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Movement patterns and habitat use within the home range of the Asiatic toad (*Bufo gargarizans*) prior to hibernation

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Abstract

Understanding the movement patterns and home range of a species is essential for developing effective conservation strategies. However, research on these aspects in the Asiatic toad (*Bufo gargarizans*) in South Korea remains limited, highlighting the need for further study. This study used radiotelemetry to examine the movement patterns and home range characteristics of *B. gargarizans*, aiming to enhance ecological understanding and inform conservation efforts. Our findings revealed that immobility (0 m) was the most frequently observed behavior among individuals. Excluding instances of immobility, individuals' movement ability was 32.1 ± 51.0 m (*N* = 131, range: 0.1–360.9 m). Home range size, estimated using the minimum convex polygon (MCP) method, was 2,484.0 ± 4,461.0 m² (*N* = 24, range: 40.7–20,644.9 m²), representing the general movement area of *B. gargarizans*. The kernel density estimation (KDE) method estimates 55,004.9 ± 113,702.5 m² (*N* = 24, range: 425.9–491,232.2 m²), representing the potential buffer zone within which *B. gargarizans* may move. Regardless of the analysis method or sex, over 50% of habitats consisted of grass, while approximately 20% was used areas. Although no significant differences in movement patterns or home range size were observed between sexes, males were primarily distributed at lower altitudes near breeding sites, whereas females were distributed at higher altitudes around valley areas. These findings provide crucial baseline data for the conservation and management of *B. gargarizans* populations in South Korea.

Key Words

conservation and management, habitat preference, non-breeding period, movement ability, radiotelemetry

Introduction

The home range refers to the area traversed by an individual while engaging in general activities, such as food gathering, mating, and caring for offspring (Burt 1943; Powell 2000; Laver and Kelly 2008), and this definition is applicable to all animal groups, including amphibians (Powell and Mitchell 2012). As ectothermic animals, amphibians are significantly influenced by their surrounding environment (Buckley et al. 2012). Due to their physiological sensitivity, they are particularly vulnerable to changes in their habitat, which can directly affect the health and stability of their populations (Watling and Braga 2015; Goff et al. 2020). Therefore, studying space use by amphibians, including their home range, is vital for supporting conservation efforts and advancing ecological knowledge (Blomquist and Hunter 2009; Daversa et al. 2012; Beebee 2013; Pittman et al. 2014).

Various methodologies have been employed in amphibian home range research to estimate home ranges and analyze movement patterns (Miaud et al. 2000; Lee et al. 2013; Park et al. 2021). These methods include fluorescent powder tracking (Okamiya and Kusano 2018), thread bobbin techniques (Waddell et al. 2016), and radio telemetry (Brown et al. 2006; Park et al. 2022). Furthermore, some studies focus on habitat fidelity within these home ranges, identifying habitat preferences to inform effective conservation strategies (Forester et al. 2006; Gamble et al. 2007; Luger et al. 2009).

However, methodological limitations, such as the lifespan of radio transmitters, the length of attachment threads, and the amount of fluorescent powder used, hinder the collection of long-term and comprehensive data (Rittenhouse and Semlitsch 2007). Additionally, amphibian habitats are often forested or covered by canopies, such as fallen leaves or shelter (Park et al. 2024), rendering capturing or locating animals challenging, which further limits research efforts. Consequently, researchers have primarily focused on the breeding season, given that amphibians typically gather at breeding ponds during this time (Lamoureux and Madison 1999; Forester et al. 2006; Hamer and McDonnell 2008; Lee et al. 2013). However, the annual rhythms of amphibians during non-breeding periods also influence subsequent breeding seasons (Su et al. 2020). Despite this, studies conducted during non-breeding periods remain limited, highlighting the need for further research into this critical phase. During non-breeding periods, particularly harsh winters, amphibians adopt various survival strategies, such as hibernation (Groff et al. 2016). During the pre-hibernation phase, amphibians search for suitable hibernation sites and consume adequate food to prepare for hibernation, resulting in seasonal differences in their home ranges and movement patterns (Baldwin et al. 2006; Groff et al. 2016; Park et al. 2024). A lack of suitable hibernation sites can lead to local extinctions and may even threaten the survival of entire species (Browne and Paszkowski 2010; Groff et al. 2016). This underscores the importance of understanding amphibian home ranges and behaviors during the pre-hibernation period to elucidate their life cycles. Consequently, research on home ranges and movement patterns during non-breeding periods is essential for advancing our knowledge of amphibian ecology and developing effective conservation strategies.

