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Morphometric study of Balkan Terrapin, *Mauremys rivulata* (Testudines: Geoemydidae) in Çanakkale (Turkey)

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Abstract
Mauremys rivulata (Family *Geoemydidae*) is a medium-sized freshwater turtle inhabiting various natural and manmade habitats, including rivers, seasonal ponds, lakes, brackish coastal lagoons, irrigation canals, and reservoirs. In this study, the morphology of four different *Mauremys rivulata* populations in Çanakkale was evaluated between populations and sexes. The straight carapace length (SCL), carapace width (CW), plastron length (PL), plastron width (PW), body weight (W) measurements were obtained from a total of 114 adult specimens from four populations. The body sizes were examined comparatively in four *Mauremys rivulata* populations from Kavak Delta located in the Thrace region, City Center located in Anatolia, and two islands (Gökçeada and Bozcaada) which are the districts of Çanakkale. Significant differences were found between males and females in all populations, with females being larger than males. When the four populations were compared, it was determined that Gökçeada population is the largest specimens (Female SCL 197,23±7,545; Male SCL 187,47±13,757) and City Center population is the smallest specimens (Female SCL 152,02±23,391; Male SCL 129,67±20,466).

Keywords: Body size, Çanakkale, morphology, freshwater turtles

1. Introduction
Turtles differ from other reptilian species by their slow growth characteristics, longevity that ensures the sustainability of the population, and long generation times [12, 27, 22]. Due to these characteristics, low individual displacement occurs between populations, making this group more susceptible to anthropogenic threats and environmental weather conditions [26, 23]. It is thought that turtles should be under special protection due to their low reproductive capacity, late maturity, and habitat sensitivity of wetlands and terrestrial environments [7, 17]. Freshwater turtles play an important role in maintaining the balance in the ecosystem of wetlands and are expressed as an indicator of a healthy aquatic ecosystem [16].
Mauremys rivulata (Family *Geoemydidae*) is a medium-sized freshwater turtle inhabiting various natural and manmade habitats, including rivers, seasonal ponds, lakes, brackish coastal lagoons, irrigation canals, and reservoirs [21]. Aegean populations of *M. rivulata* are typically found in estuaries of streams and rivers [6]. *M. rivulata* ranges from coastal Crotia, Bosnia-Herzegovina, Montenegro, and Albania, through most of Greece (many Aegean and Ionian islands), southeastern Macedonia and southern Bulgaria, to the Marmara Sea region, and widely through the Mediterranean regions and river basins of Turkey to Western Syria, Lebanon, Northwestern Jordan and Northern and Central Israel [29]. The species is not yet listed on the global IUCN Red List, but an IUCN Regional evaluation for Europe and a draft global assessment by the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group have both categorized the species as Least Concern [21]. Within its vast range across southeast Europe and western Asia Minor, a considerable local decline of this turtle's populations was observed over the last decades chiefly due to the loss of wetland habitats [6]. *M. rivulata* is common in continental Greece and quite widespread in many Aegean islands [9]. According to an inventory drawn up by WWF Greece, wetland structures on Aegean islands tend to be small in scale. That makes them more vulnerable to damage and destruction [6].
M. rivulata is a medium-sized freshwater turtle (carapace length to ca. 240 mm in females, ca185 mm in males) [21].

Shell size in *M. rivulata* reaches a straight carapace length (CL) of up to 244 mm in females, and up to 187 mm in the slightly smaller males [25, 20]. Males usually have a longer post-anal tail length, and the base of the tail is wider than that of females. Males have a generally flatter appearance than females and their plastron is slightly concave [31, 25, 4]. Morphometry and sexual dimorphism studies of the genus *Mauremys* are quite abundant [25, 15, 24, 3, 10, 19, 11, 28, 33, 32, 18]. The morphology of *M. rivulata* populations distributed in Çanakkale has been studied separately [5, 11], but there is no study comparing the populations of Kavak Delta, City Center, Bozcaada (Tenedos) and Gökçeada (Imbros).

The aim of this study is to investigate the morphological differences and sexual dimorphism between *Mauremys rivulata* populations distributed in four different localities (Kavak Delta, City Center, Gökçeada and Bozcaada) in Çanakkale.

