikeda *et al*., 2004). Their damage to agricultural production has become significant, with an economic impact totaling over 361 million yen (approximately 3.3 million USD) in 2019 (Japanese Ministry of Agriculture, Forestry and Fisheries, 2020). In the Saitama Prefecture, which is situated north of Tokyo in Eastern Japan, raccoon sightings and captures were relatively rare and limited to specific regions until around 2006, but had rapidly expanded to all regions of the prefecture by 2007 (Saitama Prefecture, 2021). In recent years, they have been sighted and captured across the prefecture, except for the remote mountainous areas of the Chichibu region in the remote west of the prefecture (Tsunoda, 2016). Yearly capture numbers of raccoons have continued to increase, reaching 7000 per year in the fiscal year of 2019 (Saitama Prefecture, 2021); consequently, their economic impact continues to grow, with agricultural damage, mainly to crops and fruits, reaching over 20 million yen (approximately 183,000 USD) in the

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fiscal year 2019 (Saitama Prefecture, 2021). The raccoon's dietary overlap with native mesocarnivores such as masked palm civets *Paguma larvata* and raccoon dogs *Nyctereutes procyonoides* has also been observed in Japan (Matsuo and Ochiai, 2009), and a drastic increase in raccoon numbers is likely to have adverse impacts on them and other native prey species. As such, raccoon population management is essential for agricultural production and conservation of native wildlife in the Saitama Prefecture. The Saitama prefectural government has implemented a raccoon management plan since 2007 (Saitama Prefecture, 2021). However, raccoon management in the remote mountainous areas of the Chichibu region was not included in this plan since no sightings or captures had been reported in this area. However, the lack of raccoon sightings in this area could be caused by its low human population density and steep geography, which could obscure raccoon invasions, even if they had already taken place. Therefore, a comprehensive survey focusing on the detection of medium-sized mammals was essential for the conservation of native species in this area.

2. Methods

A comprehensive camera trap (CT) survey was conducted across the Takikawa research area from April 2018 to April 2019; this region is a subset of the University of Tokyo Chichibu Forest (UTCF) (35° N, 138-139° E) (Fig. 1), a private forest inside the Chichibu-Tama-Kai National Park, situated in the Chichibu region, Saitama Prefecture (Tanigawa *et al*., unpublished). The Takikawa research area is approximately

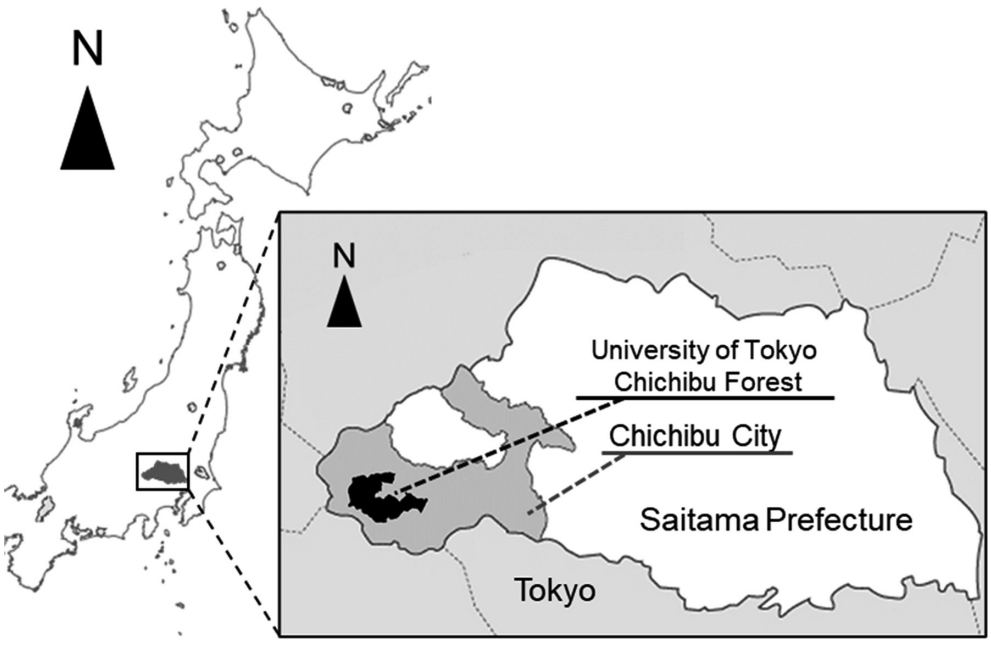

Fig. 1. The geographical location of the University of Tokyo Chichibu Forest.