The Asiatic toad (*Bufo gargarizans* Cantor, 1842) is a species widely distributed across northeast Asia (Lee et al. 2011). In South Korea, *B. gargarizans* are known to breed from February to March and hibernate starting in October (Lee et al. 2011; Park et al. 2024). Research on this species has primarily focused on its breeding behavior (Sung et al. 2007), with few studies investigating its spatial ecology and movement patterns outside of the breeding season (Lee et al. 2011; Park et al. 2021). Although previous studies have estimated home range sizes and movement patterns, the habitat use within these ranges remains largely unexplored. Moreover, *B. gargarizans* is not considered endangered; it is classified as a common species that is currently classified as "Least Concern (LC)" on the IUCN (International Union for Conservation of Nature) Red List (IUCN 2022). Common species, such as *B. gargarizans*, are often studied less frequently than endangered species. However, widely distributed common species can serve as valuable models for developing universal conservation measures, thereby aiding in the establishment of universal and comprehensive conservation strategies. Therefore, ongoing research on common species should be encouraged to ensure their long-term preservation and to enhance our understanding of ecological dynamics.

This study aimed to address gaps in knowledge regarding the behavior of *B. gargarizans* outside the breeding period by investigating their movement patterns and habitat use within their home ranges during the pre-hibernation period. In doing so, we sought to provide a more comprehensive understanding of the species' ecology and to inform the development of effective conservation strategies.

Materials and methods

Study site and radiotelemetry

The study was conducted at a pond located in Jinsang-myeon, Gwangyang-si, Jeollanam-do, South Korea (35°2.84'N, 127°42.90'E; 65 m asl). The pond covers an area of 5,300 m^2 and has a maximum depth of 5 m. A two-lane road and a village are situated to the northeast of the pond. A mountain with an elevation of 430 m is located beyond the village. This pond serves as an annual breeding site for *B. gargarizans*.

Field surveys were conducted between September and November to study the movement patterns and home ranges of *B. gargarizans* during the non-breeding season and prior to the hibernation period. Field surveys were conducted from 27 August to 13 November 2016, with additional research conducted from 12 September to 30 September 2023. Radiotelemetry was employed to track the individuals. Previous studies indicate that transmitters should weigh less than 5% of the individual's body mass (BM) to minimize potential impacts on animal behavior (Brown et al. 2006; Park et al. 2022). In this study, we used BD-2 transmitters (1.6 g, HOLOHIL, Canada) and only individuals weighing over 30 g at the time of capture were included. Sex was determined based on the presence of the nuptial pad on the forelimbs (Lee et al. 2011). The captured individuals were measured for snout-vent length (SVL) and BM using Vernier calipers (0.05–150 mm, XP Tool, Indonesia) and an electronic scale (WZ-3A, 0.1–1,000 g, CAS, South Korea), respectively. Following this, a transmitter was affixed using a fishing line, and a stainless-steel ring was secured around the waist. Following a 30-min acclimatization period post-attachment, the individuals were released at their capture sites.

Released individuals were tracked using a receiver (Sika, 138–174 MHz; Biotrack, UK) and an antenna (Yagi Antenna; Lotek, UK). Tracking sessions were conducted at least three times per week, with all individuals confirmed during the daytime (1–5 P.M.), when movement was expected to be at its lowest. The location of each individual was recorded daily using a GPS device (GPSMAP 64s, Garmin, Switzerland). Tracking was conducted on all *B. gargarizans* with attached transmitters on the day of tracking, continuing until the transmitter fell off or the individual began to hibernate. Hibernation, as defined by previous studies, was considered to occur when *B. gargarizans* burrowed more than 10 cm into the ground and the entrance was closed (Park et al. 2024). At this point, the transmitters were safely removed.

Movement patterns

The locations collected via radiotelemetry were imported into Google Earth Pro (Google, USA), where they were cross-checked with satellite imagery and landmarks to ensure accuracy (Rodgers and Carr 1998). To represent the movement paths, the locations were connected sequentially by straight lines, following the order in which they were recorded. The straight-line distances between these locations were calculated using ArcGIS (ver. 10.6, ESRI, USA). To determine actual distances, a triangulated irregular network (TIN) map was constructed based on a 1:5,000 digital map from the National Geographic Information Institute's Land Information Platform (NGII 2018).