2. Materials and Methods

2.1. Study Sites

The study area consists of 4 different localities within the provincial borders of Çanakkale. 1. Kavak Delta (Thrace region) (35T486634; 4493517; Height: 0 m): It is in the northwest of Turkey, in the region where the Kavak Creek empties into the Saros Gulf. The anthropogenic factors are effective, and the habitats of reptilian species are damaged and adversely affected. 2. City Center (Anatolia) (35T445691; 4438010; Height: 0 m): Specimens were caught from the stream flowing into the sea in the Kepez Delta located in the center of Çanakkale province. There are anthropogenic factors and agricultural areas in this area. 3. Bozcaada (Tenedos) (35S417612; 4410562; Height: 0 m): Bozcaada, the Aegean island, is one of the two islands of Çanakkale and tourism and agricultural activities are intense. There is no natural water source; small streams are formed in spring. Specimens were caught from Azmak stream located at Çayır. 4. Gökçeada (Imbros) (35T0405784; 4453706; Height: 0 m). The surface area of Gökçeada, which is an Aegean island, is larger than Bozcaada. Specimens were caught from the Büyükdere creek, which is at sea level, in Kaleköy and and this area was affected by anthropogenic factors. The map of the localities is given in Figure 1.

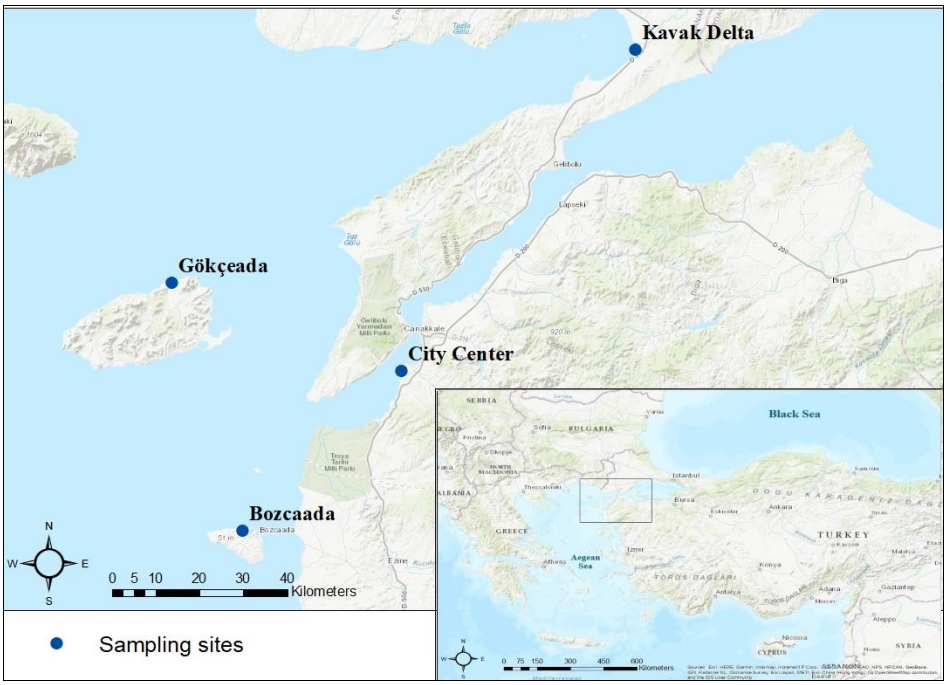

Fig 1: The locations where the specimens were collected (https://www.esri.com).

2.2. Capturing of Turtles

The necessary permissions were obtained from the Ethics Committee of Animal Experiments of Çanakkale Onsekiz Mart University (Decision number: 2018/09-06) for the studies that carried out.

Field studies were conducted at each locality between April and July 2019-2020. A total of 114 turtle specimens, 21 from Kavak Delta, 38 from the City Center, 35 from Bozcaada and 20 from Gökçeada, were caught by hand and net. The collected specimens were released back to their habitats after morphological measurements.

2.3. Morphological Measurements of Turtles

The terminology of morphological measurements was determined according to Ayaz *et al*. (2006) [2]. The straight carapace length (SCL: The straight-line measurement from the anterior of the nuchal scute to the posterior end of the supracaudals), carapace width (CW: The straight-line measurement between the lateral margins of the midline of the carapace), plastron length (PL: The straight-line measurement from the the anterior of the gular scute to the posterior tip of the anal scute), plastron width (PW: The straight-line measurement between the lateral margins of the plastron at the abdominal scutes) were measured using tortometer and digital caliper to the nearest 0.1 mm. Body weights (W) were measured with digital scales to the nearest 0.1 g. In turtle's straight carapace lengths of 10 cm and greater than 10 cm were accepted as adults [30]. If the plastron is straight, it is considered as female, if it is concave, it is considered as male [4].

