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Ecological factors influencing the selection of sett location by the Asian badger *Meles leucurus*

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We studied the sett characteristics and habitat variables of the Asian badger *Meles leucurus* in a temperate forest in South Korea. Logistic regression models were utilized to explain the effects of habitat variables on the location of badger setts. The presence of rocks and trees nearby and of dense ground vegetation and sub-overstory vegetation were correlated positively with sett location. Abundance of setts was higher in deciduous forest compared with coniferous forest, mixed forest and non-forest. The animals showed a preference for a steeper slope of sett location, which likely allows for easier removal of soil during sett settling, as well as improved drainage in that area. In low and high altitudinal areas disturbed by humans, a lower abundance of setts was found. Thus, selection of sett location was strongly influenced by structures around the setts, vegetation cover, forest type, slope and altitude. These variables should be considered and handled carefully though forest management for the conservation of the mammals and their habitats.

Keywords: conservation, forest management, habitat variables, sett characteristics, temperate forest

The distribution of animals is an essential element of wildlife ecology (Macdonald and Rushton 2003) that depends on various ecological factors (Guisan and Zimmermann 2000). Knowling the distribution of wildlife permits an understanding of habitat impact on the species and their ecology (Feore and Montgomery 1999). Identification and interpretation of important factors affecting distribution are critical for conservation of species and their habitat (Krebs 2002).

Burrowing behavior is widespread among mammals. Protection from predators and buffering against environmental extremes are major advantages of burrows (Roper et al. 2001, Kaneko et al. 2010). Badgers are one representative species of burrowing mammals, and well-known as ecosystem engineers because of their impact on plant and soil composition. They can input organic materials such as feces, prey and carcasses to the soil (Neal 1986). Badgers are capable of exploiting a variety of habitats (Feore and Montgomery 1999) and may maximize their fitness by selecting a particular habitat type. This choice can be affected by ecological factors, such as food and cover resources, physiological constraints and predation pressure (Prigioni and Deflorian 2005).

A badger's den is called a sett, and usually is comprised of a network of tunnels and numerous entrances created by badgers digging in soil or rocks. The Asian badger *Meles leucurus* is well-adapted for digging and well-known for its digging ability (Choi and Choi 2007). Patterns of sett use are of pivotal importance for this species (Hipólito et al. 2018). Thus, the spatial ecology of the Asian badger can be determined by sett location (Byrne et al. 2014). Sett site selection may reflect favorable conditions inside the sett or it may reflect a preference for conditions outside the sett (Tammeleht and Kuuspu 2017).

Setts represent a limiting resource for these mammals (Fischer and Dunand 2016). Setts are used for daily shelter, winter sleep and reproduction throughout the year (Kowalczyk et al. 2000). Moreover, setts are seen as an essential resource for survival and for maintenance of social behavior of badgers (Roper 1992, Revilla et al. 2001).

The aim of this study is to explore Asian badger sett site selection and the effects of environmental conditions on sett location. We studied the sett characteristics and habitat variables in a temperate forest in South Korea. In addition, we analyzed the factors that determine sett location in relation to coverage of vegetation, distance from the nearest structure, altitude and forest type.

Table 1. Description of habitat variables examined in the study of sett location by the Asian badger *Meles leucurus*.

Variable	Description
Coverage of foliage layer	
v0	Coverage of ground vegetation (0–1 m)
v1	Coverage of understory vegetation (1–2 m)
v2	Coverage of mid-story vegetation (2–8 m)
v8	Coverage of sub-overstory vegetation (8–20 m)
v20	Coverage of overstory vegetation (20–30 m)
Coverage of plant type	
CT	Coverage of trees
CS	Coverage of shrubs
Distance from the nearest structure	
DT	Distance from the nearest tree < 2 m: 0, > 2 m: 1
DS	Distance from the nearest shrub < 2 m: 0, > 2 m: 1
DR	Distance from the nearest rock* < 2 m: 0, >2 m: 1

*Rock volume > 2 m^3.