Typically, radiotelemetry is used to measure the distance traveled by amphibians, with the "average (mean) movement distance" being calculated through the points where individuals are located (Ra et al. 2008; Mitrovich et al. 2011). However, in our study, there is a longer gap until the next tracking (about 1 day), as we conducted tracking only three times a week. To address this, we referred to the methodology proposed by DeVore et al. (2021), who evaluated the distance between shelters during diurnal periods. In our study, we used this approach to calculate the distance between consecutive locations (in meters) and interpret it as the movement ability of *B. gargarizans*. Additionally, if an individual remained in the same location during consecutive tracking events, the distance was recorded as 0 m (indicating immobility).

Weather variables were collected to examine the potential correlations between the distance traveled and environmental conditions. The weather variables were provided by the Korea Meteorological Administration, including precipitation, humidity, minimum temperature, maximum temperature, average temperature, and daily temperature range (Korea Meteorological Administration, 2025). To analyze movement patterns, we conducted a frequency analysis to identify the most frequently occurring movement distance. Given the variability in distances, we categorized them into six groups, each representing 10 m intervals (0 m, 1–10 m, 11–20 m, 21–30 m, 31–40 m, and > 40 m).

Home range

Commonly used methods for analyzing home range include the minimum convex polygon (MCP; Mohr 1947) and kernel density estimation (KDE; Worton 1989; Laver and Kelly 2008), each with its specific strengths and limitations. Previous studies have employed both methods concurrently to enhance the accuracy of home range estimates (Okamiya and Kusano 2018; Young et al. 2018). Consistent with these approaches, both methods were employed in this study. Home range analysis was conducted using the Home Range Tools (HRT) extension for ArcGIS (Rodgers et al. 2007), with the sample restricted to individuals that had at least three confirmed movement points, as outlined in the HRT manual. Given the limited number of movement points collected for each individual, the results from both methods (MCP and KDE) were extrapolated to a 95% confidence level. For the KDE analysis, bandwidth settings were automatically calculated to account for significant variation in average movement distances across individuals. Additionally, land use within each home range was analyzed using a thematic map (Land use map) obtained from the Environmental Spatial Information Service (EGIS 2018). This map featured seven land use categories: used area (areas with human activity, including residential and industrial zones), agricultural land (areas where crops such as rice paddies and agricultural fields are cultivated), forest (broadleaf and coniferous forests), grassland (areas covered with grass and a low proportion of trees), wetland (areas that remain saturated and accumulate water during the rainy season), barren (soil types such as sand or gravel), and water (water bodies such as rivers and banks).

Statistical analysis

All statistical analyses and graphs were performed using SPSS software (ver. 20, IBM, USA). The normality of the distance and home range data was assessed using the Kolmogorov-Smirnov test, which indicated that the data did not follow a normal distribution ($p < 0.05$). Given the absence of normality, the Mann-Whitney U test was used for mean comparisons, and Spearman's correlation was used to analyze the relationship between distance and weather variables. Frequency analysis was performed to count the occurrences of each classified group, and the results were presented graphically.

Result

Radiotelemetry

A total of 28 individuals (16 males and 12 females) were tracked in this study. All individuals had a mass exceeding 30 g, making them suitable for radiotelemetry tracking. The radio transmitters weighed between 2 and 2.5 g including fishing line and a stainless-steel ring, corresponding to 2.1–2.6% of the average BM for all individuals. The average BM of all tracked individuals was 95.5 ± 66.1 g (*N* = 28, range 33.2–234.3 g) and the average SVL was 90.2 ± 24.9 mm (*N* = 28, range 66.1–174.8 mm). For males, the average BM was 44.1 ± 8.5 g (*N* = 16, range 33.2–64.8 g) and the average SVL was 72.8 ± 4.5 mm (*N* = 16, range 66.1–79.2 mm). For females, the average BM was 164.1 ± 45.1 g (*N* = 12, range 85.3–234.3 g) and the average SVL was 113.4 ± 21.7 mm (N = 12, range 87.1–174.8 mm). Females exhibited significantly higher BM and SVL compared to males (Mann–Whitney U test, $p < 0.05$). A total of 443 movement points were recorded using radiotelemetry. Of these, 245 points were from males, with an average of 15.3 points per individual, and 198 points were from females, with an average of 16.5 points per individual. No significant difference was observed between the sexes ($p > 0.05$).