2.4. Statistical Analysis

The data obtained from the morphometry of specimens were analysed by SPSS software (version 11.5). Comparisons

between sexes and populations were made with the Mann Whitney U test for data were not distributed normally. Significance levels for all tests were set at p≤0.05.

3. Results

A total of 114 specimens of *M. rivulata* (70 female; 44 male) were examined in four different localities. It was found that there were significant differences between males and females of Kavak Delta, City Center and Bozcaada populations in terms of all measurements. Besides that, it was found that there was a significant difference in PL and W values (p≤0,05) in Gökçeada population (Table 1).

Table 1: Morphological measurements of *Mauremys rivulata* specimens from four different localities. N: Number of specimens, Min: Minimum, Max: Maximum, SE: Standard Error, SD: Standard Deviation. The unit of SCL, CL, PL, PW are millimetre, and W is gram.

Kavak Delta													
	Female							**Male**					
	N	**P**	**Min**	**Max**	**Mean**	**SE**	**SD**	**N**	**Min**	**Max**	**Mean**	**SE**	**SD**
SCL*	10	0,001	160,00	193,00	174,60	3,442	10,885	11	120,00	180,00	162,63	5,375	17,828
CW*	10	0,005	109,00	127,00	117,40	1,454	4,599	11	88,00	123,00	110,00	2,882	9,560
PL*	10	0,002	150,00	166,00	157,30	1,612	5,100	11	100,00	155,00	140,60	4,891	16,223
PW*	10	0,004	91,00	106,97	100,55	1,520	4,808	11	70,00	100,00	91,06	2,891	9,589
W*	10	0,011	680,00	910,00	796,00	27,006	85,401	11	300,00	780,00	574,72	45,967	152,456
CITY CENTER													
	Female							**Male**					
	N	**P**	**Min**	**Max**	**Mean**	**SE**	**SD**	**N**	**Min**	**Max**	**Mean**	**SE**	**SD**
SCL*	25	0,005	115,71	195,00	152,02	4,678	23,391	13	106,15	162,00	129,67	5,676	20,466
CW*	25	0,042	84,53	145,00	106,77	3,185	15,926	13	76,39	133,30	95,18	4,954	17,864
PL*	25	0,001	108,21	170,10	139,76	4,091	20,456	13	94,10	150,00	115,76	5,356	19,311
PW*	25	0,014	65,53	114,00	91,53	2,568	12,843	13	60,45	104,30	78,40	4,316	15,563
W*	25	0,004	200,00	860,00	485,64	41,772	208,864	13	162,00	600,00	302,46	42,702	153,965
BOZCAADA													
	Female							**Male**					
	N	**P**	**Min**	**Max**	**Mean**	**SE**	**SD**	**N**	**Min**	**Max**	**Mean**	**SE**	**SD**
SCL*	25	0,024	129,53	186,00	159,38	3,074	15,371	10	113,35	168,00	145,45	5,725	18,104
CW*	25	0,015	92,29	131,00	109,71	2,038	10,190	10	80,76	110,92	99,93	3,342	10,569
PL*	25	0,000	112,43	168,00	142,60	2,829	14,147	10	92,13	136,00	117,61	4,159	13,152
PW*	25	0,001	75,02	112,00	95,70	2,071	10,357	10	67,49	94,00	82,90	2,964	9,375
W*	25	0,001	309,00	958,00	620,08	34,217	171,088	10	186,00	494,00	387,70	34,362	108,663
GÖKÇEADA													
	Female							**Male**					
	N	**P**	**Min**	**Max**	**Mean**	**SE**	**SD**	**N**	**Min**	**Max**	**Mean**	**SE**	**SD**
SCL	10	0,081	184,00	210,00	197,23	2,385	7,545	10	155,70	200,00	187,47	4,350	13,757
CW	10	0,064	122,00	170,00	144,55	6,414	20,284	10	104,00	159,00	130,15	7,588	23,995
PL*	10	0,000	164,00	190,00	178,10	2,592	8,198	10	153,80	165,00	161,28	1,070	3,383
PW	10	0,705	78,00	112,40	98,24	4,179	13,216	10	91,00	110,00	99,29	2,056	6,504
W*	10	0,000	670,00	880,00	738,00	20,154	63,735	10	520,00	670,00	608,00	14,282	45,166

* Measurements differing significantly between males and females according to the Mann Whitney U Test.

