



Habitat use and preferences of the least weasel (*Mustela nivalis*) in South Korea

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Background: The least weasel (*Mustela nivalis*) holds the distinction of being the world's smallest carnivorous animal, yet its presence in South Korea has remained poorly understood. To address this knowledge gap, this study investigates the habitat preferences and distribution of the least weasel in South Korea.

Results: Our study compiled presence data from various sources, including citizen reports, national surveys, and expert observations. The results confirmed the nationwide presence of the least weasel in mainland South Korea, with notable concentration regions such as Gangwon province. Among the various habitats, forest edges and forests emerged as the predominant choice, with over half of the documented locations situated within these environments, particularly in broadleaf forests. Additionally, the data reveal a year-round presence of the least weasel, with recorded cases occurring at varying levels throughout the year.

Conclusions: Our research advances the understanding of least weasels in South Korea. Despite the relatively modest dataset, our results provide as a valuable resource for future conservation initiatives, emphasizing the significance of forested landscapes. Additionally, it assists in identifying priority areas for protection and management efforts. To secure the future of the least weasel in South Korea and beyond, further research, including long-term monitoring and genetic studies, is imperative.

Keywords: endangered species, habitat preference, least weasel, South Korea

Introduction

The least weasel (*Mustela nivalis*) is the world's smallest carnivorous animal belonging to the Mustelidae family of Carnivora. This diminutive creature boasts a wide distribution, ranging across regions in Russia, Europe, China, Japan, and other parts of the northern hemisphere (Abramov and Baryshnikov 1999; Lin et al. 2010; Wozencraft 2005). Notably, the species exhibits significant geographic variation, leading to its classification into 18 or 19 subspecies (Abramov and Baryshnikov 1999; Wozencraft 2005). The presence of the least weasel was first recorded in the Korean Peninsula in 1927, specifically in the Musan region of Hamgyong province, North Korea. It was subsequently classified as the subspecies *M. nivalis musanensis* Mori 1927, earning the name 'Musan least weasel' in Korea.

Although the least weasel can consume bird eggs, lizards, fish, moles, and carrion based on food availability (Moors 1975), their primary prey are rodents with similar body size to the least weasels, which restrict the diet and

potentially risk their local extinctions (Aunapuu and Oksanen 2003; Korpimäki et al. 1991). Least weasels feed approximately 5 to 10 times a day but store excess food due to prey sizes typically exceeding their daily intake requirements, especially during the winter (Jędrzejewska and Jędrzejewski 1989; Oksanen et al. 1985). With high metabolic demands, their lifespan in the wild is short, usually less than a year (Gillingham 1984; King 1980; Ylönen et al. 2019). However, it's worth noting that individuals in captivity have been known to live up to a maximum of 10 years (Sheffield and King 1994). The least weasel is known to be solitary except during the breeding seasons and reproduce twice during the summer (Fitzgerald 1981; Jędrzejewska 1987).

Previous studies show least weasels prefer forest edges (Brandt and Lambin 2007; Macdonald et al. 2004; Magrini et al. 2009). Interestingly, the Least weasel's distribution appears quite versatile, as it was found in nearly equal proportions across various sub-areas, demonstrating a habitat generalist behavior (Aunapuu and Oksanen 2003; Červin-



ka et al. 2014). Notably, the least weasel changes the habitat preference in response to the cyclic fluctuations of prey populations, often avoiding the most productive habitats (Aunapuu and Oksanen 2003; Feige et al. 2012; Hellstedt et al. 2006). Some suggest that the weasel is particularly drawn to structurally complex environments, such as willow scrublands and forests with a dense understory of tall forbs, which are known to host abundant vole populations while reducing the risk from avian predation (Haapakoski et al. 2013; Korpimäki and Norrdahl 1989; Ylönen et al. 2019). Despite its adaptability, the least weasel tracks were not found on the surfaces of lakes or streams due to the risk of intraguild and avian predation (Aunapuu and Oksanen 2003; Korpimäki and Norrdahl 1989).