Material and methods

Study area

Our study area was located in Mt. Gariwang (37°27′–37°29′N, 128°32′–128°34′E), Pyeongchang, South Korea. The study area (5700 ha) lies between 423 m and 1546 m a.s.l. The annual precipitation was 1305 mm and the annual mean temperature was 11°C (range −17.8 to 36.0°C). The landscape is mainly natural deciduous forest, but some areas are plantation forests, in which large areas are planted with conifers. The deciduous forest is dominated by oak *Quercus* spp. and the coniferous forest is dominated by Korean red pine *Pinus densiflora* and Japanese larch *Lalix kaempferi*. The forest type map (scale 1:5000) for GIS analysis was obtained from the Korea Forest Service.

Data collection

The sett survey was conducted from September to October 2019 and April to September 2020 (survey work was not conducted from November 2019 to March 2020, a snow-covered period). We confirmed field signs of badger footprints, hair and scats to identify locations of badger activity. We recorded sett points (i.e. coordinates) using GPS (GPSMAP62s and GPSMAP64s, Garmin Ltd.) and morphological characteristics of each sett. All detected setts were classified according to the categories of Thornton (1988) and Chris (1995) as follows: main, annex, subsidiary and outlier. Sett classification is related to information such as number of entrances, conspicuous soil heaps and paths.

In September 2020, habitat variables were surveyed at all detected sett points. We randomly selected points as a control group for comparing the variables. Each sett and random point was at the center of a buffer with a radius of 5.64 m. Habitat variables were analyzed from microhabitats. A description of habitat variables is found in Table 1.

We measured coverage of foliage layer and coverage of plant type (Table 1). The foliage layer was classified as ground vegetation (0–1 m); understory vegetation (1–2 m); mid-story vegetation (2–8 m); sub-overstory vegetation (8–20 m); and overstory vegetation (20–30 m). The plant types were categorized as shrubs and trees. These coverage variables were measured in the 5.64-m radius area on point with four categories as fallows: 0 (percentage coverage = 0%), 1 (1–33%), 2 (34–66%) and 3 (67–100%).

The distance from the nearest structure (a rock or tree) for a given sett site is considered an important habitat variable, in accordance with Prigioni and Deflorian (2005), and is related to structural stability of each sett. We determined whether a structure existed within 2 m from the sett point. For rocks, the minimum volume to affect structural ability was 2 m^3 based on previous study.

We also examined the impact of forest type on sett site selection. The preferences of badgers in forest type were analyzed in an area within a 100-m radius from sett point. Forest practices and types were analyzed because the GIS data from forest type maps were separated into different layers. Forest type was classified as coniferous, deciduous, mixed and non-forests. The non-forest areas included human disturbances such as road, houses, arable lands and meadow.

Geomorphological units were determined by altitude above sea level, slope gradient and aspect. To confirm effects of the slope gradient on sett site selection, we compared the point-slope with mean slope of the buffer region (radius 100-m) for both sett and random points.

Statistical analysis

To determine the habitat variables affecting sett site selection, we used a logistic regression model. We used the Akaike information criterion (AIC) to select a model from a set of

Table 2. Predictive models of habitat variables affecting sett selection by the Asian badger *Meles leucurus*.

Model	Factor	AIC_c	ΔAIC_c	Weight	ROC-AUC
1	DR + DT + v0 + v8	81.20	0.00	0.41	0.84
2	DR + DT + v0 + v8 +v20	82.00	0.83	0.27	0.85
3	DR + DT + v0 + v2 + v8	82.90	1.73	0.17	0.85
4	DR + DT + v0 + v8 + CT	83.20	1.98	0.15	0.84

DR = distance from the nearest rock < 2 m: 0, > 2 m: 1, DT = distance from the nearest tree < 2 m: 0, > 2 m: 1, v0 = coverage of ground vegetation (0–1 m), v2 = coverage of mid-story vegetation (2–8 m), v8 = coverage of sub-overstory vegetation (8–20 m), v20 = coverage of overstory vegetation (20–30 m), CT = coverage of trees, AIC_c = Akaike information criterion, ΔAIC_c = changes in corrected Akaike information criterion, ROC-AUC = receiver operating characteristics-area under curve.