Statistically significant differences were determined in some morphological measurements between males and females in four different populations. For this reason, males and females were evaluated separately and it was tested whether there was a statistically significant difference between the populations.

In males; there were statistically significant differences in SCL, CW, PL, W values between Kavak Delta and City Center, in SCL, CW, PL, PW, W values between Kavak Delta and Bozcaada, SCL and PL values between Kavak Delta and Gökçeada, in SCL, CW, PL, PW, W values between City Center and Gökçeada, in SCL, CW, PL, PW, W values between Bozcaada and Gökçeada (p≤0,05). There were no significant differences between the City Center and Bozcaada specimens (p ≥0,05) (Table 2).

In females; there were statistically significant differences in SCL, CW, PL, W values between Kavak Delta and City Center, in SCL, CW, PL, W values between Kavak Delta and Bozcaada, in SCL, CW, PL values between Kavak Delta and Gökçeada, in W values between City Center and Bozcaada, in SCL, CW, PL, W values between City Center and Gökçeada, in SCL, CW, PL, W values between Bozcaada and Gökçeada (p≤0,05) (Table 2).

Table 2: Comparison of the relationship between populations. The table shows the results of the Mann-Whitney U test.

Populations	**Sex**	**SCL**	**CW**	**PL**	**PW**	**W**
Kavak Delta-City center	♀♀	U: 36,500	U: 57,500	U: 62,500	U: 72,000	U: 31,500
		W: 361,500	W: 382,500	W: 387,500	W: 397,000	W: 356,500
		Z: -3,236	Z: -2,466	Z: -2,283	Z: -1,937	Z: -3,416
		P: 0,001	P: 0,014	P: 0,022	P: 0,053	P: 0,001
	♂♂	U: 14,500	U: 32,500	U: 24,500	U: 40,500	U: 14,000
		W: 105,500	W: 123,500	W: 115,500	W: 131,500	W: 105,000
		Z: -3,304	Z: -2,261	Z: -2,729	Z: -1,796	Z: -3,335
		P: 0,001	P: 0,024	P: 0,006	P: 0,072	P: 0,001