Given that the population had substantially decreased due to natural or artificial threats in South Korea, the least weasel was designated Class II endangered wildlife in 2005 (Wildlife Protection and Management Act 2022). Further, recognizing difficulties associated with detecting these animals in the wild and the limited research available, the species conservation status was elevated to Class I endangered wildlife in 2022 (Wildlife Protection and Management Act 2022). This heightened status underscores the urgency of species protection and recovery efforts. Despite the significant role the least weasel plays in regulating small mammal populations such as voles, shrews, and lemmings, it has rarely been the subject of ecological research, probably owing to its elusive behavior and the limited understanding of its economic values (Proulx 2012). Additionally, their short lifespan presents challenges for conducting long-term studies and tracking individual animals. In South Korea, the least weasel has rarely been studied, and no concrete ecological information is available for its habitat, population, prey, and threats.

Understanding the habitat requirements and preferences of this endangered species is essential for its conservation and effective management. Habitat analysis aids in estimating the population size and distribution. Therefore, this study aims to understand the habitat preference of least weasels in South Korea based on information from presence observation across South Korea thus to confirm whether the subspecies prefers forest edges like other subspecies worldwide.

Materials and Methods

Study area

This study was conducted on the mainland of South Korea, encompassing a land area of 100,210 square km, situated between latitudes 33° to 43°N and longitudes 124° to 131°E. The geographical features of South Korea vary significantly across its regions. The northern and eastern areas are predominantly characterized by mountainous ter-

rain, while the southern and western parts consist of lowlands and flat plains (National Geography Information Institute 2020). South Korea's climate can be categorized into three main types: warm-temperate, temperate, and cold-temperate. The temperate climate prevails in the northern and central regions, whereas the southern coastal areas and islands experience a warm-temperate climate. The high mountainous regions exhibit a cold-temperate climate. Summer temperatures typically range from 20°C to 26°C, while winter temperatures vary between -5°C and 5°C. The northern region tends to be relatively cold and arid, in contrast to the warm and humid conditions prevalent in the southern region. South Korea experiences its heaviest levels of rainfall during the summer months, with winter being the driest season. Annual precipitation levels range from 1,200 mm to 1,700 mm (Korea Meteorological Administration 2022).

Data collection

To gather data regarding the presence of Least Weasels in mainland South Korea, we pursued a comprehensive data collection approach spanning three distinct sources. At first, prominent web search engines, specifically Google (www.google.com), Naver (www.naver.com), and Daum (www.daum.net), were instrumental in our inquiry. This preliminary step entailed the utilization of keywords encompassing both the Korean common nomenclature and the scientific nomenclature assigned to the least weasel. Given the potentially limited familiarity of the general public with the term "least weasel," we judiciously incorporated related search terms such as "Siberian weasel," "Siberian weasel pup," and "otter pup." Subsequent to the search process, our examination extended to the scrutiny of photographs and videos uploaded by citizens. Instances wherein the content was confirmed to depict least weasels prompted direct communication with the individuals responsible for the data, thereby facilitating the procurement of precise chronological and geographical coordinates. Secondly, we searched for pertinent information within the confines of authorized national reports such as the 2nd, 3rd, and 4th National Ecosystem Surveys (1997–2018) conducted by the National Institute of Ecology (NIE), the Baekdu-daegan surveys (2012–2017) by the NIE, and the Endangered Species Distribution Surveys (2012–2020) by the National Institute of Biological Resources. Lastly, we solicited presence information of least weasels from mammal research group, including wildlife rescue centers, actively engaged in South Korea. It is noteworthy that our adherence to a stringent criterion throughout these successive phases dictated the exclusive inclusion of data sets fortified by explicit location information and substantiated through photographic or videographic corroboration. This meticulous selection process was stringently enforced to safeguard the precision and integrity of the data subsequently subjected to analyti-

cal scrutiny.

Data analysis

Environmental attributes for habitat analysis were procured from various sources. Land cover data was extracted from the 9th edition of the land cover map, provided by the Ministry of Environment. Furthermore, we obtained pertinent environmental characteristics, including slope and aspect, from a 90-m Digital Elevation Model (DEM) generated by the National Geographic Information Institute. Additionally, we conducted calculations to determine the distances from distinct land cover categories for the analysis. For the delineation of the forest edge and inner space, we adopted a criterion of 400 m from the forest edge (Pfeifer et al. 2017). The classification of terrestrial ecoregions adhered to the scheme established by Olson et al. in 2001. We used ArcGIS Pro version 3.0 (ESRI Inc., Redlands, CA, USA) for the analysis.

