



# A preliminary study on habitat selection of the Japanese serow (*Capricornis crispus*) at two temporal scales, season and time of day, in a montane forest

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Received: 30 June 2021 / Accepted: 8 October 2021 / Published online: 23 October 2021  
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## Abstract

Habitat selection has a significant influence on animals' fitness, and has been well studied in various ungulates. A trade-off between the access to forage and to shelter often occurs for ungulates' habitat selections, which vary temporally. However, habitat selections for primitive ungulates with solitary and sedentary, such as the Japanese serow (*Capricornis crispus*), are poorly known. We examined habitat selection at the within-home range scale of the Japanese serow in a montane forest of Mt. Asama, central Japan, at two temporal scales, season and time of day (day or night), by radio-tracking. Serows selected shrub-rich habitats with steep slopes and avoided shrub-poor habitats with gentle slopes, and their selection showed little variation according to season. Shrub-rich habitats with steep slopes provide both abundant food and shelter against potential danger, which suggests that it is an adequate habitat for serows throughout the year. The habitat selection of serows had few differences according to time of day, which suggests that shrub-rich habitats with steep slopes are suitable for both feeding and resting (i.e., all times of day). Our results suggest that trade-offs between the access to forage and to shelter may be less likely to occur for serow's habitat selection, unlike other ungulates.

**Keywords** Habitat selection · Japanese serow · *Capricornis crispus* · Forage · Shelter · Trade-off

## Introduction

Habitat selection is an important aspect of the ecology of a species (Rosenzweig 1981). For ungulates, habitat selection has been well studied in various species, and forage conditions and shelters against predator or harsh climate are thought to be key factors in determining habitat selection (Dussault et al. 2004; Godvik et al. 2009). Each habitat type may not contain an adequate combination of these factors, and thus a trade-off between the access to forage and to shelter often occurs for habitat selection (Houston et al.

1993). Alternatively, predation risks or food conditions in each habitat type often vary temporally, such as season and time of day (Bjørneraas et al. 2011).

The Japanese serow (*Capricornis crispus*) is a typical forest-dwelling ungulate, and most populations inhabit in a cool temperate forest of Japan (Ochiai 2015). This species is monomorphic with a small body size and thought to retain traits similar to ancestral Caprinae (Geist 1987). Although there are some studies on the habitat use of Japanese serows based on observation of unidentified individuals or pellet-group survey (Nowicki and Koganezawa 2001; Takada et al. 2020a), little is known about their habitat selection. Since Japanese serows are sedentary (Takada et al. 2020b), habitat selection at within home ranges scale is particularly important. However, they inconspicuously inhabit in a closed forest, thus capturing is relatively difficult, and radio or GPS tracking have been rarely performed. In addition, habitat selections for primitive ungulates, such as the Japanese serow, with solitary and resource-defense territory are poorly known.

In this study, we aim to preliminary report the first data on habitat selection at the within-home range scale of the

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Japanese serow in a montane forest, typical habitat of them, of Mt. Asama, central Japan. We examined variations of habitat selection at two temporal scales, season and time of day.