Movement patterns

The total number of tracking days was 56. Consequently, a total of 415 distances between locations across 443 points (including identical locations) were calculated. Correlation analysis revealed that the average distance of *B. gargarizans* points was significantly correlated with minimum temperature ($r = 0.131$, $p < 0.05$), daily temperature range ($r = -0.145$, $p < 0.05$), precipitation ($r = 0.246$, $p < 0.05$), and humidity (r = 0.195, p < 0.05; Fig. 1). Specifically, the distance between locations increased as minimum temperature, precipitation and humidity increased, whereas the daily temperature range decreased. When tracking on dry days, individuals are found in shelter under various structures, such as dry leaves, rocks, or artificial objects. In contrast, on rainy days, they tend to remain outside or move around.

The frequency analysis of the distances between locations revealed that the most common distance was 0 m (immobility), occurring 284 times (males: 154, females: 130). This was followed by movement within the 1–10 m range, occurring 42 times (males: 25, females: 17), 11–20 m (32 occurrences; males: 19, females: 13), 21–30 m (19 occurrences; males: 12, females: 7), 31–40 m (14 occurrences; males: 8, females: 6), and movements exceeding 40 m (24 occurrences; males: 11, females: 13; Fig. 2). Immobility (0 m) accounted for 284 out of 415 total movements, accounting for 68% of the total. Males accounted for 154 of these instances, with an average of 9.6 occurrences per individual, whereas females accounted for 130 instances, with an average of 10.8 occurrences per individual. No significant difference was found between the sexes ($p > 0.05$).

All locations were located within a 1 km radius of the breeding site. Given that over 50% of all calculated distances were zero, statistical analysis was conducted using 131 non-zero distances between locations to compare movement ability across sexes. The average distance between locations for all 28 individuals was 32.1 ± 51.0 m (*N* = 131, range: 0.1–360.9 m). For the 16 males, the average distance between locations was 25.2 ± 27.9 m (*N* = 75, range: 0.3–144.2 m), whereas for the 12 females, the average distance between locations was 41.3 ± 70.3 m (*N* = 56, range: 0.1–360.9 m) (Table 1). A comparative analysis between males and females indicated that females tended to cover greater distances (males: 25.2 m, females: 41.3 m). However, this difference was not statistically significant ($p > 0.05$).

Home range estimation

Home range analysis was conducted on individuals with at least three tracked points (*N* = 24, 14 males and 10 females). The average home range for all individuals, as determined using the MCP method, was 2,484.0 ± 4,461.0 m^2 (*N* = 24, range: 40.7–20,644.9 m^2). For males, the average home range was 1,621.9 ± 2,673.2 m^2 (N = 14, range: 48.6–9,379.2 m^2), whereas for females, it was 3,690.8 ± 6,144.9 m^2 (*N* = 10, range: 40.7–20,644.9 m^2) (Table 1). Statistical analysis revealed no significant differences between the sexes ($p > 0.05$). KDE analysis indicated an average home range for all individuals of 55,004.9 ± 113,702.5 m^2 (*N* = 24, range: 425.9–491,232.2 m^2). For males, the average home range was 16,625.7 ± 19,576.7 m^2 (*N* = 14, range: 425.9–56,209.4 m^2), whereas for females, it was 108,735.6 ± 164,275.0 m^2 (N = 10, range: 429.2–491,232.2 m^2) (Table 1). Similarly, statistical analysis did not reveal any significant differences between the sexes ($p > 0.05$). Land use analysis, using both the MCP and KDE methods, indicated a predominance of grassland habitat (Table 2). According to the MCP analysis, males predominantly occupied grassland

Table 1. Average distance between consecutive locations (DBL) of *Bufo gargarizans* and the results of home range estimation methods (minimum convex polygon; MCP and kernel density estimation; KDE). The data are presented as mean ± SD (N; Number of data, range min-max).

	DBL (m)	MCP (m^2)	KDE (m^2)
Male	25.2 ± 27.9 (*N* = 75, 0.3–144.2)	1,621.9 ± 2,673.2 (*N* = 14, 48.6–9,379.2)	16,625.7 ± 19,576.7 (*N* = 14, 425.9–56,209.4)
Female	41.3 ± 70.3 (*N* = 56, 0.1–360.9)	3,690.8 ± 6,144.9 (*N* = 10, 40.7–20,644.9)	108,735.6 ± 164,275.0 (*N* = 10, 429.2–491,232.2)
Total	32.1 ± 51.0 (*N* = 131, 0.1–360.9)	2,484.0 ± 4,461.0 (*N* = 24, 40.7–20,644.9)	55,004.9 ± 113,702.5 (*N* = 24, 425.9–491,232.2)