The Neu method was used to test for habitat selection (Neu et al. 1974). The hypothesis to assess was that least weasels consistently use certain land cover types either more or less frequently than would be expected had the least weasels been living randomly among habitats. The Neu method is a straightforward application of the χ^2 goodness-of-fit test, commonly used to compare observed counts of animals in each habitat with the counts expected if habitats were used in proportion to their availability (Allredge and Ratti 1986; Allredge and Ratti 1992). We estimated the expected counts for each land cover type by multiplying the proportion of simulated values within each habitat by the total number of observed locations for each least weasel. Expected habitat use was calculated as the total of all expected counts within the mainland of South Korea, while observed land cover use was calculated as the total of all observed locations for all least weasels. We computed expected and observed habitat separately for each habitat variable and for observed location of least weasels. The hypothesis that observed habitat use was equal to the expected habitat use, indicating no habitat selection, was tested for habitat variable using a χ^2 goodness-of-fit test ($df = \text{number of habitats} - 1$). When the χ^2 test indicated that observed and expected habitat use were significantly different ($\alpha = 0.05$), a Bonferroni Z statistic (Miller 1981) was used to determine which habitats were used more or less frequently than expected.

Results

Among 55 occurrence records of the least weasel (*M. nivalis*) in South Korea from citizen reports, national surveys, and expert observations, 33 cases were verified with photographs or videos with geographic coordinates. The least weasel showed a nationwide distribution throughout

the mainland of South Korea (Fig. 1). Within the administrative landscape, confirmation of the species' presence extends to 8 out of the 17 local governments. Notably, Gangwon province emerged as the epicenter of recorded cases, constituting 42.4% of the total, followed by Chungnam province with 15.2%, and Gyeongbuk province with 12.1%. Sources of the occurrence data were diverse. Detection from camera traps accounted for 11 cases, citizen reports comprising 8 cases, carcasses denoting 6 cases, reports from rescue centers amounting to 4 cases, live captures contributing 2 cases, and traces of feeding activity adding another 2 cases. In terms of seasonality, the least weasel showed a year-round presence, with documented occurrences spanning all four seasons. Among these, months of May, June, and November claimed prominences, each boasting 5 recorded cases. This was followed by August and October with 3 cases each (Table 1).

In our analysis of least weasel habitat preferences based on land cover types, forests emerged as the predominant choice, representing 57.6% ($n = 19$) of the documented locations. Grasslands follow as the second most frequently chosen habitat at 18.2% ($n = 6$), with urban areas accounting for 5% ($n = 5$) of the observed locations. According to Neu's test for habitat preferences vis-à-vis habitat availabil-



Fig. 1 Geographic distribution of confirmed least weasel (*Mustela nivalis*) records in mainland South Korea.

