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Field body temperatures and microclimatic influences in Hermann's Tortoise, *Testudo hermanni* Gmelin, 1789, from Thrace

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Abstract. Temperature is considered a fundamental factor in reptile ecology because their body temperature generally varies depending on environmental temperature. This study investigated the thermal ecology of *Testudo hermanni* populations inhabiting two different habitat types in the Thrace region (Karakoç/Kırklareli–open habitat, Keşan/Edirne–closed habitat) by examining the relationship between body temperatures (Internal Body Temperature: T_{int} and External Body Temperature: T_{ext}), microclimatic parameters (Substrate Temperature: T_s and Air Temperature: T_{air}), and morphological features (Body Weight: BW and Straight Carapace Length: SCL). Additionally, the effect of different weather conditions (cloudy and sunny) on the body temperatures of the populations was determined. Significant positive correlations were found between body temperatures and microclimatic parameters in both populations, whereas no significant relationship was detected between body temperatures and morphological features. Behavioural analyses indicated that activities such as basking and movement were associated with higher body temperatures. It was also found that individuals had higher body temperatures under sunny weather conditions. However, no significant difference in body temperatures was detected between the two populations, one inhabiting the densely wooded, closed habitat of Keşan and the other in the sparsely vegetated, open habitat of Karakoç. The results suggest that *T. hermanni* individuals have a high capacity to maintain optimal body temperatures under varying environmental conditions. This ability is crucial for the species' survival in the face of environmental challenges. However, increasing habitat fragmentation and habitat loss may significantly limit this adaptability. Moreover, rising temperatures could affect thermoregulation strategies, potentially threatening the long–term survival of populations. Future studies should focus on the long–term impacts of climate change on the thermal ecology and habitat use of *T. hermanni* to contribute to effective conservation strategies.

Keywords. Behaviour, climate vulnerability, habitat structure, thermoregulation, Testudinidae

Introduction

Global temperature changes are causing devastating effects on ecosystems and rapidly altering the living conditions of ectothermic organisms (Parmesan and Yohe, 2003; Dubois et al., 2009; Kearney et al., 2009). Since ectotherms regulate their body temperature by acquiring heat from the environment, thermal changes in their habitats can directly affect their behavioural and physiological processes (Huey and Kingsolver, 1989). Therefore, temperature plays a central role in controlling many essential functions in ectotherms, such as metabolic rate, growth, reproduction, and survival (Bogert, 1949; Vitt and Caldwell, 2013).

Among ectothermic organisms, reptiles rely on various body temperature regulation strategies, which are crucial for their response to thermal environments (Heatwole and Taylor, 1987; Berman and Quinn, 1991). Because reptiles depend on environmental heat sources for temperature acquisition, their daily activities are significantly limited. Thus, they engage in behavioural thermoregulation to find suitable temperatures (Dubois et al., 2009). Many reptiles regulate their body temperature within a relatively narrow range by adjusting their activity levels, basking duration, and body posture (McConnachie et al., 2011; Vitt and Caldwell, 2013). These thermoregulatory behaviours vary on both daily and seasonal scales (Shine and Lambeck, 1985; Bauwens et al., 1996; Diaz and Cabezas–Diaz, 2004).

Tortoises are highly vulnerable to temperature changes due to their low dispersal tendencies and habitat fragmentation (Fernández–Chacón et al., 2011). Additionally, tortoises move much more slowly than many other reptiles and have higher thermal inertia, making species inhabiting open habitats with limited

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vegetation cover more susceptible to overheating (Branch, 1984; Moulherat et al., 2014; Vujovic et al., 2023).

The Hermann's Tortoise, *Testudo hermanni* Gmelin, 1789, is a medium-sized testudinid with a relatively broad yet patchy distribution across the Mediterranean and sub-Mediterranean regions of Europe, particularly fragmented in the western parts of its range (Cheylan, 2001; Vetter, 2006; Bertolero et al., 2011). The species is listed as "Vulnerable (VU)" following criteria of the International Union for Conservation of Nature, with declining population trends (Luiselli, 2024). *Testudo hermanni* is included in Appendix II of the Bern Convention on the Conservation of European Wildlife and Natural Habitats (strictly protected fauna species), and in CITES Appendix II, which lists species not necessarily threatened with extinction but for which trade must be controlled to avoid utilisation incompatible with their survival. Additionally, it is listed in Annexes II and IV of the Habitats Directive (Council Directive 92/43/EEC), which ensures the conservation of natural habitats and of wild fauna and flora within the European Union. The species is becoming increasingly rare due to threats such as pollution (Mingo et al., 2016), habitat fragmentation (Guyot and Clobert, 1997), agricultural activities (Matache et al., 2006; Rozylowicz and Dobre, 2009), and wildfires (Hailey, 2000). In addition, collection of individuals from the wild for the pet trade and private keeping, alongside both legal and illegal commercial trade, remains a significant threat to *T. hermanni* populations, intensifying their decline at local, regional, and global scales (Luiselli et al., 2007; Türkozan and Kiremit, 2007; Luiselli, 2024). Recent findings by Shearer and Türkozan (2024) further highlight the global scale of the issue, showing that *T. hermanni* is among the most frequently traded *Testudo* species worldwide. Despite a rise in captive-bred individuals, inconsistencies in trade records suggest ongoing illegal activities and challenges in enforcement.