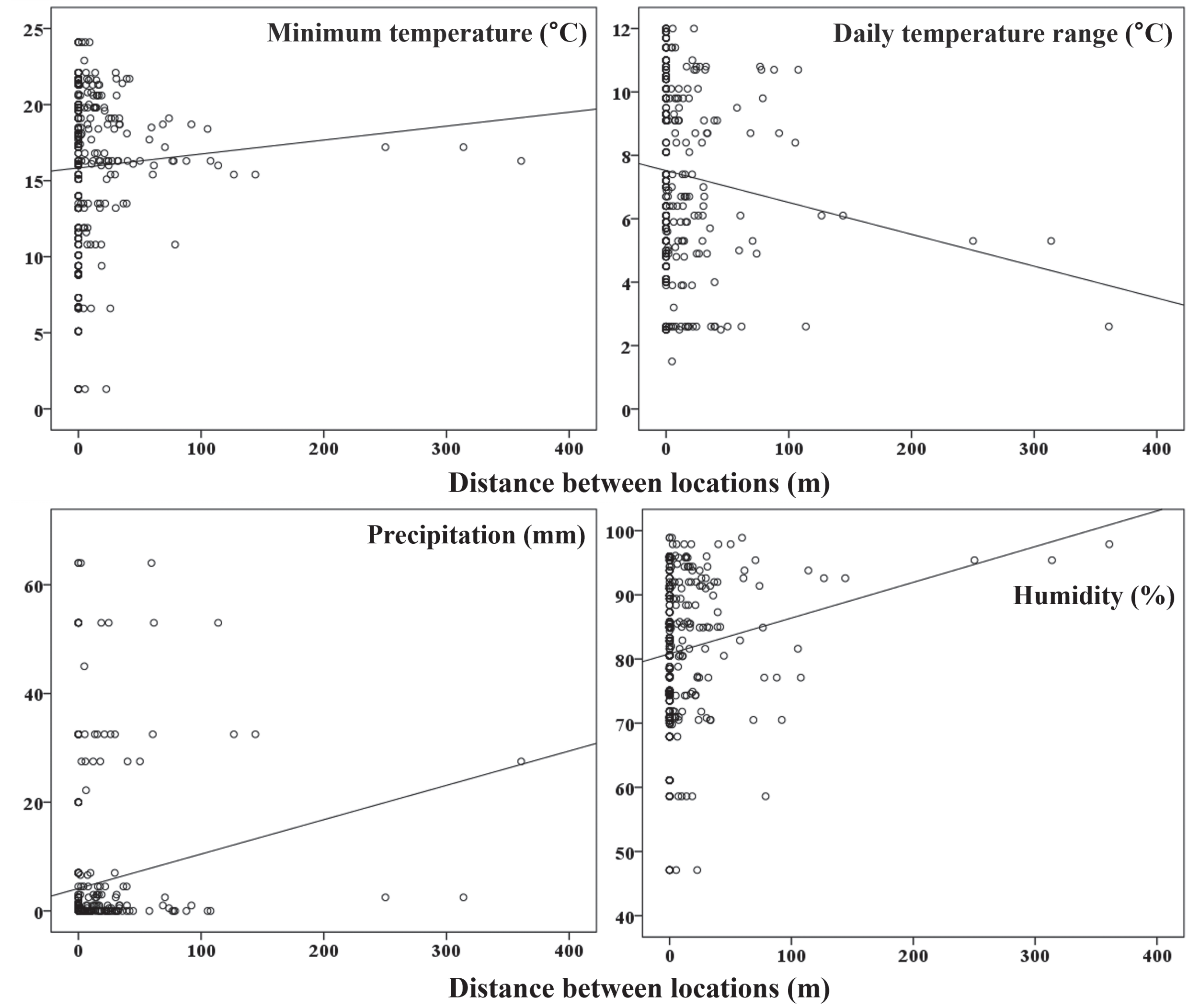

Figure 1. Scatterplots of correlation between weather variables and distance between locations. The distance increased as minimum temperature, precipitation and humidity increased, whereas the daily temperature range decreased. Correlation with minimum temperature ($r = 0.131$, $p < 0.05$), daily temperature range ($r = -0.145$, $p < 0.05$), precipitation ($r = 0.246$, $p < 0.05$), and humidity ($r = 0.195$, $p < 0.05$).