## Methods

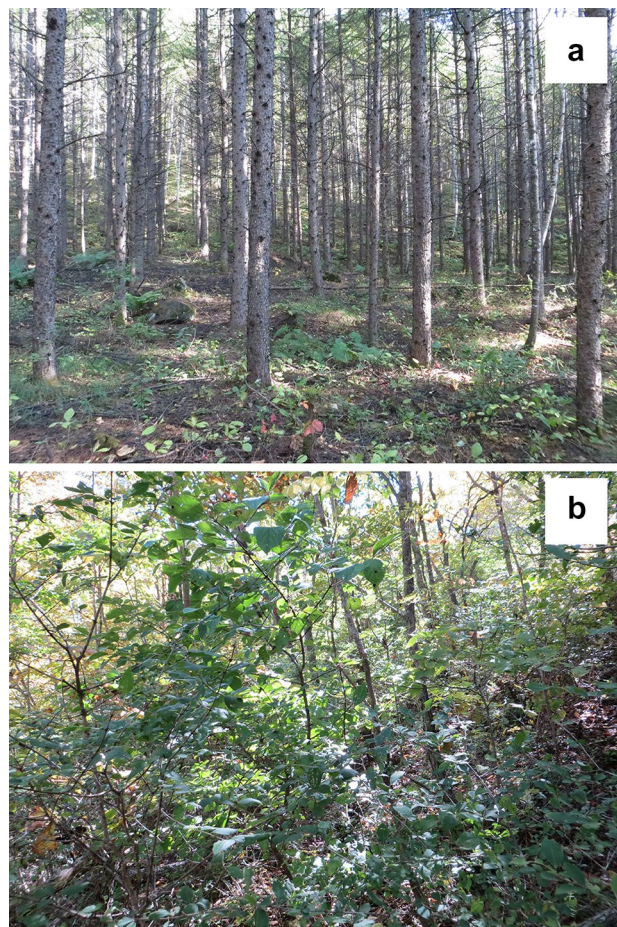
### Study site and population

The study site (36°38' N, 138°47' E) was located on Mt. Asama, central Japan and covered approximately 210 ha (elevation range: 1180–1590 m above sea level, Fig. 1). The area was in the cool temperate zone and covered by snow (approximately 30–50 cm in depth) between December and March. The overstory primarily comprised coniferous forests (87%) of Japanese larch (*Larix kaempferi*) and Japanese red pine (*Pinus densiflora*), and partly comprised broad-leaved forests (13%) of Mongolian oak (*Quercus crispula*). The understory mostly comprised dwarf bamboo (*Sasa nipponica*) and deciduous broad-leaved shrub thickets. The population density of serows was 4.5 individuals/km<sup>2</sup> and six adult serows were identified during the study periods (Takada et al. 2020b). Wild predators were absent, because wolves have been extinct in the area for more than 100 years, but serows in this site have exhibited vigilance toward humans, indicating that they perceive humans as a potential danger (Takada et al. 2019).

### Habitat type

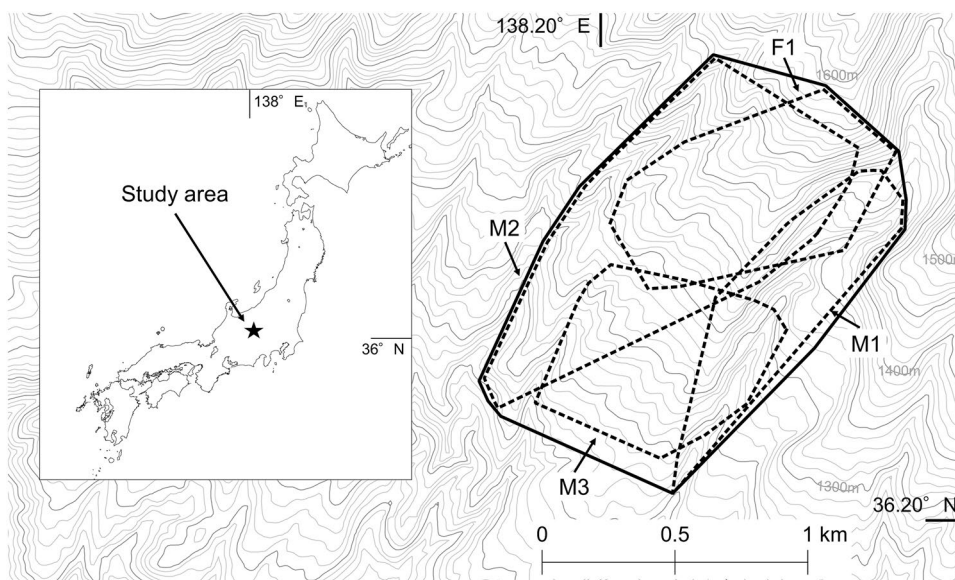
According to Takada et al. (2020a), vegetation types were classified as “shrub rich” and “shrub poor” based on understory vegetation (0.5–2.0 m, within reach of serows), which

is important for both forage availability and cover for serows (Fig. 2). Shrub-rich and shrub-poor habitat accounted for



