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Please cite this article as:

Özgül, C.N., Boran, B., Kurtul, D., Baycan, B., Gül, Ç., Tosunoğlu, M. (2026): 13-Year Resurvey of *Emys orbicularis* (Linnaeus, 1758) in the Kavak Delta (Northwestern Türkiye):

Population Density, Morphology, and Body Condition. Acta Herpetol. **21**. DOI:

10.36253/a_h-20318

13-Year Resurvey of *Emys orbicularis* (Linnaeus, 1758) in the Kavak Delta (Northwestern Türkiye): Population Density, Morphology, and Body Condition

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Running Title: Population Dynamics of *Emys orbicularis* After 13 Years

Submitted on: 2026, 20th April; revised on: 2026, 30th September; accepted on: 2026, 1st October.

Editor: Francesco Luigi Leonetti

Abstract.

This study examines the morphological and demographic changes of the *Emys orbicularis* population inhabiting a geographically discrete wetland habitat in the Kavak Delta of northwestern Türkiye over a 13-year period between 2012 and 2025. Population size and density were estimated through capture-mark-recapture studies conducted during both periods, and morphometric characteristics and body condition indices (BCI) of individuals were analyzed. The results showed that female-biased sexual size dimorphism ($SDI > 0$) was maintained in both sampling periods. More importantly, comparisons between 2012 and 2025 revealed significant temporal changes in several morphometric traits and body condition, with males differing in carapace width, shell height, and body condition index, and females showing changes in body weight, straight carapace length, carapace width, plastron width, and body condition index. The decrease in BCI values in both sexes in 2025 suggests the possibility of resource limitation associated with increasing population density. These findings highlight the importance of long-term monitoring and wetland habitat conservation to assess the status of geographically discrete *E. orbicularis* populations and guide their effective conservation and management.

Keywords. *Emys orbicularis*, capture–mark–recapture, population density, body condition index (BCI), wetland ecology.

INTRODUCTION

Emys orbicularis (Linnaeus, 1758) is distributed across North Africa, the Mediterranean Basin, temperate regions of Europe, and the Middle East extending to the Aral Sea (Fritz, 1998; 2001; 2003; Ramos et al., 2009). In Türkiye, the species occurs in both Anatolia and the Thrace region (Baran et al., 2005). The population inhabiting the Kavak Delta belongs to the subspecies (or lineage) *Emys orbicularis orbicularis* (Pöschel et al., 2018). According to the International Union for Conservation of Nature (IUCN) Red List criteria, *E. orbicularis* is classified globally as Near Threatened (NT) (IUCN, 2026). While the species is considered threatened in many regions and throughout the Mediterranean coasts (Fritz and Andreas, 2000; Keller and Andreu, 2002), it is also under threat in Türkiye due to habitat loss and fragmentation (Ayaz et al., 2007). Additionally, this species is increasingly vulnerable to the loss of suitable habitats resulting from intensified agriculture and increased water management practices. Research on local population size and structure is of great importance, as such data forms the basis for any conservation measures to be implemented.

Body size in freshwater turtles is an important life history feature, as it is closely related to growth, survival, reproductive efficiency and individual fitness. Variation in body size and body fitness may reflect habitat quality, resource availability, and long-term environmental changes, making these parameters valuable indicators for population health and conservation status. In long-lived species such as *E. orbicularis*, monitoring temporal changes in morphometric characteristics can provide important information about the population's responses to environmental conditions and habitat quality. Body size in *E. orbicularis* is greatly influenced by external factors such as geographical location and environmental conditions (Fritz, 2001; 2003). While individuals from some populations in Central Anatolia can reach a body size of up to 200 mm, populations living in areas closer to the Aegean and Mediterranean

coasts tend to exhibit smaller body sizes (Fritz, 2001; 2003; Taşkavak and Ayaz, 2006; Bayrakçı et al., 2015).