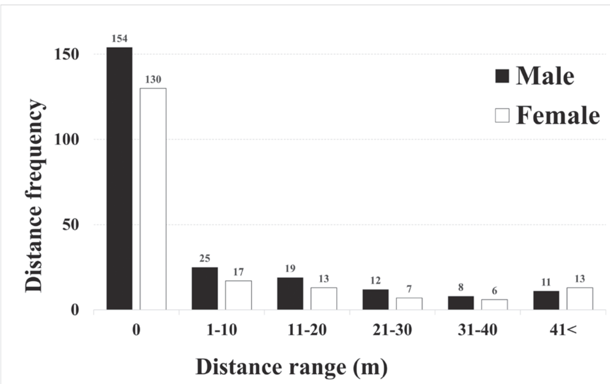

Figure 2. Distance between locations frequency distribution. Closed bars represent males, open bars represent females, and the numbers above the bars indicate frequencies. The distances were categorized into six ranges. Most individuals exhibited immobility (0 m), with a total frequency of 284 occurrences (male 154, female 130).

(58.4%), with a secondary preference for used areas (26.1%). Females similarly favored grassland (57.0%) and had a secondary preference for used areas (27.4%). The KDE analysis revealed similar patterns, with grassland as the primary habitat (males: 58.2%, females: 43.5%), followed by used areas (males: 15.5%, females: 27.1%) (Table 2). Mapping the home ranges revealed that males exhibited wider dispersal around the breeding sites, occupying lowland areas, whereas females were primarily concentrated around valleys and distributed across higher-altitude regions (Fig. 3).

Discussion

In this study, we estimated the movement patterns and habitat use within the home ranges of *B. gargarizans* prior to hibernation. Most individuals exhibited minimal movement

Table 2. Land use analysis results. The area of each land use variable within the home range is expressed as a ratio (%). Regardless of the analysis method or sex, over 50% habitats consisted of grass, with approximately 20% consisting of used areas.

Method	Sex	Grass	Used area	Agricultural land	Forest	Water	Barren
MCP	Male	58.4	26.1	6.9	7.0	1.3	0.3
	Female	57.0	27.4	8.5	7.1	0.0	0.0
KDE	Male	58.2	15.5	13.0	6.8	2.8	3.6
	Female	43.5	27.1	16.2	10.6	2.6	0.0

