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RESEARCH

Exploring small mammal monitoring in South Korea: The debut of the Mostela

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Background: Traditional wildlife monitoring has often relied on invasive techniques posing risks to species and demanding substantial resources. To address this, camera traps emerged as non-invasive alternatives, albeit primarily tailored for larger mammals, posing limitations for small mammal research. Thus, the Mostela, an innovative tool designed to overcome these challenges, was introduced to monitor small mammals in South Korea.
Results: The Mostela was deployed at two study sites in South Korea, yielding compelling evidence of its efficiency in capturing small mammal species. By analyzing the collected data, we calculated the relative abundance of each species and elucidated their activity patterns.
Conclusions: In summary, the Mostela system demonstrates substantial potential for advancing small mammal monitoring, offering valuable insights into diversity, community dynamics, activity patterns, and habitat preferences. Its application extends to the detection of endangered and rare species, further contributing to wildlife conservation efforts in South Korea. Consequently, the Mostela system stands as a valuable addition to the toolkit of conservationists and researchers, fostering ethical and non-invasive research practices while advancing our understanding of small mammal populations and ecosystems.

Keywords: camera trap, Mostela, non-invasive, small mammal monitoring

Introduction

Monitoring is essential for wildlife conservation and management (Magurran 2021; Nichols and Williams 2006; Yoccoz et al. 2001). As wildlife is distributed across diverse habitats, requiring significant resources and manpower for monitoring, optimizing the efficiency of monitoring is crucial (Field et al. 2005; Palencia et al. 2022). Monitoring methods can be categorized into invasive and non-invasive approaches based on the tools used and the extent of disturbance to the target species. In the past, invasive methods like capture, anesthesia, and tagging were frequently required for wildlife monitoring (Gruber 2023; Soulsbury et al. 2020). These traditional techniques, being highly invasive, can induce stress in wildlife, disrupt natural behaviors, and potentially have negative impacts on individual behaviors and survival (Gruber 2023; Soulsbury et al. 2020; Wilson and McMahon 2006). To address these issues, recent developments have introduced non-invasive methods, with camera traps being a prominent example (Burton et al. 2015; Field et al. 2005; Oliver et al. 2023; Palencia et al. 2022). Camera traps have been widely used in wildlife research since the 1990s and are currently employed worldwide as standardized monitoring tools (Burton et al. 2015; Gompper et al. 2006; Oliver et al. 2023). They offer a non-invasive monitoring solution that has little or no adverse effects on target species, ranging from hunted or invasive species to rare and endangered ones, making them versatile tools for various research applications (Delisle et al. 2021). However, most camera trap monitoring efforts have focused on medium to large terrestrial mammals (MCCleery et al. 2014; Naing et al. 2019; Rasphone et al. 2021; Van der Weyde et al. 2018).

Small mammals constitute approximately 90% of the total mammal population and contribute significantly to species diversity (Lidicker 2011). They play essential roles in ecosystems, such as seed dispersal, nutrient cycling, and serving as prey for larger carnivores (Avenant and Cavallini 2007; Boone et al. 2022; MCCleery et al. 2014). Small mammals encompass a wide range of species, from apex predators like least weasels (*Mustela nivalis*) and Siberian weasels (*M. sibirica*) to rodents, soricomorphs, and mesopredators, and their small size often makes direct observation challenging. Consequently, traditional monitoring of small mammals has relied on invasive methods, including direct trapping using devices like Sherman traps (HB Sherman Traps, Tallahassee, FL) (Burger et al. 2009; O'Farrell et al. 1994). While invasive trapping offers the advantage of obtaining precise information about the target species, it comes with the drawback of causing stress to individuals and posing a high risk of capture myopathy, injuries, or death (Breed et al. 2019; Soulsbury et al. 2020). As a result, there is a growing need for less intrusive approaches that minimize stress on target animals and the labor-intensive tasks associated with trap installation and maintenance while maximizing capture efficiency.