**Fig. 2** Views of **a** shrub-poor habitat and **b** shrub-rich habitat at Mt. Asama, central Japan (photographed in September 2013)

**Fig. 1** Study site (solid line) and annual home ranges of four collared Japanese serows (*Capricornis crispus*) estimated by the 100% minimum convex polygon method (dashed line) at Mt. Asama, central Japan. M1–3 and F1 indicates individual IDs (M = males, F = females)



57.5% and 42.5% of the study area, respectively. Shrub-rich habitat provides five times more deciduous broad-leaved trees than shrub-poor habitats, whereas shrub-poor habitat provides more forbs or graminoids than shrub-rich habitat (Takada et al. 2020a). We generated a slope map for the study site from a 10-m digital elevation model (Geographical Information Authority of Japan) using QGIS 2.18 (QGIS Development Team 2012). The mean slope was 20.8° (range: 4.1°–51.0°). We defined four seasons, spring (March–May), summer (June–August), autumn (September–November), and winter (December–February), based on plant phenology in the study site.

### Serow location and home range estimation

We captured four adult serows (three males and one female) using a dart rifle in March 2012 and fitted each with a VHF radio collar (ATS, USA). Their home range locations are stable throughout the year and inter-annually (Takada et al. 2020b). We located the collared serows by standard triangulation using VHF receivers (YAESU, Japan) and a 6-element Yagi antenna at 2-h intervals 2–6 days per month during Jun 2013–May 2014 (total: 12 months, Table S1). We attempted to locate individuals from at least three receiving locations as soon as possible to obtain the most accurate telemetry locations. The time period was defined as day (sunrise to sunset) and night (sunset to sunrise), and we recorded the time period in which the serow was located. Home ranges of serows for each season were estimated using the 100% minimum convex polygon method (MCP100) to analyze habitat selection (Table S2).

### Statistical analyses

We completed the following analyses in R 3.4.1 (R Core Team 2017) using the packages ‘lme4’ (Bates et al. 2015), ‘MuMIn’ (Barton 2019), and ‘car’ (Fox and Weisberg 2011). Because there was no clear sexual difference in habitat use of the serow (Takada et al. 2019), the following analysis was performed using pooled data of the three males and one female.

To assess the habitat selection of serows, we compared serow telemetry locations with random locations using generalized linear mixed models (GLMM) with binomial distributions and a logit-link function (Table S3). We generated random locations within the seasonal home ranges (as determined by MCP100) of each radio-collared individual for each season. For each individual, each season, and each time period, we used the same number of random locations as there were telemetry locations. We set the dependent variable as the probability of serow locations (1 = serow location, 0 = random location). Fixed effects included the vegetation type, slope, and following interactions:

season × vegetation, season × slope, time period × vegetation, and time period × slope. Individual identity was set as a random-effect factor to minimize variation among individuals. To select the model that best explained the observed pattern of serow habitat selection, Akaike’s information criterion corrected for small sample size (AICc; Burnham and Anderson 2002) was used. Models with the lowest AICc value were considered the best models; any pair of models with a difference in AICc values ( $\Delta\text{AICc}$ ) less than 2 was considered to have similar support. We conducted model averaging on competing models with a  $\Delta\text{AICc}$  less than 2 to obtain model-averaged conditional beta estimates and p-values of the effect of predictor variables.