Numerous studies have addressed distribution, population structure, population estimates, and body size in *E. orbicularis* populations (Ayaz, 2003; Ayaz et al., 2004; Auer and Taşkavak, 2004; Taşkavak and Ayaz, 2006; Ayaz et al., 2007; Ayaz et al., 2008; Ayaz and Çiçek, 2011; Bayrakçı et al., 2015). Long-term monitoring is essential to understand temporal changes in population size, body condition and demographic structure in freshwater turtles, which provides valuable information to assess population health and guide conservation management (Rhodin et al., 2018; Stanford et al., 2020). However, long-term capture-mark-recapture studies on the *E. orbicularis* species are still scarce in a large part of the species' distribution area, including Türkiye. The population living in the Kavak Delta (Çanakkale, northwestern Türkiye), provides a valuable opportunity to assess changes over a 13-year period. Although various ecological and health-related studies have been conducted on this population, including its microbial flora, pathogenic bacteria, and the hematological, microbiological, and genotoxic effects of environmental pollutants (Hacıoğlu et al., 2022; Çördük et al., 2024); there are no previous studies evaluating long-term changes in body condition, morphometric characteristics, sexual size dimorphism, and population size. Therefore, the aim of this study is to evaluate the temporal changes in the morphometric characteristics, sexual size dimorphism, body condition and population parameters of the *E. orbicularis* population living in the Kavak Delta using the capture-mark-recapture data collected in 2012 and 2025.

MATERIAL AND METHODS

Study area

Kavak Delta is located in the northeastern Aegean Sea of Türkiye, on the eastern shore of the Saros Gulf, in the northwestern part of the Gallipoli Peninsula (40°38'7.34"N, 26°51'24.61"E). The Delta represents an important coastal wetland ecosystem located at the transition between the Marmara and Mediterranean climate zones. The delta has a high biodiversity and forms a mosaic of various habitats, including wetlands, coastal dunes, halophytic vegetation, shrublands, rocky areas, and woodland patches (Kelkit et al., 2008; Uysal, 2011). Kavak Delta has been designated as a Wetland of Local Importance by the Ministry of Agriculture and Forestry of the Republic of Türkiye under the National Wetlands Commission (Ministry of Agriculture and Forestry, 2025). Although *E. orbicularis* occurs in various wetlands along the delta, this study focused on a geographically discrete wetland area of 6.26 hectares (Fig. 1). The study wetland also provides habitat for *Mauremys rivulata* (Valenciennes, 1883) population, which occurs sympatrically with *Emys orbicularis*. This area was chosen because it supports a natural population of *E. orbicularis* and was studied using the same capture-mark-recapture protocol in 2012; this provided an opportunity to assess temporal changes in population size, morphometric characteristics and body condition over a 13-year period under comparable sampling conditions. Long-term monitoring based on standardized capture-mark-recapture methods is necessary to detect temporal changes in freshwater turtle populations and provides valuable information for conservation planning (Lovich et al., 2018; Stanford et al., 2020). No reintroduction or translocation of terrapins has been documented for this population; therefore, it is considered native. The study wetland consists of shallow freshwater habitats with abundant emergent and aquatic vegetation that provide suitable basking, foraging, and nesting habitats for *E. orbicularis* (Uysal, 2011). All capture-mark-

recapture surveys and morphometric measurements were carried out within this 6.26-hectare study area.

Field studies and data collections

Terrapins used in this study were captured from a locality in the Kavak Delta during two sampling periods: 2012 (April, May, and June) and 2025 (March, April, and May). In each sampling period, three capture sessions were conducted at approximately monthly intervals using standardized net trapping methods. During each capture session in both years, three observers conducted field surveys, each using a hand net, between 09:00–11:00 and 12:00–14:00. To ensure comparability between sampling periods, the same sampling area, capture method, and research protocol were applied in both years (McDiarmid, 2012). Sampling effort (e.g., number of survey days, number of observers, and capture hours) was kept comparable between 2012 and 2025 to ensure methodological consistency. A total of 62 adult individuals (35 males and 27 females) were sampled in 2012 and 79 adult individuals (46 males and 33 females) in 2025. Juvenile and subadult individuals lacking distinguishable secondary sexual characteristics were occasionally captured but were excluded from sex-specific analyses as their sex could not be reliably determined. Individuals with a straight carapace length (SCL) of less than 100 mm were classified as juveniles (Escoriza et al., 2020). Only adult individuals were included in the analyses. Sex was determined based on evident phenotypic sexual characteristics (Zuffi et al., 1999), including tail length, the position of the cloaca relative to the anal scutes, and head coloration (Alarcos et al., 2019).