1875 ha in size, and the elevation of the area ranges from approximately 750 m to 1,800 m. In the UTCF, the mean annual precipitation and mean annual temperature for 15 years from 2002 to 2016 as measured at the Tochimoto meteorological station (35° 94'46"N, 138° 86'32"E, 740 m a.s.l.) were 1,494 mm and 11.1℃, respectively. The forest of the UTCF is a mixture of plantation, secondary, and old-growth forest types. In total, 64 CTs were utilized, with 49 Bushnell Aggressor 20 MP Low-Glow trail cameras (Bushnell Outdoor Products, Overland Park, Kansas, USA), and 15 Bushnell Trophycam trail cameras (Bushnell Outdoor Products, Overland Park, Kansas, USA) pre-deployed from 2016 for other purposes. All CTs shared the same setting of three shots per detection, "normal" sensor sensitivity, and a detection interval of 60 s. Continuous 500 m × 500 m grids were overlaid on the study area to systematically determine points for CT placement (Fig. 2) (Tanigawa *et al*., unpublished).

3. Results and Discussion

Raccoons were detected by two CTs in the low elevation regions of the research area in February 2019 (Figs. 2, 3, and 4), thus proving that raccoons have invaded into the remote mountainous area of the Chichibu region.

The survey spanned a total of 17,870 CT days, and we obtained 18,665 captures of animals, including

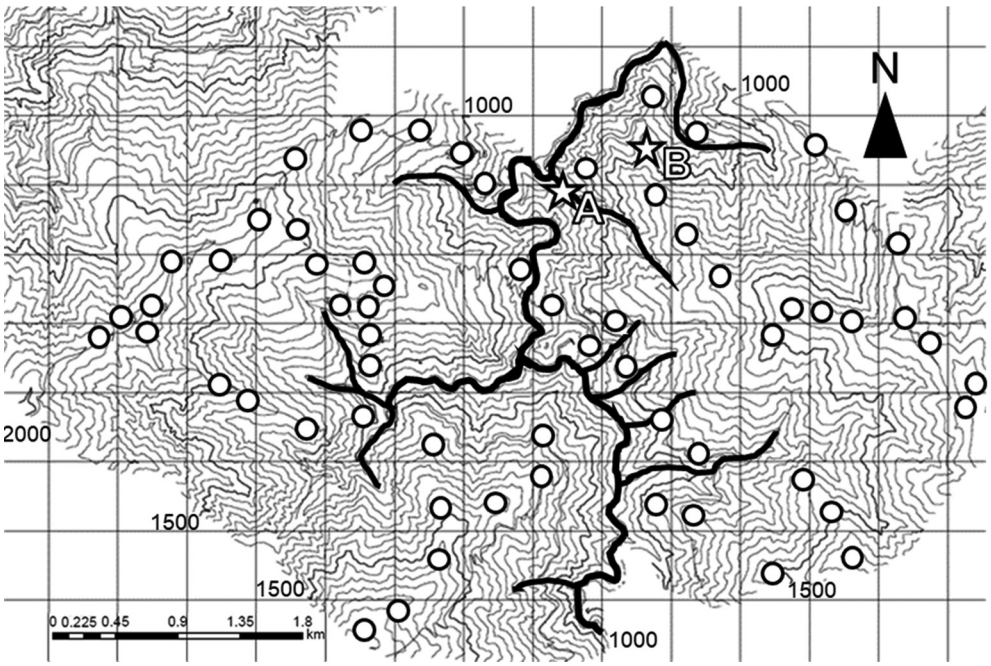

Fig. 2. The placement of camera traps utilized in the survey. Circles show the placements of camera traps and stars indicate the two camera traps, A and B, that detected raccoons. Grids are 500 m × 500 m. Thick lines show the streams in this area.