In Türkiye, its presence is limited to the Thrace region, representing the easternmost edge of the species' distribution (Türkozan 2019a, b; Baran et al., 2021). Recent studies in this region have provided data on the species' distribution, size structure, daily movements, home range, and population genetics (Türkozan et al., 2019a, b; Yılmaz et al., 2023). These studies indicate that populations in Thrace are fragmented and relatively isolated, potentially increasing their vulnerability to environmental pressures.

Although thermal ecology studies have been conducted on *T. hermanni* in other parts of its range (Meek, 1984, 1988; Wright et al., 1988; Ortega et al., 2017; Vujovic et al., 2023), no study has yet investigated the relationship between body temperatures and microclimatic variables in Turkish populations. Given the species' ecological sensitivity, low mobility, and ongoing habitat pressures, understanding thermal responses at a local scale is critical. This study aims to investigate the relationship between body temperatures (T_{int} and T_{ext}) and microclimatic parameters (substrate and air temperatures) of *T. hermanni* individuals living in the Thrace region, examine the behaviours they exhibit under these temperatures, and determine the effect of different weather conditions (cloudy and sunny) on body temperatures. Additionally, this study also examined whether there were differences between two populations inhabiting regions with different habitat types. This research will provide valuable data on the thermal ecology of *T. hermanni*, contributing to the understanding of how the species may respond to climate change.

Material and Methods

Study sites. The Thrace region, located in northwestern Türkiye, is an important ecological transition zone between Europe and Asia (Erdoğan, 2010). Its strategic position and the presence of diverse climatic conditions enhance the region's ecological significance and enable a wide range of habitats. In this study, adult *T. hermanni* individuals were collected by hand from two localities in the Thrace region; 1) Karakoç/Kırklareli, and 2) Keşan/Edirne. These localities were selected to represent different climatic zones and habitat types (Fig. 1). Individuals of the Karakoç population were collected from an open grassland habitat located in Karakoç/Kırklareli (41.7848°N, 27.2091°E, elevation 287 m). This region is influenced by a mix of Black Sea and continental climates. Individuals of the Keşan population were collected from a more isolated habitat consisting of rows of trees in Keşan/Edirne (40.7545°N, 26.7147°E, elevation 71 m). This area is characterised by a Mediterranean climate in the southern parts bordering the Aegean Sea, while the northern parts exhibit a continental climate. Karakoç is located in the northern part of the Thrace region, while Keşan is in the southern part. An important isolation mechanism separating the two populations is the Meriç River.

Field study and measurements. Field studies were conducted between March and October during 2024,