Kavak Delta-Bozcaada	♀♀	U: 32,000	U: 34,000	U: 38,500	U: 86,000	U: 57,000
		W: 357,000	W: 359,000	W: 363,500	W: 411,000	W: 382,000
		Z: -3,402	Z: -3,329	Z: -3,160	Z: -1,424	Z: -2,483
		P: 0,001	P: 0,001	P: 0,002	P: 0,154	P: 0,013
	♂♂	U: 21,500	U: 24,500	U: 12,000	U: 21,500	U: 19,000
		W: 76,500	W: 79,500	W: 67,000	W: 76,500	W: 74,000
		Z: -2,361	Z: -2,149	Z: -3,032	Z: -2,360	Z: -2,537
		P: 0,018	P: 0,032	P: 0,002	P: 0,018	P: 0,011
Kavak Delta-Gökçeada	♀♀	U: 3,500	U: 3,000	U: 1,000	U: 44,500	U: 35,000
		W: 58,500	W: 58,000	W: 56,000	W: 99,500	W: 90,000
		Z: -3,524	Z: -3,558	Z: -3,705	Z: -0,417	Z: -1,135
		P: 0,000	P: 0,000	P: 0,000	P: 0,677	P: 0,256
	♂♂	U: 9,000	U: 33,000	U: 2,000	U: 29,000	U: 46,000
		W: 75,000	W: 99,000	W: 68,000	W: 95,000	W: 101,000
		Z: -3,242	Z: -1,551	Z: -3,739	Z: -1,833	Z: -0,635
		P: 0,001	P: 0,121	P: 0,000	P: 0,067	P: 0,525
City centre-Bozcaada	♀♀	U: 241,000	U: 264,500	U: 296,500	U: 262,000	U: 197,500
		W: 566,000	W: 589,500	W: 621,500	W: 587,000	W: 522,500
		Z: -1,388	Z: -0,932	Z: -0,310	Z: -0,980	Z: -2,232
		P: 0,165	P: 0,352	P: 0,756	P: 0,327	P: 0,026
	♂♂	U: 37,500	U: 46,000	U: 59,000	U: 46,000	U: 35,000
		W: 128,500	W: 137,000	W: 150,000	W: 137,000	W: 126,000
		Z: -1,706	Z: -1,178	Z: -0,372	Z: -1,178	Z: -1,862
		P: 0,088	P: 0,239	P: 0,710	P: 0,239	P: 0,063
City Center-Gökçeada	♀♀	U: 5,000	U: 15,000	U: 5,000	U: 82,500	U: 31,000
		W: 330,000	W: 340,000	W: 330,000	W: 407,500	W: 356,000
		Z: -4,383	Z: -4,017	Z: -4,382	Z: -1,552	Z: -3,435
		P: 0,000	P: 0,000	P: 0,000	P: 0,121	P: 0,001
	♂♂	U: 2,000	U: 15,000	U: 0,000	U: 22,000	U: 9,000
		W: 93,000	W: 106,000	W: 91,000	W: 113,000	W: 100,000
		Z: -3,909	Z: -3,103	Z: -4,033	Z: -2,667	Z: -3,494
		P: 0,000	P: 0,002	P: 0,000	P: 0,008	P: 0,000
Bozcaada-Gökçeada	♀♀	U: 1,000	U: 9,500	U: 2,000	U: 96,000	U: 54,000
		W: 326,000	W: 334,500	W: 327,000	W: 421,000	W: 379,000
		Z: -4,529	Z: -4,220	Z: -4,491	Z: -1,059	Z: -2,593
		P: 0,000	P: 0,000	P: 0,000	P: 0,290	P: 0,010
	♂♂	U: 3,000	U: 12,500	U: 0,000	U: 2,500	U: 0,000
		W: 58,000	W: 67,500	W: 55,000	W: 57,500	W: 55,000
		Z: -3,556	Z: -2,837	Z: -3,782	Z: -3,592	Z: -3,788
		P: 0,000	P: 0,005	P: 0,000	P: 0,000	P: 0,000

Comparison of morphological measures by sex between four different populations is given in Figures 2-6.

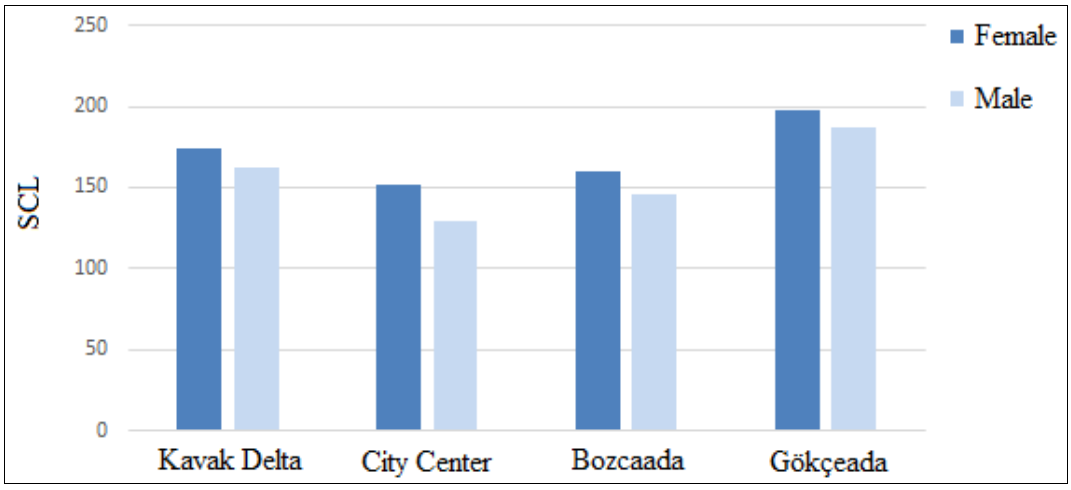

Fig 2: Comparison of Straight Carapace Length (SCL) of males and females in four different populations.