Population size was estimated using a closed population capture–mark–recapture (CMR) design (Otis et al., 1978) with separate analyses conducted for the 2012 and 2025 sampling periods. Capture histories were constructed from individual encounter records. Each captured individual was uniquely marked by applying a shell-notching code to the marginal scutes,

enabling reliable identification upon recapture. Marks were assumed to be permanent and correctly recorded. After processing, individuals were released at their point of capture. Individuals marked during the 2012 survey retained their shell notches, allowing identification if recaptured during the 2025 survey; however, the 2012 and 2025 datasets were analyzed independently, and encounter histories from the two sampling periods were not combined. Density estimates assumed a uniform spatial distribution of individuals within the defined study boundaries and equal sampling coverage across the entire study area.

Morphometric measurements, including straight carapace length (SCL), carapace width (CW), carapace height (CH), plastron length (PL), and plastron width (PW), were obtained using Mitutoyo digital calipers (± 0.01 mm). For larger individuals whose shell dimensions exceeded the measuring capacity of the calipers, a tortometer, a measuring device specifically designed for turtles that enables accurate measurement of straight shell dimensions, was used to measure straight carapace and plastron lengths. Body mass was measured using either a digital balance (precision: 0.01 g) or an analog scale, depending on the size of the individual.

Body condition index (BCI) was calculated as the ratio of body mass (g) to shell volume (cm^3 ; $\text{SCL} \times \text{CH} \times \text{CW}$), following Nagy (2002). Sexual size dimorphism was assessed using the sexual dimorphism index (SDI) for adult individuals (Lovich and Gibbons, 1992). SDI was calculated as the ratio of the mean size of the larger sex to that of the smaller sex, with +1 added when males were larger and -1 when females were larger. Accordingly, negative SDI values indicate male-biased sexual size dimorphism, whereas positive values indicate female-biased sexual size dimorphism.

Statistical analysis

The standard values of the obtained data were evaluated by using Microsoft Excel, IBM SPSS Statistics 27 and R Project for Statistical Computing programs. Data normality was

assessed using the Kolmogorov-Smirnov test. Morphometric comparisons were performed in two ways: (i) between males and females within each sampling year and (ii) between sampling years for males and females separately. For each comparison, variables satisfying the normality assumption were analyzed using Student's t-test, while variables violating the normality assumption were analyzed using the Mann-Whitney U test. Differences between the observed and expected (1:1) sex ratios were assessed separately for each sampling year using chi-square goodness-of-fit tests.

Population size analyses were conducted in R version 4.4.2 (R Core Team, 2025) using the package Rcapture (Baillargeon and Rivest, 2007). Closed-population abundance was estimated using the closedp() function, which fits log-linear Poisson regression models to capture histories under the framework of closed-population capture-mark-recapture models (Otis et al., 1978; Baillargeon and Rivest, 2007). Competing models were fitted to the encounter histories: M0 (constant capture probability), Mt (time-dependent capture probability), Mh (individual heterogeneity in capture probability), Mb (behavioral response to capture), Mth, and Mbh (interaction models). Model selection was based on Akaike's Information Criterion (AIC), and the model with the lowest AIC was considered the best-supported model. Abundance estimates ($\hat{N}$) and their standard errors (SE) were obtained from the selected model. Approximate 95% confidence intervals were calculated as:

$$\hat{N} \pm 1.96 \times SE$$

The assumption of population closure (no births, deaths, immigration, or emigration during sampling) was considered biologically reasonable given the short duration of each sampling session and the restricted study area. Closure was additionally evaluated using capture frequency patterns and goodness-of-fit diagnostics within the closed-population framework. Capture frequency distributions were examined to evaluate detection heterogeneity and to interpret differences in model performance between years.