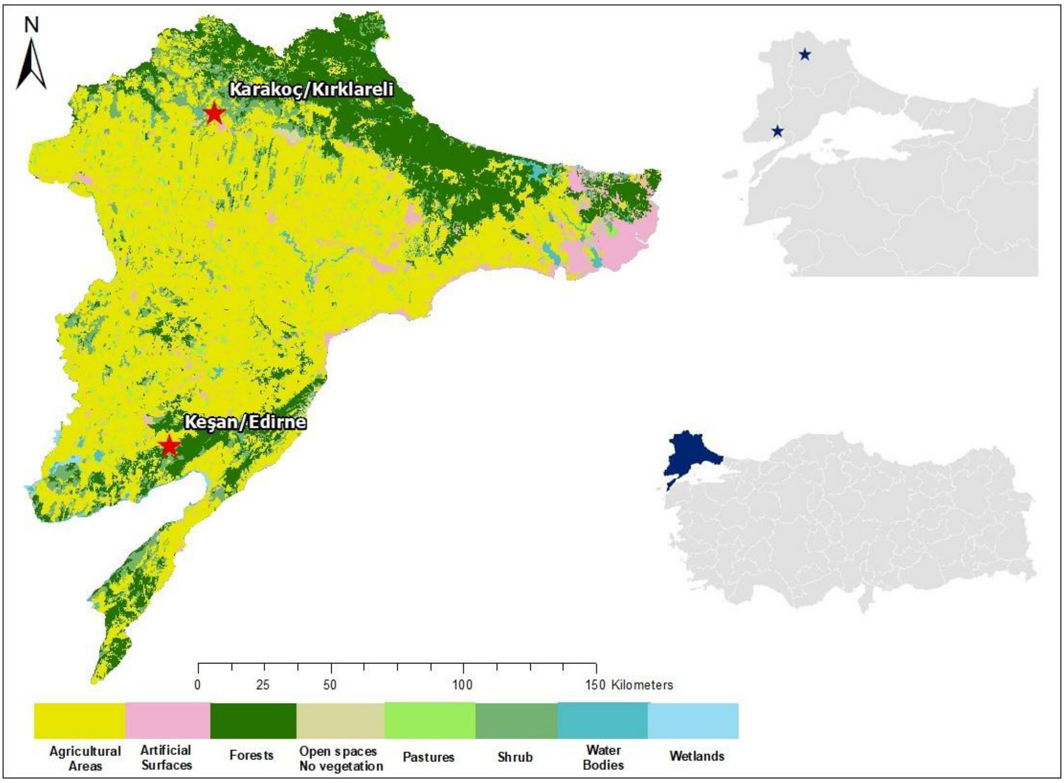

Figure 1. The habitat characteristics of the Thrace Region and the areas where the *T. hermanni* populations were studied (ESRI Global, 2024).

with data collection taking place between 08:00–12:30 and 13:30–20:00 hrs. A total of 99 adult individuals were collected from the study sites: 37 individuals (16 ♂♂, 21 ♀♀) from the Karakoç population, and 62 individuals (27 ♂♂, 35 ♀♀) from the Keşan population. The sex of each individual was identified by examining secondary sexual characteristics, such as the concave plastron in males (flat in females) and tail length, following the criteria outlined by Willemsen and Hailey (2003).

The body weight (BW) and straight carapace length (SCL) of the tortoises were measured using a Mitutoyo digital calliper (0.01 mm accuracy) and a tortometer, while weights were recorded with a Sinbo digital scale and an Orion analogue scale. Substrate temperature (T_s) was measured using a Proscan 510 Infrared Thermometer (± 1 °C accuracy), and air temperature (T_{air}) was recorded 15 cm above the ground with a UNI–T UT333 Mini Temperature Humidity Meter. The body temperature was determined via cloacal measurements, considered the internal body temperature (T_{int}), using a Trotec BT20 cloaca thermometer (± 1.5 °C accuracy). External body temperature (T_{ext}) was calculated as the mean of carapace (T_c) and plastron (T_p) temperatures, measured with a Proscan 510 Infrared Thermometer. Observed behaviours were categorised into seven groups: immobile, hiding, moving, basking, feeding, reproduction, and oviposition, based on criteria from Mazzotti et al. (2002). The weather was recorded at the moment individuals were captured on each fieldwork day: cloudy: when more than 50% of the sky is covered by clouds; sunny: when 50% or less of the sky was covered by clouds.

Data analyses. The data obtained were analysed using IBM SPSS Statistics 27 and R Project for Statistical Computing. The Kolmogorov–Smirnov test was applied to assess the normality of the data. The Pearson Correlation Coefficient was used to examine the relationships between variables such as T_{int}, T_{ext}, SCL, BW, T_s and T_{air}. Two-way Analysis of Variance (two-way ANOVA) was used to evaluate the effects of two independent variables (weather and sex) and their interactions (weather:sex) on T_{int} and T_{ext}. To determine whether there were significant differences between populations and sexes, the Student's *t*–test was used for parametric data, while the Mann–Whitney U test was applied for non–parametric data. In all analyses, a *p*–value ≤ 0.05 was considered statistically significant.

Results

Temperature measurements, behaviour and weather effects for the Karakoç population. Microclimatic parameters (T_s, T_{air}), body temperatures (T_{int} and T_{ext}), and morphological features (BW, SCL) were recorded from 37 adult individuals (16 ♂♂, 21 ♀♀) of the Karakoç population. During the field studies, the minimum T_{int} was recorded as 17.80 °C, while the maximum T_{int} was 36.10°C. The minimum T_{ext} was recorded as 15.60 °C, and the maximum T_{ext} was 35.75 °C. The minimum recorded T_{air} was 17.40 °C, and the maximum was 35.40 °C. T_s ranged from 15.90 °C to 45.50 °C. Morphological features revealed that SCL ranged from 11.50 cm to 21 cm, while BW ranged between 445 g and 1840 g.