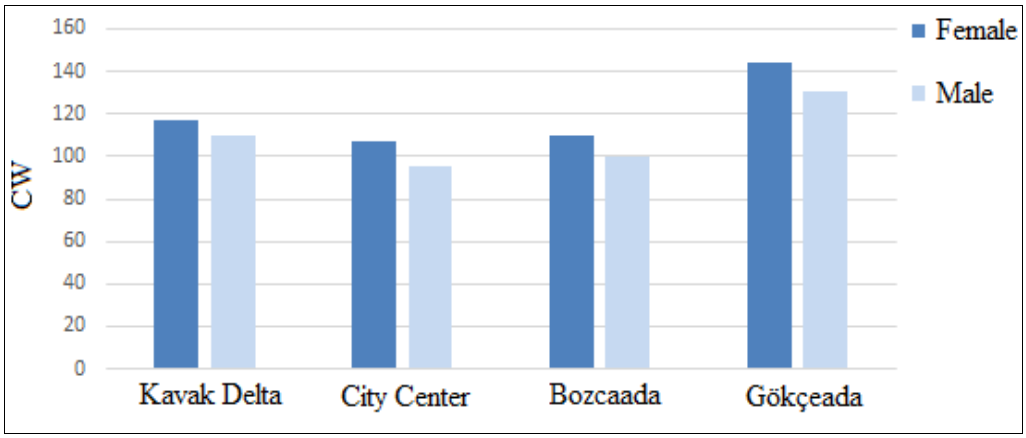

Fig 3: Comparison of Carapace Width (CW) of males and females in four different populations.

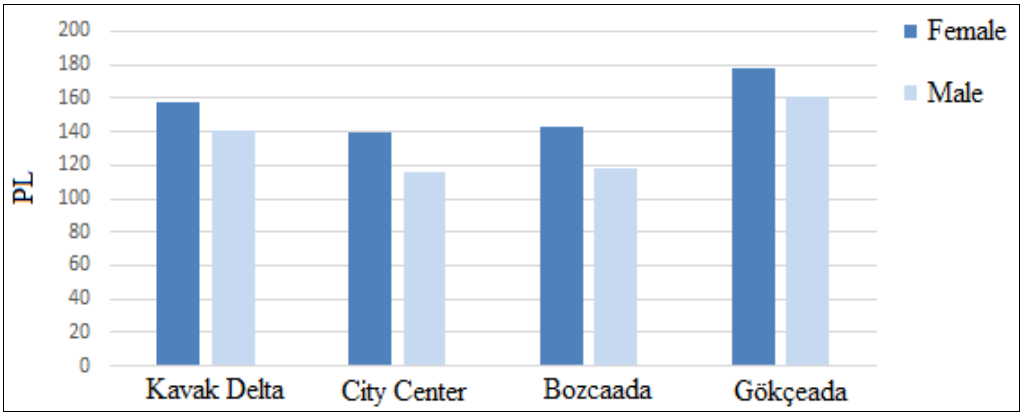

Fig 4: Comparison of Plastron Length (PL) of males and females in four different populations.

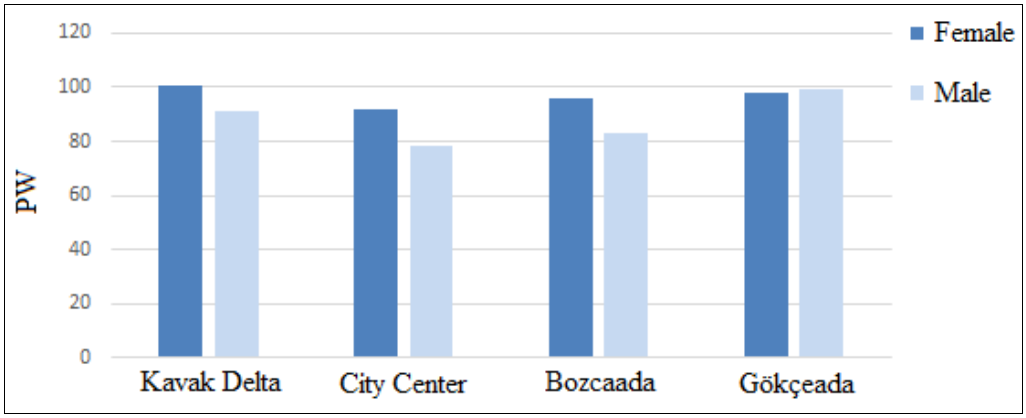

Fig 5: Comparison of Plastron Width (PW) of males and females in four different populations.