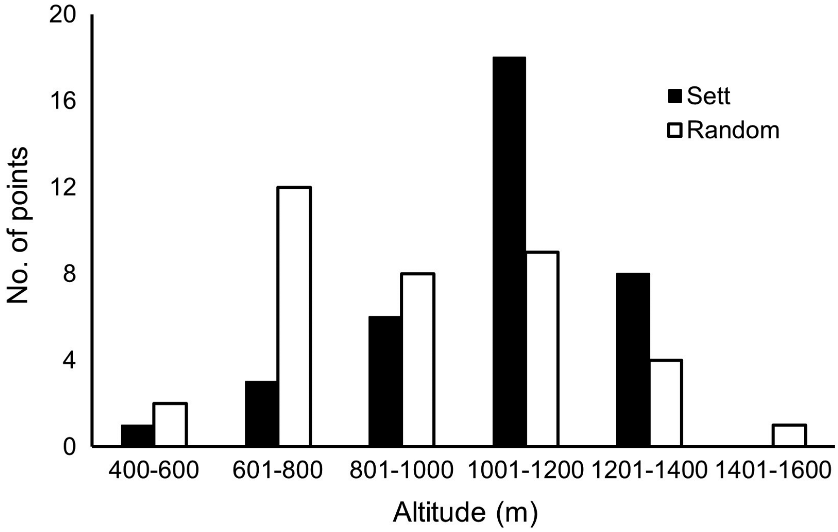

Figure 1. Number of points in relation to altitude among setts of the Asian badger *Meles leucurus* and within random areas.

models. We calculated the Akaike weights of each model and compared them to predictive models with similar AIC_c values ($\Delta AIC_c < 2$). In addition, we evaluated the accuracy of models by calculating receiver operating characteristic-area under curve (ROC-AUC) statistics. We analyzed total Akaike weight of the factors in each model instead of evaluating each predictive model.

Before the statistical analysis, altitudinal variables were tested for normality. The occurrence of setts regarding relation to altitude was examined by the Mann–Whitney U test. This test was performed to find significant differences among mean altitude between sett and random points. We used paired t-tests to calculate the mean gradient of buffer areas and the slope gradient of points from sett and random areas, respectively.

Habitat selection was studied by using Jacob's index. The formula of Jacob's index is explained as follows: $D = (r - p)/(r + p - 2rp)$ where r is the proportion of habitat used and p the proportion of habitat available. The habitat was divided into forest type to analyze the habitat characteristics preferred by badgers. The result of Jacob's index showed the range from −1 (strong avoidance) to +1 (strong preference). All statistical analyses were carried out with R (ver. 4.0) and the IBM SPSS (ver. 27) Statistics.

Results

In our study, 36 setts were found. However, we could not classify them into four categories, such as main, annex, subsidiary and outlier, because the setts were not clearly different in shape and size. The sett structure of Asian badgers may be different from that in European species.

Selected logistic regression models that explain the effects of habitat variables on the location of badger setts are shown in Table 2. Four models included six habitat variables: distance from the nearest rock (DR), distance from the nearest tree (DT), coverage of ground vegetation (v0), coverage of mid-story vegetation (v2), coverage of sub-overstory vegetation (v8), coverage of overstory vegetation (v20) and coverage of trees (CT). Four factors (DR, DT, v0, v8) were present in all models, and all had a weight = 1.

The presence of dense ground vegetation and sub-overstory vegetation and close proximity to structures were positively correlated with sett site selection. The model from logistic regression is regarded as good because the AUC value reached higher than 0.84. AUC ranges in value from 0 to 1. A model whose predictions are 100% wrong has an AUC of 0.0: a model whose predictions are 100% correct has an AUC of 1.0. Thus, our model displayed good predictive performance.

We found a significant difference in altitude between the sett and random points in this study (Mann–Whitney U test, $Z = 12.95$, $p < 0.02$). The mean altitude of sett points (1092 m) was higher than that of random points (939 m). Most setts were located at higher altitude rather than lower altitude (Fig. 1).

We did not find a difference in mean slope between the random points and their buffer areas (paired t-test, $t = 0.04$, $p = 0.96$). However, we did not find a significant difference in mean slope between sett points and their buffer areas ($t = 7.07$, $p < 0.01$) (Table 3).

The Jacob's index for forest type was positive for only the deciduous forest. The Jacob's index for other forest types (coniferous, mixed and non-forests) were negative (Fig. 2).

Table 3. Differences in mean slopes between center point and buffer area in the setts of the Asian badger *Meles leucurus* and random areas using a paired t-test.

Variable	Mean	SD	t	p
Random				
Point	21.00	8.53	0.04	0.96
Buffer area	20.94	5.54		
Sett				
Point	33.03	8.75	7.07	0.00
Buffer area	21.50	4.77		

SD = standard deviation.