In recent years, therefore, camera trapping methods have expanded the scope of monitoring to small mammals (Hobbs and Brehme 2017; Lidicker 2011; Moore et al. 2021). However, existing camera trap setups, designed primarily for monitoring large mammals, have faced challenges in reliably triggering and identifying small and relatively fast-moving mammals in captured images (Kolowski and Forrester 2017; Meek et al. 2014). To address these limitations, various customized monitoring devices tailored for small mammals have been developed, including Mostela, Hunt traps, selfie traps, camera trap tunnels, and AHDriFT (Croose et al. 2022; Gracanin et al. 2022; Littlewood et al. 2021; Martin et al. 2017; MCCleery et al. 2014; Mos and Hofmeester 2020). Among these devices, Mostela system is relatively simple and easy to construct and shows high detection of small mammals (Cepeda-Duque et al. 2023; Croose et al. 2022; Mos and Hofmeester 2020). Until now, however, there has been no research in South Korea utilizing the specialized camera trap to monitor small mammals. Given the need for the application of customized small mammal monitoring methods developed in previous studies, we tested the effectiveness of the Mostela system in monitoring terrestrial small mammals in South Korea.

Materials and Methods

Study site

To evaluate the Mostela system, we selected two distinct study sites within the National Institute of Ecology (NIE), noted for their diversity in small mammal species. These sites are recognized for their high suitability for monitoring small mammals and accessibility without additional permissions. Site 1 was situated on the hill edge composed of baby roses (*Rosa multiflora*) at the NIE headquarters in Seocheon, while Site 2 was located at the forest edge of the Research Center for Endangered Species within the NIE premises in Yeongyang (Fig. 1). The elevation of Site 1 was low (16 m), while the elevations of Site 2 ranged between 290 and 460 m (Table 1).

Field test

The Mostela system was devised for monitoring small mammals, including the least weasels and rodents (Croose et al. 2022; Mos and Hofmeester 2020). In accordance with the specifications outlined in the Mostela method (Mos and Hofmeester 2020), we built rectangular wooden boxes (350 × 610 mm, shuttering plywood) and accommodated both a standard camera trap (Browning BTC-8A for Site 1, Reconyx HP2X for Site 2) and a PVC pipe (ø 80 mm × 350 mm), as illustrated in Fig. 2. In a PVC pipe, a ruler was attached to measure body length of the small mammals entering the Mostela. Additionally, considering the habitat types and slopes at the monitoring sites, two types of Mostela units were fabricated: a basic type for flat terrain (Fig. 2A) and a standing type for sloped terrain with tree attachment (Fig. 2B). To eliminate bias in animal presence due to baiting, no lure bait was employed (Palencia et al. 2022; Yoccoz et al. 2001). We randomly deployed a single Mostela unit at Site 1, operating it continuously from October 27, 2020, to August 17, 2021. In contrast, Site 2 featured three Mostela units in operation, running from August 8, 2021, to January 12, 2022. All camera settings were configured with a 1-minute trigger interval to facilitate species identification. At Site 1, the camera captured three consecutive still images per a trigger, while at Site 2, a 30-second video recording was initiated per trigger following Mos and Hofmeester (2020).

Data analysis

Photographs and videos obtained from camera traps were achieved and manually segregated to species. We calculated relative abundance index (RAI) for each species in each study site as the number of independent photographs or videos per 100 camera trap-nights (Carbone et al. 2001). Consecutive photos or videos of the same taxon captured <30 minutes apart were considered as a single independent event (Chen et al. 2022; Nottingham et al. 2021).

As camera traps offer non-invasive method for observing and quantifying animal behavior on a population scale, with a reasonable cost-effectiveness (Rowcliffe et al. 2014), we computed activity pattern of small mammals using time stamp metadata obtained from Mostela using the 'activity' packages in R. The package employs a kernel density function that aligns with the species' photo-capture rate within a specific time interval. The integral of the curve derived from the kernel density function signifies the proportion of time during which the species exhibited activity. The frequency of camera trap images capturing the species over time serves as an indicator of the species' activity (Rowcliffe et al. 2014). In addition, a recent study emphasized the importance of selecting data sources for activity analyses. Their findings indicate that utilizing time-to-independence data filters in estimates of activity patterns based on camera traps is inappropriate (Peral et al. 2022).