Table 1 Details of least weasel (*Mustela nivalis*) records in South Korea

ID	Province	City	Year	Month	Sources
1	Gangwon	Pyeongchang	2009	6	Live capture
2	Gyeongbuk	Yeouju	2015	7	Camera trap
3	Gyeongbuk	Bonghwa	2015	-	Live capture
4	Gyeongbuk	Gimcheon	2017	1	Carcass
5	Gyeongnam	Changwon	2017	9	Citizen report (video)
6	Gangwon	Hoengseong	2018	4	Citizen report (picture)
7	Gyeongnam	Jinju	2018	10	Carcass (roadkill)
8	Gyeongbuk	Uljin	2019	6	Camera trap
9	Chungnam	Geumsan	2020	11	Citizen report (video)
10	Gangwon	Gangneung	2020	5	Camera trap
11	Chungnam	Geumsan	2021	2	Carcass
12	Chungnam	Dangjin	2021	5	Rescue
13	Kangwon	Jeongseon	2021	5	Citizen report (picture)
14	Daegu	Suseong	2021	6	Citizen report (video)
15	Gwangju	Buk	2021	6	Camera trap
16	Gyeonggi	Gapyeong	2021	6	Citizen report (video)
17	Gangwon	Taebaek	2021	8	Camera trap
18	Gangwon	Taebaek	2021	11	Camera trap
19	Gangwon	Taebaek	2021	11	Camera trap
20	Chungbuk	Danyang	2021	12	Carcass
21	Gangwon	Taebaek	2021	5	Camera trap
22	Gangwon	Chuncheon	2022	5	Camera trap
23	Chungbuk	Danyang	2022	8	Carcass
24	Gangwon	Chuncheon	2022	8	Camera trap
25	Gangwon	Chuncheon	2022	10	Camera trap
26	Gangwon	Hwacheon	2022	10	Citizen report (picture)
27	Gangwon	Pyeongchang	2022	11	Citizen report (picture)
28	Chungnam	Nonsan	2022	11	Trace of feeding activity
29	Chungnam	Cheongyang	2022	12	Trace of feeding activity
30	Jeonnam	Suncheon	-	-	Rescue
31	Jeonnam	Suncheon	-	-	Rescue
32	Gangwon	Pyeongchang	-	-	Carcass
33	Gangwon	Pyeongchang	-	-	Rescue

ity with respect to land cover type for location of least weasels, it showed marked disparity relative to their availability in the landscape (Pearson chi-square test: $\chi^2 = 23.67$, $p < 0.005$). The least weasel's preference for habitats was notably skewed towards forests, urban areas, and grasslands, while showing an aversion to agricultural and wetland settings (Table 2). Of the 19 recorded sightings in forests, the majority (52.6%, $n = 10$) were within broadleaf forests, followed by coniferous forests at 36.8% ($n = 7$), and mixed forests at 10.5% ($n = 2$). The average distance from forest to other land cover types measured 227.1 ± 306.2 m, with a notable 84.2% ($n = 16$) of these locations situated at the forest's edge, while 15.8% ($n = 3$) were inside the forest, approximately 400 m from the edge. Elevation ranged from 0 to 1,087 m above sea level, with a mean of 484.3 ± 395.6 m. The slope varied within a range of 0 to 23.15, with a mean slope of 10.3 ± 6.3 degrees. Regarding ecoregions, the analysis identified 78.8% ($n = 26$) of sightings within Central Korean deciduous forests, 15.2% ($n = 5$) in Manchurian mixed forests, and 6.1% ($n = 2$) in Southern Korean evergreen forests.

Discussion

The least weasel (*M. nivalis*) is a remarkable yet one of the most understudied endangered species in South Korea. Our study aimed to shed light on its habitat preferences and distribution in the region. Our findings confirmed a nation-wide presence of the least weasel across the South Korean mainland, with particular regions showing a higher concentration of sightings. Gangwon province emerged as a prominent hotspot for recorded cases, followed by Chungnam and Gyeongbuk provinces. This distribution information can serve as a valuable baseline, offering essential guidance for future conservation endeavors. It enables the identification of priority areas that requires protection and management attention, with Gangwon province standing out as a promising region for further research.

Regarding habitat preferences, forests emerged as the predominant choice, with more than half of the documented locations occurring in these habitats, although previous studies showed least weasels demonstrating a habitat gen-

Table 2 Habitat classification and preferences of least weasels (*Mustela nivalis*) in South Korea

Habitat classification	Observed count	Habitat proportion	Expected use	Selection ratio	Inference
Urban	5	0.048	1.61	9.401	Preferred
Agriculture	1	0.261	8.58	0.353	Avoided
Forest	19	0.401	13.27	4.340	Preferred
Grassland	6	0.106	3.51	5.185	Preferred
Wetland	0	0.105	3.45	0	Avoided
Bare land	2	0.035	1.17	5.183	Neutral
Water	0	0.043	1.41	0	Avoided

Preferred indicates selection for a habitat and avoided indicates selection against a habitat, using the Bonferroni Z statistic. Observed: chi-square 23.67. p -value < 0.005.