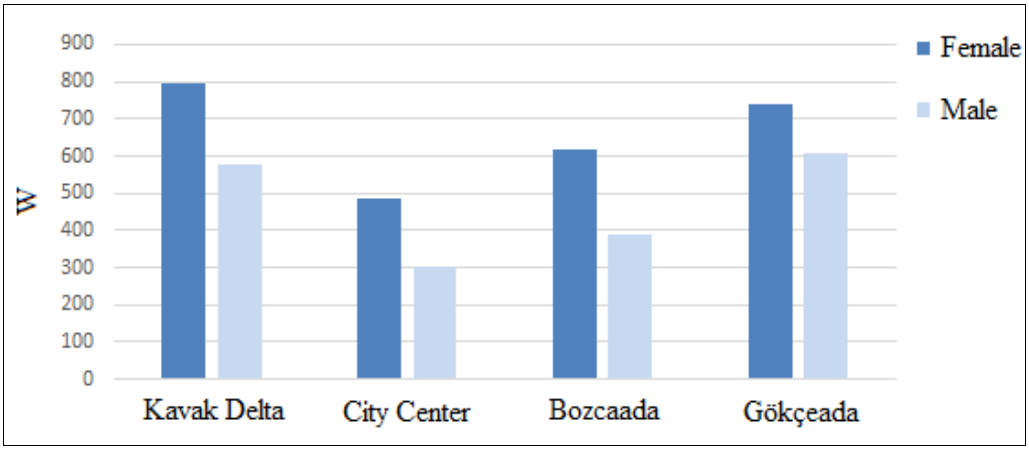

Fig 6: Comparison of Weight (W) of males and females in four different populations.

The correlation of SCL and W values showing body sizes and the distribution graph between the populations are given in Figure 7 and Figure 8. According to the SCL value; the largest specimens were found in Gökçeada (females: 197, 23 mm; males 187, 47 mm), while the smallest specimens were found in city center (females: 152, 02 mm; males 129, 67 mm).

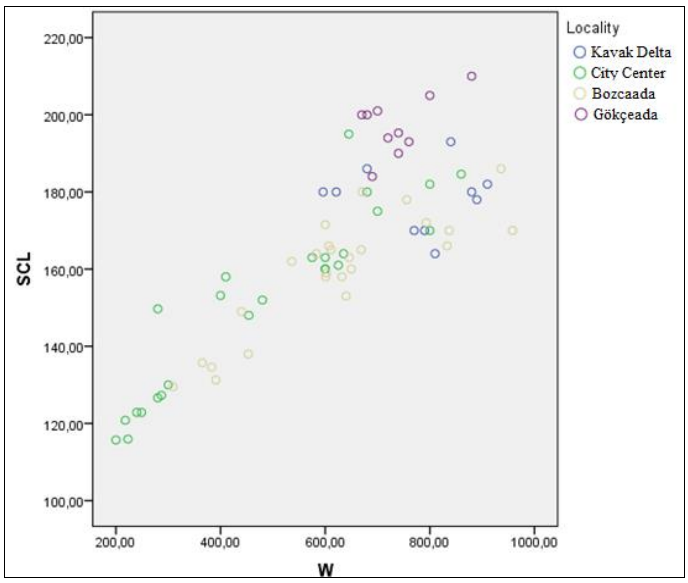

Fig 7: Correlation of SCL and W values in females and scatter-plot between populations.