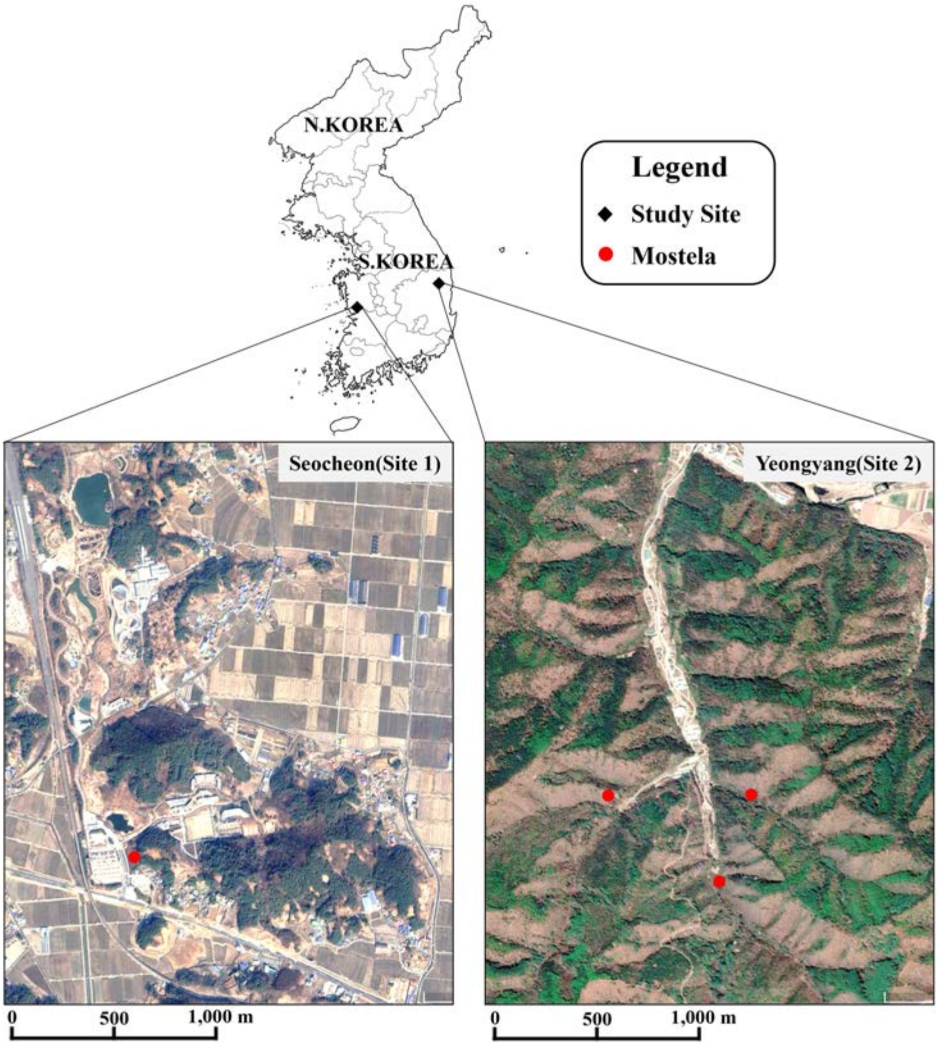

Fig. 1 Map depicting study site locations and deployment of Mostela units. Site 1 (left) is situated at the hill's edge in Seocheon, while Site 2 (right) is at the forest's edge in Yeongyang. At Site 1, a single Mostela unit was deployed, while at Site 2, three units were utilized for monitoring small mammals.