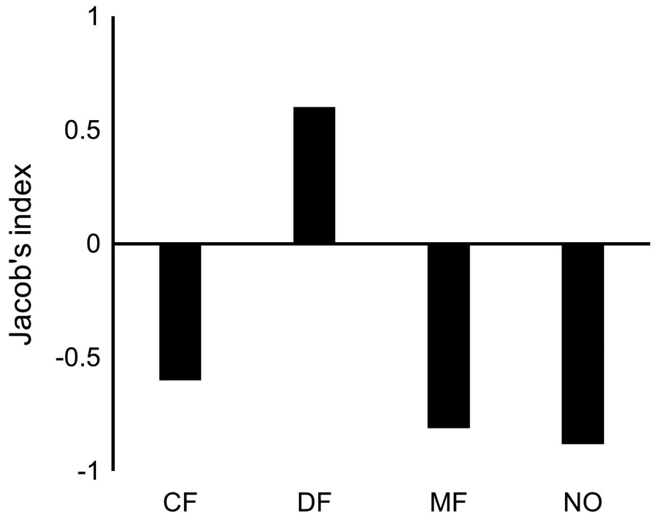

Figure 2. Differences in Jacob's index for forest type in relation to selection of sett by the Asian badger *Meles leucurus*. CF = coniferous forest, DF = deciduous forest, MF = mixed forest, NO = non-forest.

Discussion

Selection of sett location by Asian badgers depends on several factors including terrain, geomorphological land form, soil fertility, vegetation coverage and human disturbances (Obidziński et al. 2013). Although badgers can adapt to various habitats, and can live in arid, mountainous and farm habitats (Virgós and Casanovas 1999), pine forests are not good for badgers because of poor cover and low supply of food resources (Neal 1986).

We conducted logistic regression using setts found in our study area. Distance from the nearest rock and trees, ground cover, mid-story and sub-overstory vegetation, and coverage of trees influenced location of setts. Rocks can serve as shelters in case of disturbance and can be used as thermal cover. Trees, especially in the deciduous forest, offer protection. Dense ground vegetation is favorable for sett construction (Virgós and Casanovas 1999, Biancardi et al. 2014). Moreover, bedding was abundant in the deciduous forest. The bedding can provide good insulation from loss of heat in colder weather (Prigioni and Deflorian 2005).

Sett site location by badgers can be determined by characteristics of land cover because vegetation types can influence their habitat use pattern (Hipólito et al. 2018). Tree number of setts was higher in the deciduous forest compared with the coniferous forest, mixed forest and non-forest. Earthworms and fruits are important food items for badgers (Zabala et al. 2002, Bartmańska and Nadolska 2003). In this study, we observed greater abundances of food resources, such as earthworms and fruits, in the deciduous forest. Coniferous forest and non-forest lacked shrubs on the ground, making those areas inadequate for the setts of badgers (Bae 2021).

Geological conditions are one of the most important factors influencing the sett settling. Ground diggability and slope are critical for the sett (Rosalino et al. 2005, Romenti et al. 2006, Obidziński et al. 2013). In our study, the animals showed a preference for steeper slope in sett locations. Steep slopes allow for easy removal of soil during sett settling. In addition, better drainage is possible in areas with steep inclines (Macdonald et al. 2004).

Badgers stay away from areas close to human activities (Kurek 2011, Tammeleht and Kuuspu 2017) and anthropogenic disturbances (Jenkinson and Wheater 1998). In our study, the negative effects of human habitation and disturbance on sett location was associated with avoidance in low altitudinal areas. The negative effects of trail density and human usage was associated with avoidance in high altitudinal areas. As a result of human disturbance in low and high altitudinal areas, abundance of setts was lower in those areas.

Conclusion

The selection of sett location by Asian badgers was strongly influenced by vegetation cover, structures around the setts, altitude, slope and forest type. These variables should be considered and handled carefully though forest management for the conservation of this species and its habitat.

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Author contributions

All authors contributed to the conceptual design, field work, analysis and writing of the manuscript.

Data availability statement

Data are available from the Figshare Digital Repository <https://figshare.com/s/e7eef208f315b7e6647f> (Bae et al. 2021).

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