## Results

### Habitat selection

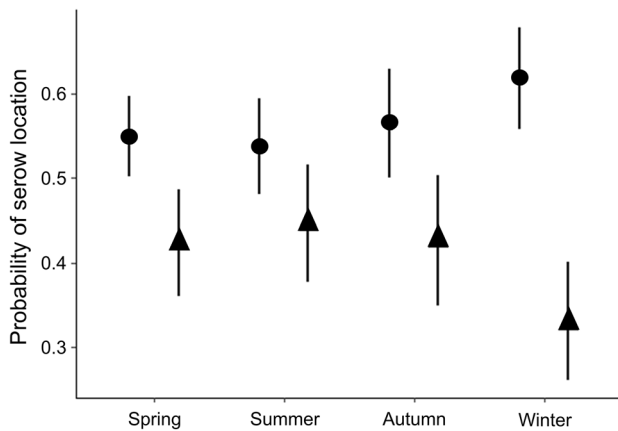
Between Jun 2013 and May 2014, we obtained a total of 1176 telemetry locations (Table S4). Serows used habitats in a non-random manner. The ranking of models predicting serow locations showed that the best models ( $\Delta\text{AICc} < 2$ ) included vegetation type, slope, interaction between season and vegetation type, and interaction between time period and slope (Table S3). Serows significantly avoided shrub-poor habitats and gentle slopes and significantly selected shrub-rich habitats and steep slopes (Table 1, Figs. 3, 4).

**Table 1** Model-averaged (any pair of models with a difference in  $\Delta\text{AICc}$  less than 2) conditional beta estimates for the probability of Japanese serow (*Capricornis crispus*) locations at Mt. Asama, central Japan. ‘Shrub rich’, ‘Spring’, and ‘Day’ are not shown, because they serve as reference levels for vegetation type, season, and time period, respectively. The table reports beta coefficients ( $\beta$ ), and standard errors (SE)

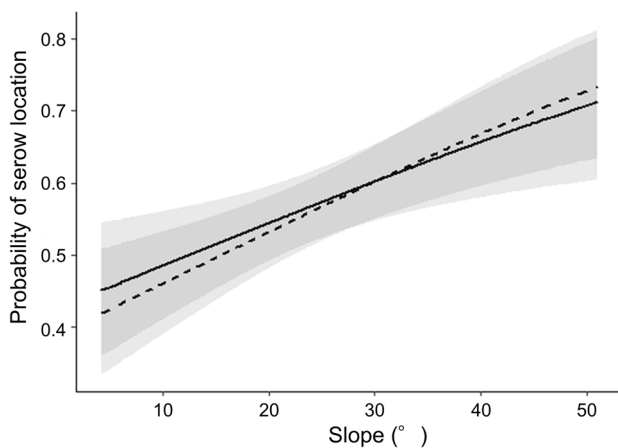
Predictor variables	$\beta$	SE	z-value	p-value	Significance
Shrub poor	−0.63	0.14	4.45	$8.5 \times 10^{-6}$	***
Slope	0.02	0.00	5.35	$1.0 \times 10^{-7}$	***
Shrub rich × summer	−0.05	0.14	0.34	0.73	
Shrub poor × summer	0.10	0.17	0.57	0.57	
Shrub rich × autumn	0.02	0.15	0.13	0.90	
Shrub poor × autumn	0.08	0.18	0.43	0.67	
Shrub rich × winter	0.29	0.14	2.02	0.04	*
Shrub poor × winter	−0.40	0.19	2.13	0.03	*
Slope × night	−0.002	0.00	0.48	0.63	

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$





**Fig. 3** Seasonal relative probability predicted by generalized linear mixed models (GLMM) (with 95% confidence intervals) of locations of Japanese serows (*Capricornis crispus*) within their home ranges in relation to vegetation type at Mt. Asama, central Japan. Circles and triangles indicate shrub-rich habitats and shrub-poor habitats, respectively



**Fig. 4** Relative probability predicted by generalized linear mixed models (GLMM) (with 95% confidence intervals) of locations of Japanese serows (*Capricornis crispus*) within their home ranges in relation to slope for each time period at Mt. Asama, central Japan. The solid line and the dashed line indicate daytime (sunrise to sunset) and nighttime (sunset to sunrise), respectively

Interaction between season and vegetation type suggests that serows significantly avoided shrub-poor habitats and significantly selected shrub-rich habitats in winter compared with other seasons (Table 1, Fig. 3). Interaction between time period and slope suggests that serows tend to select steep slopes more during the day than at night (Fig. 4), but the difference was not significant (Table 1). The magnitude of random effects (individual identity) in the best model was very weak (variance = 0.006, standard deviation = 0.077), which suggests that there was little individual variation in habitat selection.