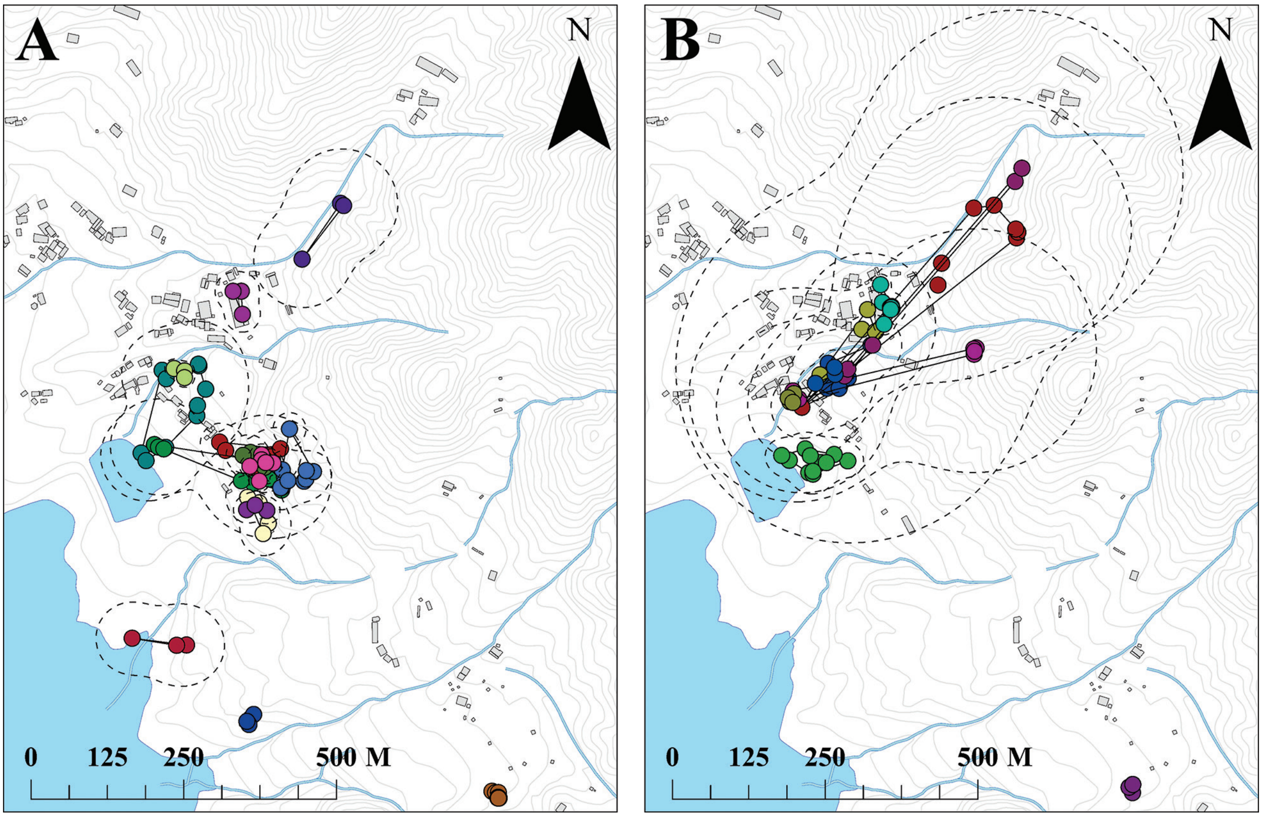

Figure 3. Home range analysis. Each colored dot represents the tracking points of *Bufo gargarizans* (if an individual did not move, only one point is shown). The solid line represents the MCP method, and the dotted line represents the KDE method. The MCP represents the general home range inhabited by the *B. gargarizans*, while the KDE represents the potential buffer home range where the *B. gargarizans* may move. **A.** Male home ranges, predominantly distributed at lower altitudes near the breeding site; **B.** Female home ranges, primarily located at higher altitudes around the valley.

(0–10 m), with the average distance between locations for all tracked individuals being approximately 32 m. Home range sizes varied significantly, ranging from 2,400 to 55,000 m^2, with individuals predominantly inhabiting grassy habitats. Specifically, males were primarily concentrated in low-altitude areas surrounding breeding sites, whereas females were distributed in higher-altitude regions, primarily concentrated around the valley of the mountain.

Movement patterns

In this study, locations were recorded during the daytime when the activity levels of individuals were at their lowest. Like most amphibians, *B. gargarizans* is more active at night when humidity is higher (Lee et al. 2011). Therefore, we conducted the survey during the day, as we determined that recording the location at night could potentially disturb the movement of the individuals. In particular, *Rhinella marina* belonging to the same Bufonidae family have also been confirmed to move mainly at night and return to their daytime hiding places after foraging (DeVore et al. 2021). These findings suggest that *B. gargarizans* may also have different behavioral patterns during the day and night. However, the objective of this study was to assess the movement ability of *B. gargarizans*; therefore, we suggest that the coordinates collected during the day are able to cover these aspects.

Our findings suggest that *B. gargarizans* has the ability to cover significant distances. The average distance between locations for *B. gargarizans* was approximately 32 m. This movement ability differs from that of other species in different genera. For instance, *Pelophylax chosenicus* has an average movement distance of 5.3 m (Ra et al. 2008), whereas the mean movement distance of *Lithobates catesbeianus* is 3.2 m (Park et al. 2022), and *Dryophytes japonicus* moves approximately 1 m (Borzée et al. 2019). Common frog species, including these three, are highly dependent on water and may face survival risks if they are away from water bodies (Ra et al. 2008; Borzée et al. 2019; Park et al. 2022). In contrast, the average distance of *B. gargarizans* is similar to that of other species within the same family, such as *Anaxyrus boreas*, which moves an average of 39.1 m (Bartelt et al. 2004), *B. japonicus formosus*, which moves 98.5 m (Kusano et al. 1995) and *A. californicus*, which moves 77.8 m (Mitrovich et al. 2011). Generally, species in the Bufonidae family are known for their thick skin compared to other anurans (Lee 2003), which provides greater resistance to dry environments (Vitt and Caldwell 2013). This characteristic enables members of the Bufonidae family, including *B. gargarizans*, to travel greater distances than other anuran species.