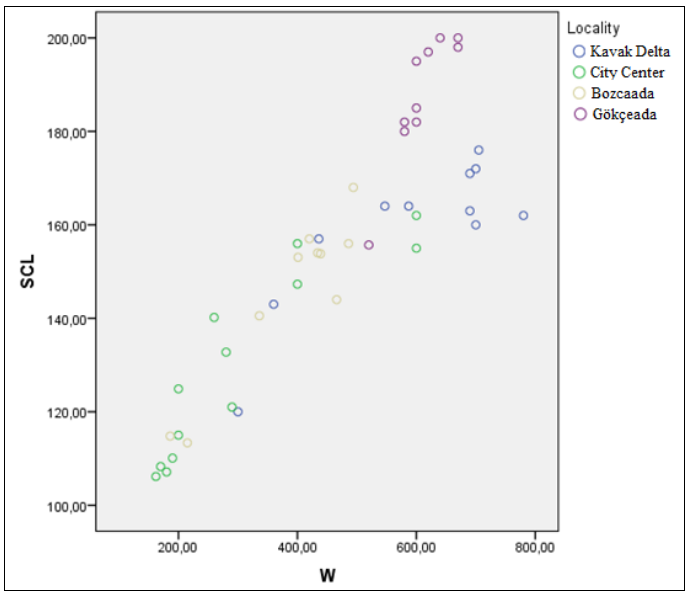

Fig 8: Correlation of SCL and W values in males and scatter-plot between populations.

4. Discussion

In the Kavak Delta population, Thrace region, SCL and W values were determined as 162, 63 (120-180) mm, 574, 72 (300-780) g in males and as 174, 60 (160-193) mm, 796 (680-910) g in females, respectively. In the population located in the City Center, Anatolian part of Turkey, SCL and W values were determined as 129, 67 (106, 15-162, 00) mm., 302,46 (162-600) g in males and as 152,02 (115,71-195) mm, 485,64 (200-860) g in females, respectively. The mean SCL of Bozcaada was 159, 8 (129, 53-186) mm and 145, 45 (113,35-168) mm; their body mass was determined as 620,08 (309-958) g and 387,70 (186-494) g in females and males, respectively. In the Gökçeada population, the SCL value was 197, 23 (184-210) mm in females and 187, 47 (155, 70-200) mm in males; the weight was determined as 738 (670-880) g in females and 608 (520-670) g in males. Gül *et al*., (2014) [11] reported that the SCL values of *M. rivulata* samples in Bozcaada were 154 mm for males, 155.4 mm for females, and body mass of 426 g for males and 606.71 g for females. Bayrakçı *et al*., (2016) [5] reported that the SCL and body mass values in the Gökçeada population were 157,7 (95-192) mm, 476,8 (105-781) g in males and 174,3 (104-204) mm, 761,6 (154-1019) g in females respectively. Güçlü and Türkozan (2010) [10] reported that the SCL and body mass values in the İzmir population were 94 (78-142) mm, 109, 4 (66-380) g in males and 120 (82-181) mm and 257,5 (80-823) g in females, respectively. Ayaz *et al*., (2006) [2] reported that the mean SCL values were 177,2 mm for males, 182,4 mm for females in the İzmir population.

According to our results, the SCL value, which is the parameter indicating body size in *M. rivulata*, differs both between males and females and between populations. Females

are larger than males in all populations, and these findings are consistent with the literature [1, 25, 10, 11]. Variation in body size may also reflect adaptations to environments, and sexual size dimorphism arises from ultimate and proximate factors acting differently on males and females in those environments [32]. It has been discussed by Lovich *et al*. (2010) [19] that estimations of sexual size dimorphism may vary under the influence of several factors, such as sampling bias, inappropriate dimorphism measurements, inaccurate estimation of size at sexual maturity, geographic variation in growth or body size, and geographically varying selective pressures.

Among the studied populations, the largest specimens were found in Gökçeada population, and the smallest specimens were found in the City Center population. Body size evolution on islands is widely studied and hotly debated [14]. Body size changes are often hypothesized to become more extreme as island area diminishes and isolation increases, because species experience ecological release from predators and competitors [8]. Itescu *et al*. (2018) [13] reported that overarching generalizations oversimplify patterns and processes of reptile body size evolution on islands. Instead, species' autecology and island particularities interact to drive the course of size evolution.

In the present study, body sizes of four *Mauremys rivulata* populations from Kavak Delta located in the Thrace region, City centre located in Anatolia, and two islands (Gökçeada and Bozcaada) which are the districts of Çanakkale, were examined comparatively. Significant differences were found between males and females in all populations, with females being larger than males. When the four populations were compared, it was determined that the largest specimens were in Gökçeada and the smallest specimens were in the City Center.

5. Conclusion

Although it has been determined that *M. rivulata* populations show sexual dimorphism and differ geographically, it is recommended to consider the interaction of many factors such as habitat characteristics, climate, competition, food preferences, anthropogenic effect, population size, reproductive success.

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7. References

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