## Discussion

In this study, we preliminary present the first data on habitat selection of the Japanese serow in their typical habitat. Serows selected shrub-rich habitat and steep slopes throughout the year. Serows at our site fed mainly on deciduous broad-leaved trees throughout the year (warm season: leaves; winter: twigs and buds: Takada 2018), and the foraging efficiency (bite/min) was higher in shrub-rich habitats than in shrub-poor habitats (Takada 2018). In addition, serows used shrub thickets and steep slopes for concealment and as escape terrain, respectively, against potential danger (Takada et al. 2018, 2019). Therefore, serows may have selected these habitats providing both abundant food and shelter. The snow depth of our site was relatively low (30–50 cm) and the distribution of main food hardly changed seasonally. Therefore, the habitat type selected by serows seemed to hardly change seasonally. Conversely, the avoidance of shrub-poor habitats was more pronounced in winter. Although shrub-poor habitats supply forbs in the warm seasons, snow cover severely reduces their supply in winter (Takada 2018), and this may be why serows tended to avoid shrub-poor habitats more in winter than in other seasons.

In the present study, although there were no substantial predators for serows, serows selected safer habitats (i.e., steep slopes). This habitat selection seems to support the idea of ‘ghosts of predators past’, that is, prey’s behaviors have coevolved with their predators over tens of thousands of years, and an absence of the predators for a few centuries is not sufficient to remove them (Byers 1997). In fact, it has been suggested that the habitat use of serows at a landscape scale prioritizes security over food access (Takada 2020).

Many of the studies on habitat selection of ungulates have shown trade-offs between access to foraging sites and exposure to predation risk (Houston et al. 1993). For example, for mountain ungulates, cliff-adjacent habitats provide security, whereas the most productive habitats typically occur on gentle slopes that are more easily accessible to a predator (Grignolio et al. 2007; Hamel and Côté 2007). In contrast, our results suggest that serows have few such trade-offs to make: shrub-rich habitats with steep slopes seemed to be adequate habitat, providing both good foraging conditions and shelter. The habitat selection of serows showed little variation with time of day. This also differs from some ungulates; ungulates prefer the most productive habitats at night when they actively forage and are less visible to predators or humans, whereas they prefer habitats with shelter during daytime when they are resting (Godvik et al. 2009; Bjørneraas et al. 2011). As described above, in this study there appeared to have been an adequate habitat

for serows. Therefore, it seemed to be suitable for both feeding and resting (i.e., all times of day), with the result that time of day may have little effect on habitat selection. In fact, both feeding and resting were frequently observed in shrub-rich habitats with steep slopes, while in shrub-poor habitats with gentle slopes, only movement was frequently observed (HT unpublished data).

**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.1007/s10164-021-00727-w>.

**Acknowledgements** Fieldwork was facilitated by the NPO “Earthworm”; Yuko Fukue, Naoko Higuchi, and other staff members assisted us in the field. Tsuyoshi Takeshita and the staff of the Asama-Sanso Inn also helped with fieldwork. Hiroshi Ebihara, Miki Toda, Keita Nakamura, and Nagisa Hara from Azabu University also helped with this work. We thank Clio Reid, PhD, from Edanz Group for editing a draft of this manuscript.

**Authors' contributions** HT contributed to the study conception, design, data collection, and statistical analysis. Capture of serows was conducted by MM and HT. The first draft of the manuscript was written by HT, and MM read and approved the final manuscript.

**Funding** This study was funded by a research project grant awarded to the authors by the Cooperative Research Program of the Wildlife Research Center of Kyoto University.

**Availability of data and material** All data analyzed during this study are included in this published article (and its supplementary information files).

**Code availability** The code used in the current study is available from the corresponding author on reasonable request.

## Declarations

**Conflict of interest** All authors declares that he has no conflict of interest.

**Ethical approval** All investigations were performed in accordance with the Ethics Committee for Animal Experiments, Mount Fuji Research Institute, Yamanashi Prefecture Government (ECAE-01-2013-2019). The study complies with current Japanese laws and adheres to the Mammal Society of Japan guidelines regarding animal welfare.

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