Table 1 Characteristics of the study sites

Study site	Latitude (N)	Longitude (E)	Habitat type	Elevation (m)	Mostela type
Site 1					
Seocheon	36 01 40.2	126 43 12.6	Lowland	16	Basic type
Site 2					
Yeongyang	36 38 03.7	129 09 16.5	Forest	290	Standing type
	36 37 48.5	129 09 12.2	Forest	332	Standing type
	36 37 51.1	129 08 43.9	Forest	460	Standing type

Therefore, we applied raw data of a species having over 30 events for the analysis. In addition, we estimated the overlap of activity patterns between species using the observed overlap index (Ridout and Linkie 2009).

Results

A total of four Mostela, deployed across two study sites, operated without any malfunctions in accordance with their configurations. Throughout the monitoring periods, which spanned a total of 738 trap-nights, 371 images and videos were generated. Specifically, Site 2 produced 336 photographs over 294 trap-nights, while Site 2 yielded 35 videos for 444 trap-nights (Table 2). In the monitoring process, we identified five small mammal species at both study sites. These included the Siberian weasel (*M. sibirica*), striped field mouse (*Apodemus agrarius*), species within the *Crocidura* genus (*Crocidura* spp.), Siberian chipmunk (*Eutamias sibiricus*), and brown rat (*Rattus norvegicus*) (Fig. 3). To ensure the accuracy of our study, we refrained from further species identification within the genus *Crocidura* due to inherent challenges in distinguishing species, especially when replying solely on body size. Additionally, apart from mammals, two small bird species, the Asian stubtail (*Urosphena squameiceps*) and Great tit (*Parus ma-*