RESULTS

Morphometric measurements

Morphometric measurements were analysed for 62 individuals in 2012 and for 79 individuals in 2025. Sexual size dimorphism analyses yielded positive Sexual Dimorphism Index (SDI) values for both periods (SDI = 0.1381 for 2012 and SDI = 0.1000 for 2025), indicating female-biased sexual size dimorphism in each sampling period. Descriptive statistics for the morphometric variables of both populations are presented in Table 1.

The analyses of individuals sampled in 2012 and 2025 revealed clear sexual differences in morphometric measurements. Among individuals sampled in 2012, statistically significant differences between males and females were detected for all morphometric parameters as well as for the Body Condition Index (BCI). According to the Mann–Whitney U test results, females exhibited significantly higher values than males in body weight (BW; $U = 86.500$, $p = 0.001$), straight carapace length (SCL; $U = 134.500$, $p = 0.001$), carapace width (CW; $U = 248.000$, $p = 0.001$), plastron length (PL; $U = 67.000$, $p = 0.001$), plastron width (PW; $U = 82.000$, $p = 0.001$), shell height (SH; $U = 78.000$, $p = 0.001$), and BCI ($U = 321.000$, $p = 0.031$). Similarly, in the 2025 population, significant differences between sexes were observed for all morphometric parameters. Females showed significantly higher values than males in BW ($U = 268.500$, $p = 0.001$), SCL ($U = 384.000$, $p = 0.001$), CW ($U = 352.000$, $p = 0.001$), PL ($U = 239.000$, $p = 0.001$), PW ($U = 261.000$, $p = 0.001$), and SH ($U = 220.000$, $p = 0.001$). However, unlike the 2012 individuals, no statistically significant difference between males and females was detected for BCI in the 2025 individuals ($U = 666.000$, $p = 0.355$).

Overall, the comparison of morphometric measurements between periods revealed significant differences in males for carapace width (CW), shell height (SH), and Body Condition Index (BCI) ($p < 0.05$). In females, persistent and statistically significant differences

between periods were observed for body weight (BW), straight carapace length (SCL), carapace width (CW), plastron width (PW), and BCI ($p < 0.05$) (Table 2) (Fig. 2).

The observed sex ratio was male biased in both sampling years (2012: 35 males, 27 females; 2025: 46 males, 33 females). However, chi-square goodness-of-fit tests indicated that neither deviated significantly from the expected 1:1 sex ratio (2012: $\chi^2 = 1.03$, $df = 1$, $p = 0.31$; 2025: $\chi^2 = 2.14$, $df = 1$, $p = 0.14$).

Population size and density estimate

Five individuals marked during the 2012 sampling period were recaptured in 2025, confirming long-term survival and the persistence of shell notch marks. These recaptures were recorded as part of the 2025 field survey but were not used to combine encounter histories across years, as abundance was estimated independently for each sampling period. In 2012, 74 individuals were recorded, including 12 recaptures (62 individuals captured once and 12 captured twice). Among the closed-population models fitted in Rcapture, the constant capture probability model (M0) received the strongest support ($AIC = 33.69$), yielding identical abundance estimates of 195.4 ± 45.6 individuals (95% CI, 106.0–284.8). Given the 6.26 ha study area, this corresponds to a density of 31.2 individuals per hectare (95% CI, 16.9–45.5).

In 2025, 85 individuals were recorded, including 6 recaptures (79 individuals captured once and 6 captured twice). Among the closed-population models, the time-dependent capture probability model (Mt) and the interaction model (Mth Chao LB) received the strongest support ($AIC = 31.71$), yielding an abundance estimate of 438.1 ± 162.4 individuals (95% CI, 120.2–756.1). Given the 6.26 ha study area, this corresponds to a density of 70 individuals per hectare (95% CI, 19.2–120.8).

DISCUSSION

The most widely accepted and commonly used index for calculating sexual size dimorphism in terrapins is the Sexual Dimorphism Index (SDI) (Lovich and Gibbons, 1992; Smith, 1999; Cox et al., 2003; Fairbairn et al., 2007; Lovich et al., 2014). In SDI calculations, negative values indicate male-biased sexual size dimorphism, whereas positive values represent female-biased dimorphism. The results of the present study revealed female-biased sexual size dimorphism in both sampling periods (2012: SDI = 0.138; 2025: SDI = 0.100). These findings are consistent with previous studies (Zuffi et al., 1999; Fritz, 2001; 2003; Fediras et al., 2017). Female-biased dimorphism is generally considered a common pattern within the family Emydidae (Cox et al., 2007).