eralist and found in nearly equal proportions across various sub-areas (Aunapuu and Oksanen 2003; Červinka et al. 2014). The result underscores the importance of forested landscapes, especially broadleaf forests, in supporting least weasel populations. Additionally, a significant proportion of least weasel sightings occurred at the forest edge, highlighting the importance of forest edges as foraging and movement corridors for this species (Brandt and Lambin 2007; Macdonald et al. 2004; Magrini et al. 2009). Urban areas also featured in the least weasel's habitat selection, representing 5% of observed locations. This urban presence is intriguing and warrants further investigation. Understanding how least weasels navigate urban environments and interact with human activities can inform urban wildlife management strategies. The high preference for these specific habitats including forest, grassland and urban areas and avoidance of wetlands and agricultural areas could be related to the preference for structurally complex environments, which offer protection against potential predators such as avian predators, leopard cats (*Prionailurus bengalensis*), and feral cats (*Felis catus*) (Haapakoski et al. 2013; Korpimäki and Norrdahl 1989; Ylönen et al. 2019).

Our analysis of seasonality in least weasel sightings revealed that the species exhibited a year-round presence in South Korea, with different months displaying varying levels of recorded cases. May, June, and November had the highest recorded cases, followed by August and October. While these patterns could be related to the species' activity patterns or reproductive cycle, they may also be influenced by human monitoring efforts. Further research is needed to disentangle these factors and gain a more comprehensive understanding of least weasel behavior throughout the year.

Our study also suggests that camera traps could be a reliable method for monitoring least weasels in South Korea as they contributed to 33% of our records, even though they were not specifically targeted for monitoring least weasels. These devices offer a non-invasive and continuous means of data collection, particularly beneficial for an elusive species like the least weasel. Future research could explore the effectiveness of camera traps in capturing long-term data on least weasel populations and behavior.

Additionally, our study highlighted the potential efficiency of citizen scientists monitoring elusive least weasels and collecting a wide-range of data.

We recognize that our dataset is relatively small, which could limit the extent to which we can draw definitive conclusions about habitat preferences and distribution of the least weasel in South Korea. We acknowledge the potential for data bias stemming from diverse sources, which could have influenced the observed patterns. For instance, the concentration of camera trapping efforts in Gangwon province might have led to a skewed distribution in that specific region. Furthermore, citizens frequenting forest edges may be more likely to report least weasel sightings, potentially contributing to variations in distribution patterns inside and outside the forest. To gain a more accurate and comprehensive understanding of these aspects, it is essential to collect additional data. Expanding our dataset through further data collection efforts will enhance the robustness of our findings and allow for more precise insights into the least weasel's ecological requirements. Additionally, increasing the sample size will enable us to explore variations in habitat preferences and distribution across different regions and environmental conditions. In light of the limited data at our disposal, our study can be viewed as a valuable starting point that highlights the importance of studying this elusive species in South Korea.

In conclusion, our study represents a crucial step in unraveling the least weasel's ecology in South Korea. By elucidating their habitat preferences and distribution, we lay the groundwork for their conservation and ensure that this remarkable species continues to thrive in the region. Further research, including long-term monitoring, genetic studies, and investigations into prey interactions, is essential to secure the future of the least weasel in South Korea and beyond.

Conclusions

Our study addressed the significant knowledge gap surrounding the least weasel (*M. nivalis*) in South Korea. Our findings provided essential insights into its habitat prefer-

ences and distribution in the region. We have confirmed the presence of the least weasel throughout mainland South Korea, with hotspots in regions like Gangwon province. Also, the species occupied forest edges. Our analysis highlighted forests as the primary habitat choice, emphasizing the importance of forested landscapes, particularly broadleaf forests. This distribution and habitat preference can serve as a foundational resource for future conservation efforts, helping to identify priority areas for protection and management. Our research represents a significant step in unraveling the ecology of this remarkable species in South Korea, emphasizing the need for continued research to ensure its conservation and long-term survival.

Abbreviation

NIE: National Institute of Ecology

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Authors' contributions

AK conceived the ideas and conducted the data collection and analysis. DW analyzed and visualized data, and wrote the manuscript. JML conceived the ideas and wrote the manuscript. JK wrote the manuscript. AL conceived the ideas, reviewed the manuscript, and received research funding. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets generated and analyzed during the current study are available upon reasonable request from the corresponding author.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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