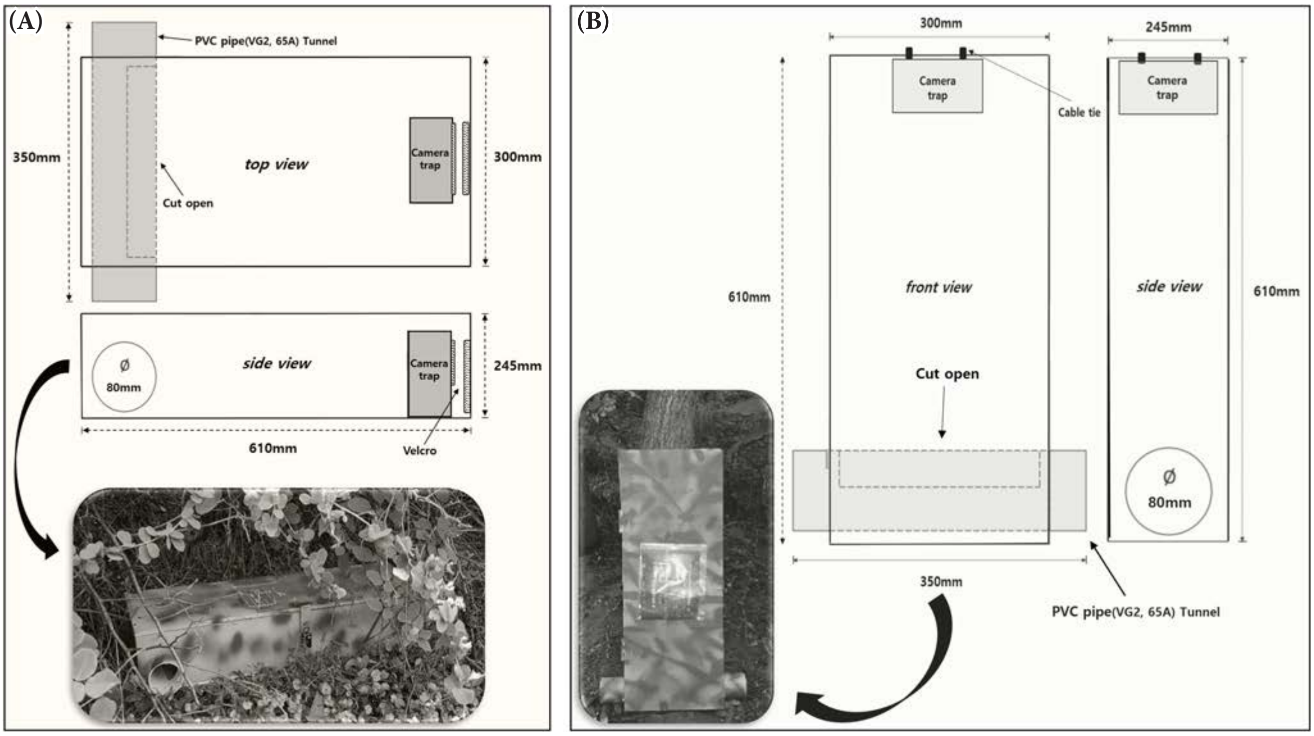

Fig. 2 Design specifications of the Mostela: (A) basic type, (B) standing type, with an example in the field.

Table 2 Photo-capture rates for species recorded on Mostela in Site 1 and 2 from October 2020–January 2022 (calculated only from 738 trap-nights)

Study Site	Species	Total photos	Independent photos	Trap-nights	RAI[a]
Site 1	*Apodemus agrarius*	235	19	294	2.57
	Crocidura spp.	97	10		1.36
Site 2	*Mustela sibirica*	1	1	444	0.14
	Eutamias sibiricus	17	17		2.30
	Apodemus agrarius	4	4		0.54
	Crocidura spp.	8	8		1.08
	Rattus norvegicus	2	2		0.27
	Urosphena squameiceps	1	1		0.14
Total		365	62	738	8.40

[a]Relative abundance index: number of independent photos per 100 trap-nights.

jor), were also detected. In Site 1, the striped field mouse had the highest RAI of 2.57 among the two small mammals captured. Conversely, in Site 2, the Siberian chipmunk was the most frequently captured species, boasting an RAI of 2.30 within the group of five identified small mammals (Table 2).

To estimate daily activity patterns, we focused on the striped field mouse and the genus *Crocidura* in Site 1, as they had ≥30 records per season for both spring and summer 2021. The total number of photos for the striped field mouse was 156 during spring and 78 during summer. Additionally, for the genus *Crocidura*, there were 67 photos in spring and 30 in summer. The striped field mouse showed a nocturnal pattern, with a peak in the midnight hours and a smaller peak in the morning during spring. In contrast, the genus *Crocidura* exhibited a diurnal pattern, with a peak around noon in spring and a peak in the afternoon during summer (Fig. 4). Furthermore, when estimating the overlap of activity patterns between these two species, the observed overlap index was 0.21 with p-value of 0. The result strongly suggests that the observed overlap significantly deviates from what would be expected by random chance alone, confirming the presence of statistically significant differences in the activity patterns of these two groups.

Discussion

In South Korea, the application of camera trap-based monitoring methods for small mammals had not been explored prior to this study. Our research represented the pioneering use of the Mostela system to monitor small mammals in South Korea, a novel approach with several distinct