According to Bury (1978), male freshwater turtles generally reach sexual maturity earlier than females. After reaching sexual maturity, growth rate decreases substantially, and growth becomes progressively slower as individuals increase in size. Furthermore, due to their smaller body size, males may benefit from greater mobility, enabling them to hide more effectively and avoid predation (Magnhagen, 1991). In contrast, the broader and higher carapace observed in females is considered an adaptation allowing the accommodation of a larger number of eggs (Ernst et al., 1998; Muñoz and Nicolau, 2006). Larger carapace length and plastron width in females are positively correlated with clutch size (Zuffi et al., 1999; Mitrus and Zemanek, 2004). Similarly, in the present study females were significantly larger than males in all morphometric parameters examined, supporting this classical reproductive strategy model.

Fritz (2001, 2003) suggested that body size in *E. orbicularis* is related to latitude and climate, with southern populations generally being smaller and northern populations tending to reach larger body sizes. Bayrakçı and Ayaz (2014) reported that individuals in Central Anatolia may reach carapace lengths up to 200 mm, whereas populations along coastal regions and in some parts of Inner Anatolia consist of relatively smaller individuals. In individuals attributed

to the subspecies *E. o. luteofusca sensu lato* average carapace length has been reported as 122.9 mm (89–155 mm) for males and 137.3 mm (105–183 mm) for females (Ayaz et al., 2008). In that study, the maximum recorded carapace length (183 mm) belonged to a female individual from Central Anatolia.

The morphometric values recorded in the present study (mean carapace length in 2012: males 11.94 cm, females 13.59 cm; in 2025: males 11.70 cm, females 12.8 cm) are consistent with those reported for western and coastal populations of Türkiye and are smaller than the large-bodied populations found in Central Anatolia. This pattern suggests that climatic conditions may play an important role in determining body size. Therefore, although some shifts in population-level size averages were observed over the 13-year interval, the morphometric characteristics remain within the known geographical variation range of the species.

When the body condition of individuals from the Kavak Delta population was examined, all individuals showed positive values in both sampling periods (BCI values in 2012: males 0.63, females 0.69; in 2025: males 0.56, females 0.57) (Fig. 2). A body condition value above zero indicates that individuals are in good physical condition (Stevenson and Woods, 2006; Alcayde, 2007). Mollov et al. (2021) reported similarly positive body condition values in all *E. orbicularis* individuals studied in Bulgaria and interpreted this finding as an indirect indicator of healthy turtles and well-preserved habitats. The positive values obtained in the present study are therefore consistent with these findings. However, one notable result is the decline in BCI values observed in both sexes in 2025. This pattern may indicate density-dependent resource limitation associated with increased population density. As highlighted by density-dependent theory, increasing population density can lead to intensified resource competition and reduced individual condition (Bonnet et al., 2002; Begon et al., 2006). Thus, the decrease in average

body condition despite an apparent increase in population density may suggest that the population could be approaching the carrying capacity of the habitat.

Although more males than females were captured during both sampling periods, the observed sex ratios did not differ significantly from the expected 1:1 ratio. Therefore, the apparent male-weighted sex ratio is more likely to reflect differences in capture probability rather than a true demographic imbalance. Since males can mate with more than one female, small deviations from an equal sex ratio are unlikely to have major consequences on the population viability, provided that a sufficient number of reproductively capable females are preserved (Bayrakçı et al., 2016). In freshwater turtles, changes in seasonal activity patterns, such as increased male activity during mate seeking, especially during breeding season, can increase their chances of being captured compared to females (Gibbons, 1990; Brown and Brooks, 1993). Furthermore, sex ratios estimated from capture-mark-recapture studies may be influenced by sex-specific differences in habitat use, basking behaviour, and detectability rather than the true operational or population sex ratio (Gibbons, 1990; Cadi and Joly, 2003).