When analysing the relationship between body temperatures, microclimatic parameters, and morphological features in all adult individuals, a positive correlation was found in males between T_s and T_{int} (p = 0.009, r = 0.627) as well as T_s and T_{ext} (p = 0.003, r = 0.691). Similarly, T_{air} showed a positive correlation with T_{int} (p = 0.011, r = 0.619) and T_{ext} (p = 0.014, r = 0.599). Additionally, T_{int} and T_{ext} were positively correlated with each other (p = 0.001, r = 0.926) (Fig. 2A). No significant correlation was detected between morphological features and body temperatures (Fig. 2B). In female individuals, T_s showed a positive correlation with both T_{int} (p = 0.002, r = 0.636) and T_{ext} (p = 0.001, r = 0.768). Likewise, T_{air} was positively correlated with T_{int} (p = 0.002, r = 0.688) and T_{ext} (p = 0.001, r = 0.688). A strong positive correlation was also found between T_{int} and T_{ext} (p = 0.001, r = 0.881) (Fig. 2C). No significant correlation was found between morphological features and body temperatures (Fig. 2D). When examining differences in body temperatures between male and female individuals, no significant difference was found

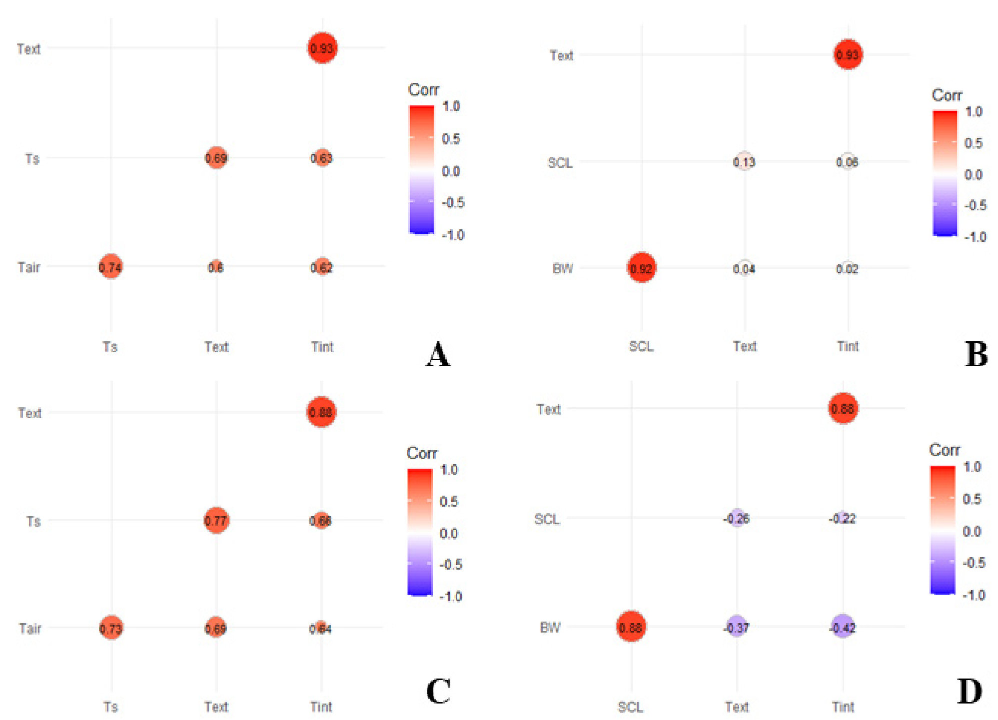

Figure 2. Multiple correlation graphs from the Karakoç population. (A) Correlation between body temperatures and microclimatic parameters in males. (B) Correlation between body temperatures and morphological features in males. (C) Correlation between body temperatures and microclimate parameters in females. (D) Correlation between body temperatures and morphological features in females.

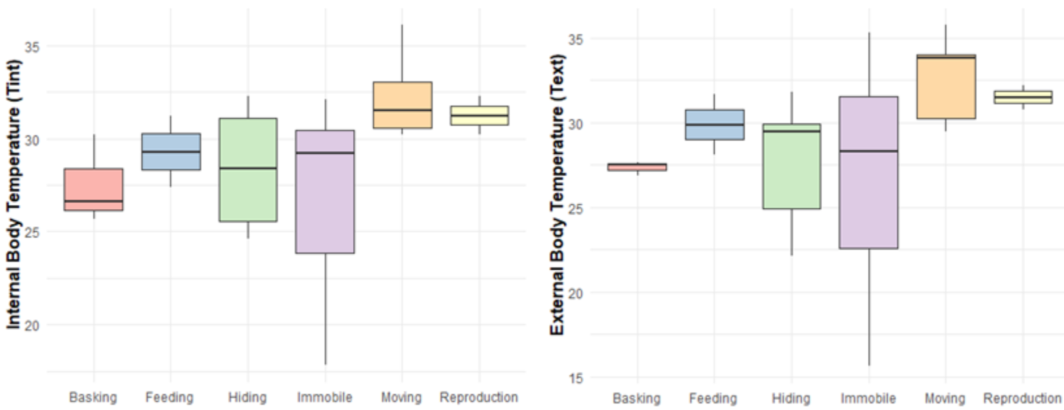

Figure 3. Box plots of internal body temperature (T_{int}) (A) and external body temperature (T_{ext}) (B) of individuals in the Karakoç population during different behaviours.