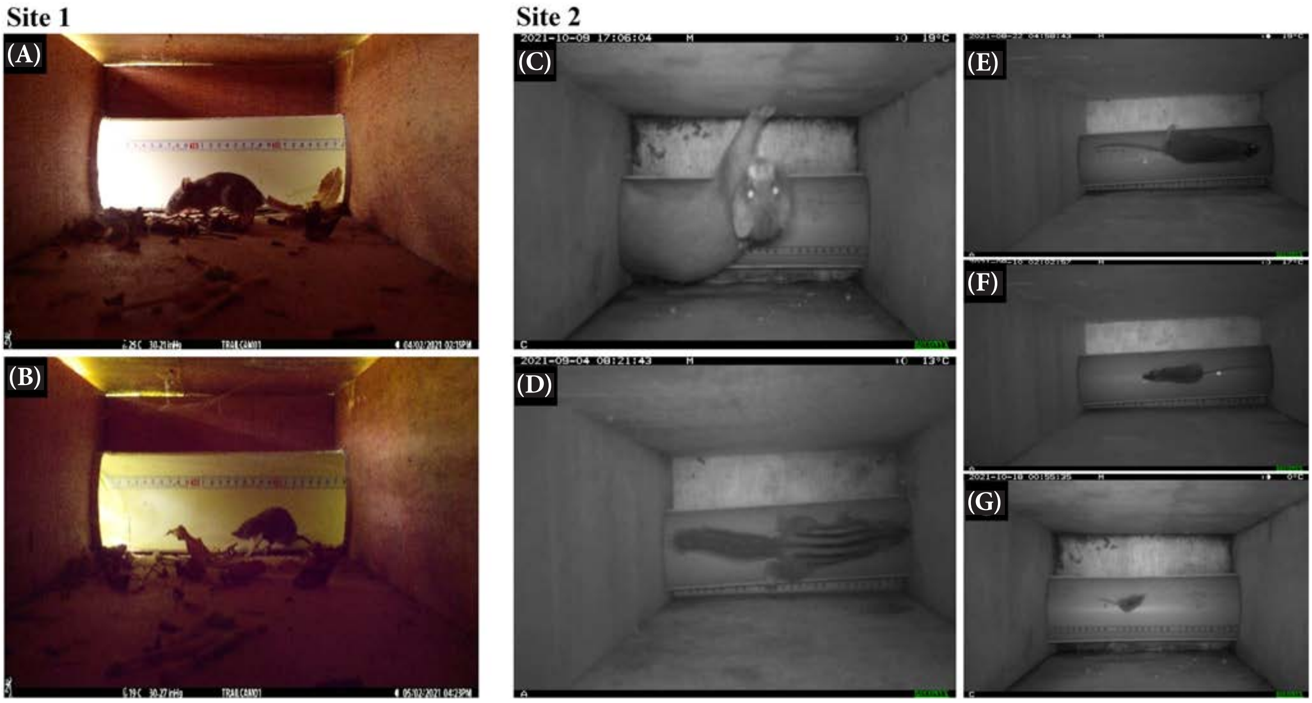

Fig. 3 Photographic and video records of mammals captured by the Mostela at Site 1 and Site 2. In Site 1: (A) striped field mouse (*Apodemus agrarius*), (B) *Crocidura* spp. In Site 2: (C) Siberian weasel (*Mustela sibirica*), (D) Siberian chipmunk (*Eutamias sibiricus*), (E) brown rat (*Rattus norvegicus*), (F) striped field mouse, (G) *Crocidura* spp.

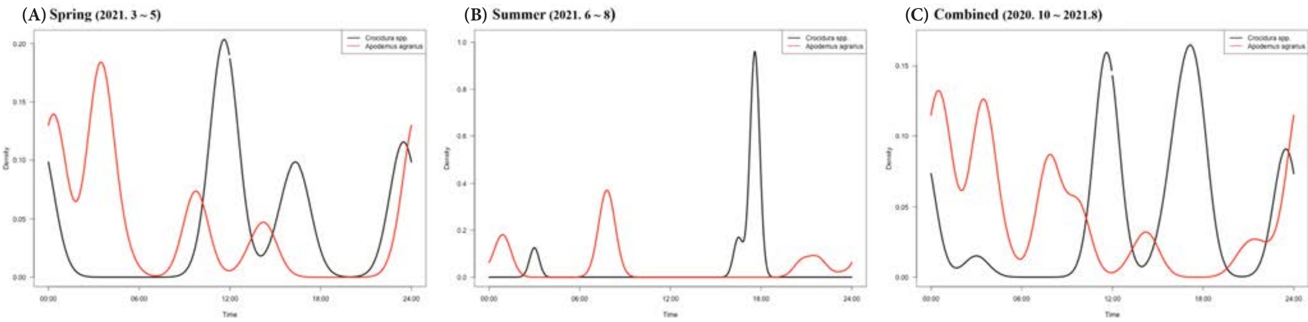

Fig. 4 Activity patterns of the striped field mouse (red line) and *Crocidura* spp. (black line) in Site 1. Activity patterns were estimated during spring (A) and summer (B) 2021, as well as the total period (C) based on Mostela detections.