Population density increased from 31.2 individuals per hectare in 2012 to 70 individuals per hectare in 2025. Reported densities for *E. orbicularis* populations in Türkiye range between 22.5 and 130 individuals per hectare (Auer and Taşkavak, 2004; Ayaz et al., 2007; Bayrakçı and Ayaz, 2014). In this context, the value recorded in 2012 falls within the lower-middle range, whereas the estimate obtained for 2025 corresponds to a moderate density for Turkish populations. Very high densities, such as 242 individuals per hectare reported by Ayaz et al. (2007), have been interpreted as indicators of well-preserved and developing populations. Although only five individuals marked in 2012 were recaptured during the 2025 survey, these long-term recaptures confirm both the persistence of shell notches and the long lifespan of *E. orbicularis*. Freshwater turtles are characterized by delayed sexual maturity, high adult survival, and longevity; consequently, individuals may remain within populations for decades (Congdon

et al., 1993; Ernst and Lovich, 2009). Nevertheless, the low number of long-term recaptures indicates that most turtles encountered in 2025 were not individuals previously captured in 2012. This pattern may reflect natural population turnover, recruitment of previously unmarked individuals, imperfect detection, and temporal variation in capture probability rather than methodological differences alone. Therefore, the abundance estimates obtained for 2012 and 2025 should be interpreted as independent estimates of the same biological population based on separate capture histories.

An important consideration of the present study concerns the assumed isolation of the study population. Although no *E. orbicularis* individuals were observed outside the study area during our surveys, complete demographic isolation from other populations in the Kavak Delta cannot be conclusively established. Thus, potential movement between the study wetland and nearby suitable habitats cannot be excluded, and the population is better considered geographically discrete rather than completely isolated at the landscape scale. This limitation should be considered when interpreting temporal changes in abundance, as immigration or emigration may have contributed to differences in population estimates.

Nevertheless, as emphasized by Liuzzo et al. (2021), abundance estimates for *E. orbicularis* may vary considerably depending on sampling effort, methodological approaches, and capture probability. The relatively low recapture rate observed in 2025 suggests that caution should be exercised when interpreting the apparent increase in population size. Similarly, Fediras et al. (2017) noted that only a small proportion of individuals are typically recaptured during capture-mark-recapture sessions and emphasized the importance of combining different sampling techniques to obtain a more accurate representation of population structure. Therefore, part of the observed increase may be related to methodological sensitivity rather than a true demographic expansion. However, there is no evidence of population decline in either sampling period.

At the European scale, population densities vary widely. Very low densities have been reported from Italy, ranging from 3–10 individuals per hectare (Mazzotti et al., 2007) to 9.4 individuals per hectare (Seglie, 2015), whereas extremely high densities reaching up to 1030 individuals per hectare have been reported from Spain (Ramos et al., 2009). In addition, *E. orbicularis* has frequently been reported to occur sympatrically with *M. rivulata* in Mediterranean and Aegean coastal habitats, where interspecific competition may influence population density (Ayaz and Çiçek, 2011; Bayrakçı and Ayaz, 2014). Considering that the population examined in the present study also coexists with *M. rivulata*, the observed moderate population density may have been influenced by interspecific competition. Overall, the density values recorded in this study fall within the intermediate range reported for the species, indicating that the habitat continues to provide adequate carrying capacity despite its relatively limited spatial extent.

As a result, the *E. orbicularis* population living in the Kavak Delta has maintained its existence during the 13-year study period and seems to maintain a viable population despite changes in demographic and morphological parameters. The increase in estimated population density, along with the decrease in body fitness, suggests that density-related processes, changes in resource availability, or other environmental factors may affect individual fitness. Although the population seems stable at the moment, these findings suggest that population size alone is not sufficient to assess population status in long-lived freshwater turtles. Our results demonstrate the value of integrating demographic, morphometric and body condition data in long-term monitoring programs to detect changes that may not be understood from abundance estimates alone. Along with maintaining wetland habitat quality and maintaining natural hydrological conditions, the continuation of standardized monitoring will be essential to ensure the long-term continuity of this native *E. orbicularis* population in the Kavak Delta.

Acknowledgements.