in T_{int} ($p > 0.05$). However, a statistically significant difference was observed in T_{ext}, with males having a higher T_{ext} than females ($U = 98.500$, $p = 0.032$). Lastly, T_{int} and T_{ext} of all individuals in the population during different behaviours are given in Fig. 3.

When examining the effects of weather conditions and sex on T_{int} and T_{ext} in the population, it was determined that weather had a statistically significant effect on T_{int} ($p = 0.0284$) and T_{ext} ($p = 0.0143$). However, neither sex nor the weather: sex interaction had a statistically significant effect on T_{int} and T_{ext} ($p > 0.05$). In cloudy weather, the mean T_{int} for male individuals was 25.97 °C, and the mean T_{ext} was 25.78 °C. For female individuals, the mean T_{int} was 26.81 °C, and the mean T_{ext} was 25.63 °C. In sunny weather, the mean T_{int} for male individuals was 30.78 °C, and the mean T_{ext} was 31.41 °C. For female individuals, the mean T_{int} was 28.58 °C, and the mean T_{ext} was 28.39 °C (Fig. 4).

Temperature measurements, behaviour and weather effects for the Keşan population. Microclimatic parameters (T_s, T_{air}), body temperatures (T_{int} and T_{ext}), and morphological features (BW, SCL) were recorded from 62 adult individuals (27 ♂♂, 35 ♀♀) of the Keşan population. During the field studies, the minimum T_{int} recorded was 20.60 °C, while the maximum T_{int} was 35.00 °C. The minimum T_{ext} was 17.95 °C, and the maximum T_{ext} was 35.45 °C. The minimum T_{air} was recorded as 20.90 °C, while the maximum was 33.90 °C. T_s ranged from a minimum of 12.30 °C to a maximum of 36.60 °C. Morphological features revealed that SCL ranged from 10.17 cm to 19.20 cm, while BW ranged between 320 g and 1700 g.

When examining the relationship between body temperatures, microclimatic parameters, and morphological features for all adult individuals in the population, a positive correlation was detected in males between T_s and T_{ext} ($p = 0.003$, $r = 0.544$), while there was no significant correlation between T_s and T_{int}. No significant correlation was found between T_{air} and body temperatures ($p > 0.05$). T_{int} and T_{ext} were positively correlated with each other ($p = 0.001$, $r = 0.807$) (Fig. 5A). No significant correlation was detected between morphological features and body temperatures ($p > 0.05$) (Fig. 5B). For female individuals, a positive correlation was found between T_s and T_{int} ($p = 0.001$, $r = 0.538$) and between T_s and T_{ext} ($p = 0.01$, $r = 0.698$). There was a positive correlation between T_{air} and T_{ext} ($p = 0.014$, $r = 0.411$), but no significant correlation was detected between T_{air} and T_{int} ($p > 0.05$). T_{int} and T_{ext} were also positively correlated with each other ($p = 0.001$, $r =$

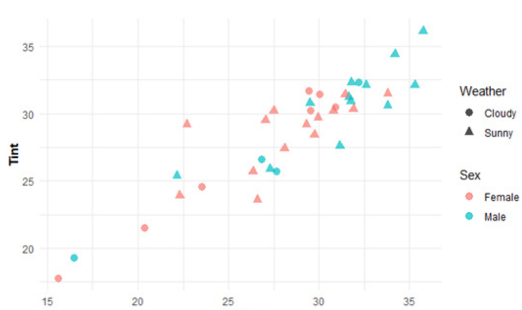

Figure 4. Scatter plots of internal body temperature (T_{int}) and external body temperature (T_{ext}) of individuals in the Karakoç population during different weather conditions.