advantages in the realm of small mammal monitoring. Notably, the Mostela offers an ethical alternative to live trapping experiments (Gracanin and Mikac 2022; Mos and Hofmeester 2020). It reduces labor-intensive efforts when compared to live trapping, eliminates the risk of mortality to target species, and is cost-effective due to its utilization of readily available materials, all without compromising detection efficiency (Cepeda-Duque et al. 2023; Littlewood et al. 2021; Mos and Hofmeester 2020). Remarkably, certain small mammal species characterized by distinctive natural markings, including variations in body size and coat patterns, enable individual identification, and camera trap errors, such as false triggers, are minimal. This feature substantially diminishes data preprocessing costs and time requirements (Croose et al. 2022; Gracanin and Mikac 2022; Gracanin et al. 2022; Mos and Hofmeester 2020; Park et al. 2019). Our results unequivocally validate the efficacy of the Mostela system in these aspects. We ascertained that several small mammals entered the PVC chamber of the Mostela, and camera traps adeptly captured them while allowing for the measurement of their body lengths (Fig. 3). Furthermore, Mostela's design is adaptable to accommodate different environmental conditions. In the mountainous terrain-rich landscape of South Korea, applying the original Mostela is not always feasible due to limited flat areas for deployment. As a solution, we successfully modified the Mostelas unit into a standing position, allowing them to use minimal flat areas and be attached to trees in the forest edge habitat of Site 2.

Nonetheless, there remains room for improvement. Our Mostela units in both sites did not detect small mammal species such as the Korean red-backed vole (*Craseomys regulus*) and Korean field mouse (*A. peninsulae*), which are relatively abundant in their respective habitats. Additionally, the absence of bait had an impact on the detection rate that did not meet our initial expectations. Furthermore, while individual Mostela units are not excessively heavy, transporting multiple units to mountainous regions can be burdensome due to their volume. These challenges can be addressed in the future by refining and optimizing monitoring site selection, increasing the number of deployed camera traps, considering the provision of baits, and enhancing the Mostela design, possibly making it foldable for ease of transportation.

In conclusion, this study has underscored the significant potential of the Mostela system for monitoring small mammals in South Korea. The versatility of Mostela extends beyond general aspects of monitoring small mammal diversity, community composition, activity patterns, habitat selection, and distribution. It also holds promise for detecting endangered and rare species, such as the least weasel and Eurasian Water Shrew (*Neomys fodiens*) in South Korea. The Mostela system represents a valuable addition to the toolbox of conservationists and researchers, offering innovative solutions for advancing our understanding of small mammal populations and ecosystems while promoting ethical and non-invasive research practices.

Conclusions

This study introduces the Mostela system as an effective tool for small mammal research in South Korea. It offers ethical advantages by replacing invasive trapping methods, reducing labor, minimizing risk to species, and being cost-effective. Notably, it excels in capturing small mammals with distinctive markings, reducing data processing. Our results demonstrated the Mostela system's efficiency in recording various small mammal species. Its adaptability, shown by modifying units for mountainous terrain, highlights versatility. There is room for improvement, like enhancing detection rates and transportation logistics. Future research can refine site selection, increase camera traps, provide bait, and explore foldable designs. In summary, Mostela advances small mammal monitoring, providing insights into diversity, community dynamics, and habitat preferences. It also can aid in detecting rare species, contributing to wildlife conservation. It's a valuable tool for conservationists and researchers, promoting ethical research and understanding small mammal populations and ecosystems.

Abbreviations

RAI: Relative Abundance Index
NIE: National Institute of Ecology

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Authors' contributions

HBP conceived the ideas, conducted the data collection and analysis, and wrote the manuscript. AL conceived the ideas and wrote, reviewed, and edited the manuscript. 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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