This work was supported by Çanakkale Onsekiz Mart University, The Scientific Research Coordination Unit, Project no. FHD-2025-5048. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed. For the conducted studies, the necessary permissions were obtained from the Ethics Committee of Animal Experiments of Çanakkale Onsekiz Mart University (decision no. 2024/07-0).

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TABLES

Table 1. Descriptive statistics of morphometric measurements of all periods.

		Male						Female					
		N	Min	Max	Mean	SE	SD	N	Min	Max	Mean	SE	SD
2012	BW (g)	35	172	373	269.26	9.756	57.716	27	167	721	485.67	25.404	132.003
	SCL (cm)	35	10.18	13.58	11.9440	0.16178	0.95711	27	10.17	15.21	13.5937	0.24309	1.26315
	CW (cm)	35	8.06	10.55	9.3506	0.11367	0.67247	27	7.72	11.80	10.0700	0.17658	0.91751
	PL (cm)	35	9.05	11.88	10.4154	0.13203	0.78111	27	9.36	14.54	12.6856	0.23511	1.22166
	PW (cm)	35	4.71	7.17	6.2631	0.09001	0.53248	27	5.39	8.48	7.4989	0.14525	0.75477
	SH (cm)	35	2.8	6.0	3.771	0.0967	0.5722	27	3.2	6.5	5.015	0.1323	0.6876
	BCI	35	0.41	0.76	0.6394	0.01	0.079	27	0.55	0.83	0.69	0.015	0.0792
2025	(g/cm ³)												
	BW (g)	46	140	480	247.39	9.618	65.232	33	160	640	379.39	21.681	124.548
	SCL (cm)	46	10.10	14.76	11.7085	0.13089	0.88771	33	10.40	15.30	12.8800	0.23530	1.35172
	CW (cm)	46	7.69	10.70	8.8159	0.08878	0.60216	33	7.92	11.34	9.6212	0.15296	0.87867
	PL (cm)	46	8.83	13.45	10.3259	0.11657	0.79065	33	9.40	14.60	12.0782	0.24444	1.40419
	PW (cm)	46	5.28	7.58	6.0898	0.06805	0.46155	33	5.33	8.35	7.0288	0.13688	0.78632
	SH (cm)	46	3.37	5.26	4.1757	0.05092	0.34534	33	3.62	6.21	5.1236	0.12297	0.70643
	BCI	46	0.43	0.72	0.5647	0.01040	0.07054	33	0.47	0.73	0.579	0.01126	0.06469
	(g/cm ³)												

(N: sample size, SD: standard deviation, SE: standard error; Min: minimum value; Max: maximum value, body weight: BW, straight carapace length: SCL, carapace width: CW, plastron length: PL, plastron width: PW, shell height: SH, BCI: Body Condition Index).

Table 2. Comparison of morphometric measurements between the 2012 and 2025 sampling periods for males and females.

	Male					Female				
	Mann-Whitney U		T-Test			Mann-Whitney U		T-Test		
	U	p	t	df	p	U	p	t	df	p
BW	630.000	0.094				BW*	226.000	0.001		
SCL	651.000	0.142				SCL*	294.000	0.024		
CW*	445.000	0.001				CW*	310.500	0.045		
PL	707.000	0.350				PL	326.500	0.077		
PW	604.000	0.055				PG*	276.500	0.012		
SH*	365.500	0.000				SH	380.000	0.330		
BCI*			4.415	79	0.000	BCI*		6.040	58	0.000

* Measurements showing statistically significant differences between sampling periods within males or females (t: T-value, df: Degree of Freedom, p: Significance, U: Mann-Whitney U value). Student's t-test was applied only to BCI, which satisfied the assumption of normality in both sampling years according to the Kolmogorov–Smirnov test. Other variables were analyzed using the Mann–Whitney U test.

568 **Fig. 1.** Study area (ESRI Global, 2026).

569 **Fig. 2.** Comparative boxplots of body weight (BW), straight carapace length (SCL), carapace
570 width (CW), plastron length (PL), plastron width (PW), shell height (SH), and body condition
571 index (BCI) of male and female *Emys orbicularis* between 2012 and 2025.

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