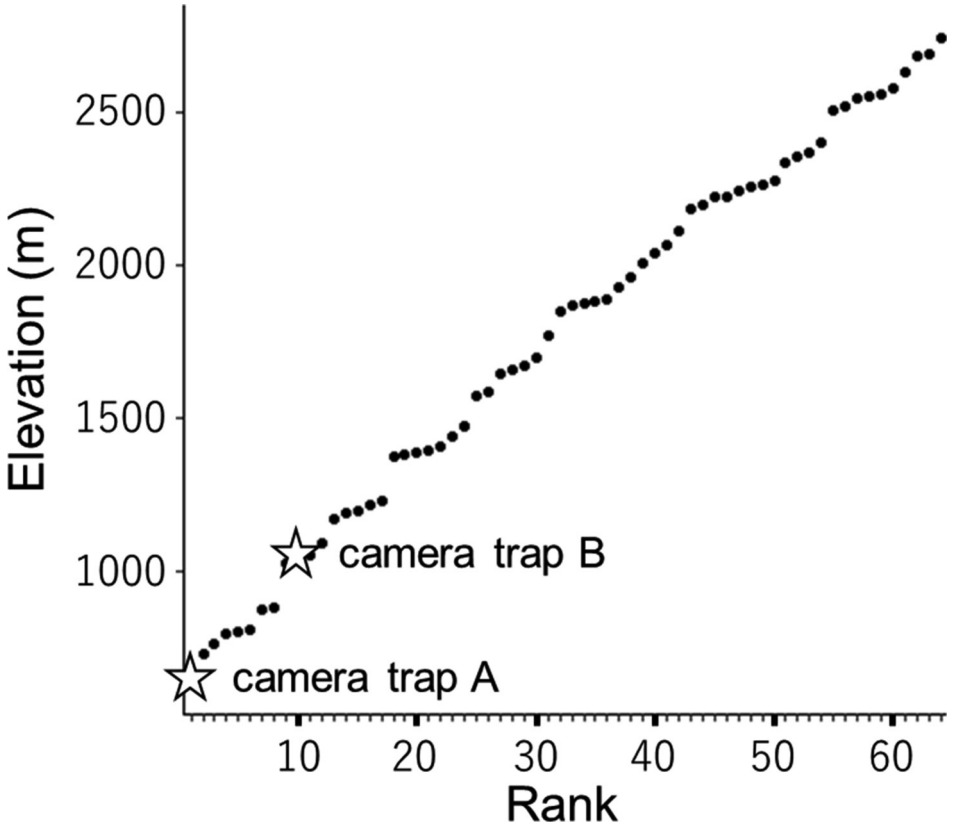

Fig. 3. Elevations of the camera traps which detected raccoons and all other camera traps utilized in the survey. Stars indicate the elevations of the two camera traps, A and B, which detected raccoons, and black circles indicate the elevations of the other camera traps. All camera traps were ranked by their elevations from lowest to highest.

2280 captures of mesocarnivores (Tanigawa *et al*., unpublished). However, raccoons were only detected at two CTs, one time each. This implies that although invasion had occurred, raccoon density in the research area was not significantly high. Both CTs that detected raccoons were placed at lower elevations and in the proximity of streams (Figs. 2 and 3). This implies that raccoons have only been able to invade lower-elevation areas with access to aqueous habitats. This is consistent with Barding and Nelson (2008), which found that raccoons prefer riparian habitats for their relative abundance of prey such as amphibians, and Matsuo and Ochiai (2009), which found amphibians to be a central part of the diet of raccoons in Japan. This indicates that the impact of raccoons on forest-dwelling animals such as native mesocarnivores and lower-nesting birds in the research area may be minimal or at least partial, but it also implies that native amphibian species in riparian habitats may be at high risk. The research area is situated inside the Chichibu-Tama-kai National Park, which is home to multiple vulnerable or near-threatened amphibians in the Saitama Prefecture, including species such as the Hida salamander *Hynobius kimurae*, the Hakone

Fig. 4. Photographs of raccoons detected at (a) camera trap A and (b) camera trap B.

salamander *Onychodactylus japonicus*, and the stream brown frog *Rana sakuraii* (Saitama Prefecture, 2018). For the conservation of such species, raccoon population management in the remote mountainous areas of the Chichibu region is essential, and further research concerning the extent of raccoon invasions and the diet of raccoons in the area should provide vital information for the assessment of their impact on native species. Furthermore, such research must be conducted speedily, before the population of invasive raccoons in the area increases to higher levels.

Acknowledgments

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