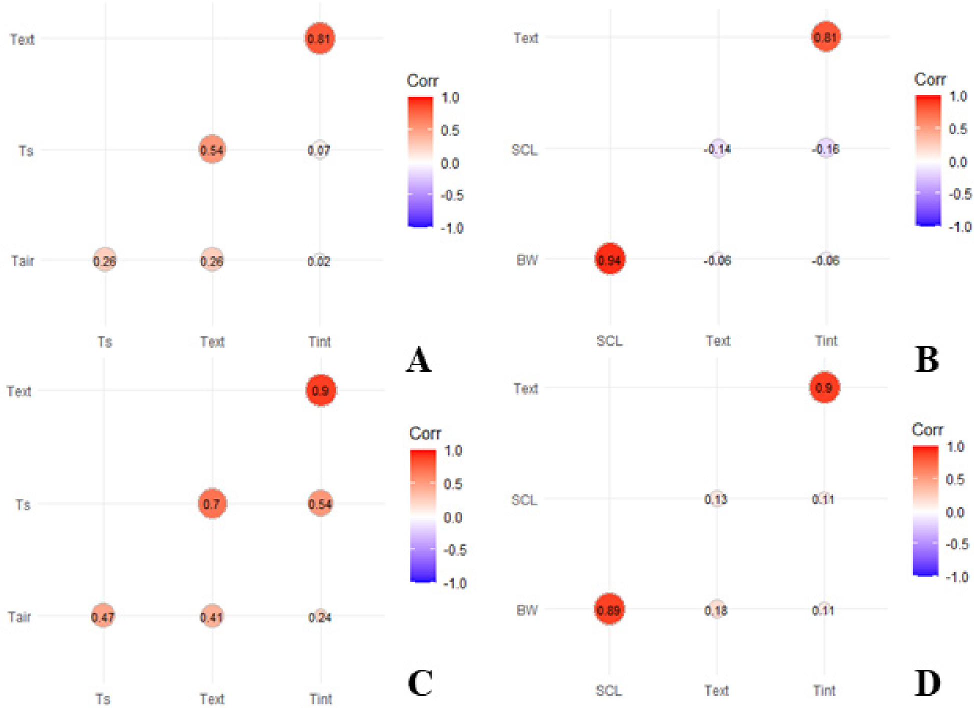

Figure 5. Multiple correlation graphs in the Keşan population. (A) Correlation between body temperatures and microclimatic parameters in males. (B) Correlation between body temperatures and morphological features in males. (C) Correlation between body temperatures and microclimate parameters in females. (D) Correlation between body temperatures and morphological features in females.

0.896) (Fig. 5C). No significant correlation was detected between morphological features and body temperatures ($p > 0.05$) (Fig. 5D). Also, no significant difference was found between male and female individuals in terms of T_{int} and T_{ext} temperatures ($p > 0.05$). Since there were no statistically significant differences between sexes, T_{int} and T_{ext} of all individuals in the population during different behaviours were given in Fig. 6.

When examining the effects of weather conditions (cloudy and sunny) and sex on T_{int} and T_{ext} in the population, no statistically significant effect of weather, sex, or the weather: sex interaction was detected ($p > 0.05$). In cloudy weather conditions, the mean T_{int} for male individuals was 29.65 °C, and the mean T_{ext} was 27.62 °C. For female individuals, the mean T_{int} was 28.63 °C, and the mean T_{ext} was 28.71 °C. In sunny weather conditions, the mean T_{int} for male individuals was 29.07 °C, and the mean T_{ext} was 28.44 °C. For female individuals, the mean T_{int} was 27.99 °C, and the mean T_{ext} was 27.53 °C (Fig. 7).

Comparison between populations. When the body temperatures of male and female individuals in the Karakoç and Keşan populations were compared, no statistically significant difference was determined ($p > 0.05$).

Discussion

This study presents important findings on the thermal ecology of *Testudo hermanni* populations in two different habitats in the Thrace region. The relationships between body temperatures, microclimatic parameters, morphological features, and behaviours were analysed to compare body temperatures between populations. Additionally, changes in body temperature under different weather conditions were examined, contributing to the limited knowledge of the thermal ecology of Hermann's Tortoise.

A strong correlation between T_{int}, T_{ext}, and T_s, highlighting *T. hermanni*'s dependence on substrate temperatures for thermoregulation, was observed in both populations. This result aligns with the study conducted