Nevertheless, extreme dry conditions can accelerate water loss in Bufonidae species (Brusch et al. 2019). To mitigate this, they can detect and absorb moisture through their ventral skin (Prates and Navas 2009). Due to these characteristics, *B. gargarizans* appears to prefer days with high humidity and precipitation for movement. Furthermore, the results of this study indicate that, although they may be active at night, they remain in one place for extended periods (0 m). This suggests that rather than engaging in extensive movement, *B. gargarizans* prioritizes selecting and remaining in optimal habitats (Cushman 2006; Pittman et al. 2014). Consistent with this, previous studies have shown that *B. gargarizans* stays within its microhabitat, feeding on passing prey with minimal movement (Park et al. 2024). Overall, *B. gargarizans* exhibits a strategy of minimizing movement and adopting an opportunistic approach, becoming more active only under favorable weather conditions, such as high humidity, precipitation, or a low daily temperature range. Moreover, since this study was conducted during the non-breeding season, when food availability increases and energy conservation becomes crucial (Yu et al. 2009), this behavioral pattern likely represents an adaptive strategy for optimizing energy use. These findings further support the observed results, as they align with the species' need to prepare for successful hibernation.

Home range estimation

This study employed both the MCP and KDE methods to estimate the home range of *B. gargarizans*. MCP and KDE are widely recognized as effective methods for home range estimation (Laver and Kelly 2008). Lee and Lee (2022) suggested that both methods are suitable for location data that do not exhibit spatial autocorrelation. However, KDE has certain limitations, such as the potential for overestimating home range size depending on the bandwidth setting and the inclusion of areas that the animal does not actually inhabit (Yoo et al. 2013). In this study, due to an insufficient number of location data, the bandwidth was set to an automatically calculated value. To address these limitations, MCP was used in conjunction with KDE. In conclusion, this study defined MCP as the general home range representing habitat use, and KDE was considered a buffer home range indicating potential habitat use.

To enhance the understanding of a target species' home range, it has been suggested that various types of information, such as land use, should be integrated (Powell and Mitchell 2012). Accordingly, in this study, we calculated the land use within the home range. Regardless of the analysis method or sex, the results showed that over 50% of *B. gargarizans* habitats consisted of grass, with approximately 20% consisting of used areas. Previous studies have indicated that the primary habitats for species within the Bufonidae family include vegetation, croplands/hayfields, and meadows. For instance, *R. marina* prefers vegetation with a height of less than 8 cm (Mayer et al. 2015), whereas *A. californicus* favors sparsely vegetated, open sandy plains (Mitrovich et al. 2011). Similarly, *A. boreas* demonstrates a preference for open habitats such as wet shrublands, disturbed grasslands, and croplands/hayfields during the active season (Browne 2010). A habitat selection study on *B. gargarizans* found that cultivated land and vegetable fields with clayey soil and an average plant height of less than 60 cm were preferred (Su et al. 2020), which is consistent with the findings of this study. This preference may be linked to factors similar to those influencing movement ability, likely associated with the species' thicker skin and its greater resistance to dry conditions (Lee 2003; Vitt and Caldwell 2013).

No significant differences were observed between the sexes in terms of movement ability or home range size. Although it is generally expected that females, owing to their larger size and presumably higher energy reserves (Cheong et al. 2007; Lee et al. 2008), would exhibit greater movement, this study did not find such a difference. Similar findings have been reported in other amphibian species, where minimal sexual dimorphism in movement patterns was observed (Miaud et al. 2000). Generally, females are known to occupy habitats at greater distances from the water bodies (etc. breeding site, pond) compared to males (Rittenhouse and Semlitsch 2007). Consistent with these findings, our results indicated that males primarily established their home ranges in lowland areas near breeding sites (ponds), whereas females formed their home ranges in higher elevations along forested valleys (Fig. 3). These patterns suggest that both sexes adopt movement strategies that minimize displacement and optimize energy use.

Conclusion

This study provides valuable insights into the pre-hibernation movement patterns and home range of *B. gargarizans*. Overall, *B. gargarizans* remain largely immobile, with movement distances increasing under conditions of high humidity, precipitation, or a low daily temperature range. The primary home ranges were grasslands and used areas. Males were predominantly located in low-altitude around breeding sites, whereas females occupied higher-altitude forested valleys. Notably, the MCP home range, which represents the actual inhabited area, can serve as a foundation for establishing protected areas, while the KDE home range can be considered a potential habitat buffer zone. This approach facilitates effective habitat evaluation and management strategies. In conclusion, this study enhances our understanding of the movement and habitat preferences of *B. gargarizans*, providing essential data for future conservation and habitat management efforts.

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