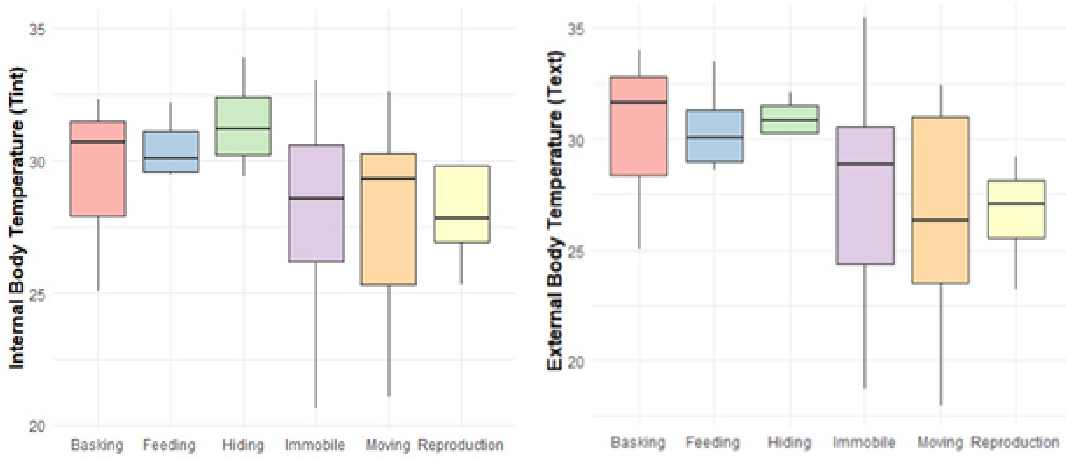

Figure 6. Box plots of internal body temperature (T_{int}) (A) and external body temperature (T_{ext}) (B) of individuals in the Keşan population during different behaviours.

by McMaster and Downs (2013), which demonstrated that carapace and plastron temperatures in Leopard Tortoises, *Stigmochelys pardalis* (Bell, 1828), closely reflect environmental temperatures. Similarly, Ortega et al. (2017) and Vujović et al. (2023) reported significant correlations between body temperature (T_b) and surface or environmental temperatures in *T. hermanni*, further supporting our findings. Moreover, the strong correlation between T_{int} and T_{ext} supports the idea that external body temperatures can serve as reliable indicators of internal temperatures in field studies (Terepolsky and Brereton, 2021).

In our study, *T. hermanni* individuals from both populations consistently exhibited body temperatures higher than air temperatures. These results are consistent with findings reported by Meek and Inskeep (1981), Meek (1984), and Filippi et al. (2010) in their studies on *T. hermanni*. The maximum T_{int} (36.10 °C) and T_{ext} (35.75 °C) recorded in the Karakoç population as well as the maximum T_{int} (35.00 °C) and T_{ext} (35.45 °C) recorded in the Keşan population were found to be higher than the 34.00 °C reported by Meek (1984) and Filippi et al. (2010). This discrepancy may be attributed to a combination of geographical and climatic differences. Our study areas were located in the Thrace region of Türkiye, where summer temperatures are generally higher and longer than in the Mediterranean regions of Italy and France, where the above-mentioned studies were conducted (Türkozan et al., 2019). Temperature differences resulting from this geographical difference exposed tortoises to more intense solar radiation and higher substrate temperature (T_s), which is critical for determining body temperature in tortoises (McMaster and Downs, 2013). Ortega et al. (2017) also emphasised that regional thermal environments can significantly affect body temperatures of tortoises, even within the same species. Therefore, climatic variation in different habitats, especially in terms of habitat type and sunlight exposure, probably played an important role in the slightly higher body temperature values recorded in our study.

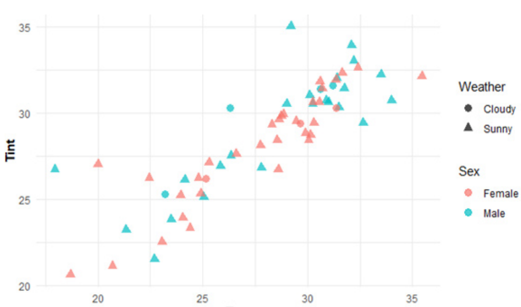

Figure 7. Scatter plots of internal body temperature (T_{int}) and external body temperature (T_{ext}) of individuals in the Keşan population during different weather conditions.

In this study, the body temperatures of male and female individuals from two different populations of *T. hermanni* were compared, and a statistically significant difference in T_{ext} between sexes was found only in the Karakoç population. This difference between the sexes may be attributed to the distinct thermal strategies used by males and females, as well as disparities in habitats. Similarly, Meek (1984) suggested that sexual differences in thermoregulation of *T. hermanni* may vary depending on habitat use. Lambert (1981) reported that small adult males of *T. graeca* Linnaeus, 1758 were active only below 28 °C, while medium and large males were active only in the morning and after 16:00 h above 28 °C. In contrast, females were active between 12:00 and 16:00 hrs, with three individuals recorded below 23 °C and two large individuals recorded above 28 °C. Furthermore, individuals in densely vegetated areas achieved lower body temperatures, likely due to the availability of shade and cooler ground temperatures. Ortega et al. (2017) found that male and female *T. h. hermanni* individuals were recorded at similar air temperatures, but males were found at higher substrate temperatures. Filippi et al. (2010) reported that female individuals had higher body temperatures than males and maintained a greater difference between body temperature and air temperature (T_b and T_a) compared to males. In our study, higher body temperatures observed in males of the Karakoç population were associated with open habitats and limited shade. This finding supports the hypothesis proposed by Moulherat et al. (2014) and is consistent with observations reported on by Vujović et al. (2023), who noted that individuals in more exposed habitats exhibited greater thermoregulatory effort and higher body temperatures in *T. hermanni* populations in Montenegro. Body size and morphology are known to affect thermoregulation efficiency in reptiles (Zimmerman and Tracy, 1989). However, no significant relationship was found between body temperatures and body size in our study. Our results align with research suggesting that behavioural thermoregulation plays a crucial role in regulating body temperatures in reptiles, making the effect of body size on thermal conductivity less apparent (Huey and Kingsolver, 1989; Akin, 2011). This result may be due to the relatively narrow size range of the studied individuals, which may have limited the detection of size–related thermal effects.

Behavioural adaptations such as basking, hiding, and movement are critical strategies reptiles use to regulate their body temperatures (Shine and Lambeck, 1985; Vitt and Caldwell, 2013). The T_{int} and T_{ext} temperature ranges observed during different behaviours in our study were consistent with activity–specific thermal ranges reported by Meek (1984) for *T. hermanni*. Meek (1984) reported that T_{int} in *T. hermanni* individuals ranged from 22.6 °C to 33.9 °C during movement, 27.5 °C to 32.8 °C during feeding, 25.5 °C to 32.0 °C during reproduction, and 21.4 °C to 34.2 °C during basking. The T_{int} and T_{ext} values in our study aligned with these findings. Higher temperatures recorded during basking and movement behaviours reflect active thermoregulation, while lower temperatures observed during inactivity or hiding indicate passive avoidance of thermal stress.

Weather conditions are known to have a significant impact on reptile body temperatures. Data from the Karakoç population showed that both male and female individuals reached higher body temperatures on sunny days, whereas these values decreased on cloudy days. These results are consistent with findings from studies by Lambert (1981) and Meek and Jayes (1982). In particular, Lambert (1981) reported that on sunny days, body temperatures of individuals were closer to the preferred thermal range of the species (28–35 °C). Ortega et al. (2017) also reported that *T. h. hermanni* individuals attained higher body temperatures in fully sunny conditions, emphasising the sun’s critical role in thermoregulation. These findings highlight the primary role of solar radiation as a crucial heat source for *T. hermanni*. In addition, our findings show important parallels with those reported by Vujović et al. (2023) for *T. hermanni* in southern Montenegro. In both studies, body temperatures of individuals were closer to the thermal ranges preferred by the species on sunny days and behavioural thermoregulation efficiency (E-score) increased in sunny conditions. For example, Vujović et al. (2023) reported that E-score increased from 0.31 to 0.38 in males and from 0.19 to 0.41 in females. This is consistent with the higher T_{int} and T_{ext} values observed in sunny weather in our study.

In this study, *T. hermanni* individuals from the Karakoç and Keşan populations in the Thrace region were compared in terms of body temperatures, and no statistically significant difference was found. Previous research has demonstrated that reptile body temperatures are closely linked to environmental temperatures, but thermoregulation mechanisms allow individuals to adapt to environmental changes (Lambert, 1981; Meek, 1984). While the Karakoç population inhabits more open and sunny habitats, the Keşan population is found in more isolated and wooded areas. However, our study revealed no significant difference in body temperatures between these two populations. This finding is consistent with other studies on similar reptile species. For instance, Lambert (1981) and Filippi et al. (2010) demonstrated that tortoises could maintain similar thermal ranges regardless of environmental conditions. One primary reason for this could be the ability of tortoises to modify their thermal behaviour under different climatic conditions. The denser vegetation in the Keşan population's habitat may allow individuals to maintain optimal body temperatures by utilising shade and cooler microhabitats. Similarly, individuals in the Karakoç population may optimise their basking durations to manage thermal stress in open areas. However, increasing habitat fragmentation and habitat loss may restrict these thermal behaviour modification abilities. Rising temperatures and decreasing microhabitat diversity may limit access to shaded or cool areas, negatively affecting tortoises' thermoregulation capabilities.

In conclusion, despite differences in habitat characteristics between the Karakoç and Keşan populations, no significant difference in body temperatures was detected. The results indicate that *T. hermanni* individuals can maintain optimal body temperatures through behavioural strategies, regardless of habitat type or climatic variations. However, increasing habitat fragmentation and loss, along with rising temperatures, may reduce the availability of shaded and cool microhabitats, potentially affecting individuals' thermoregulation strategies. Future studies should investigate the long–term effects of climate change on the thermal ecology of *T. hermanni* and focus on potential changes in behaviour, habitat use, and population dynamics. Such research is crucial for developing targeted conservation strategies for this endangered species and ensuring its survival in rapidly changing environmental conditions.

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