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Growth and body condition of thrace region (Türkiye) populations of vulnerable tortoise *Testudo graeca* Linnaeus, 1758

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Abstract

Morphometric measurements, ratios and body condition indices of *Testudo graeca* populations distributed in Thrace Region (Çanakkale, Tekirdağ, Kırklareli, Edirne) were examined in order to compare morphological differences in both intra-population and inter-population. Morphological measurements were taken from a total of 133 adult tortoises (66 ♂♂, 67 ♀♀). Statistically significant differences were found when all morphometric measurements of male and female individuals within the populations were compared, and it was found that females were larger. In addition, statistically significant differences were found between male and female individuals when four populations compared between populations, and it was found that largest individuals were in Kırklareli population, and smallest individuals were in Edirne population. When all populations were examined, it was determined that all populations showed female-biased sexual dimorphism. With this study, Body Condition Index data of *Testudo graeca* populations were revealed for the first time.

Keywords: Body size, tortoise, thrace region, morphology

Introduction

Shell morphology in tortoises provides detailed informations on reproduction, movement and protection against predators [12]. Shell shapes and body sizes affect fertility in females and sexual selection in males [4, 11]. In addition, body condition, that calculated as ratio of body mass to body size, provides information about nutrition and physiological conditions in tortoises [26, 17, 18, 20, 22].

It has been stated that there are six threat factors for reptiles on an international scale: habitat loss and fragmentation, environmental pollution, global climate change, disease, animal trade, and invasive species [16]. Among reptiles, tortoises are the most vulnerable, given their low dispersal tendencies and habitat fragmentation [15]. *Testudo graeca* is an endangered species due to habitat loss and fragmentation, agricultural activities, urbanization pressure, environmental pollution, collection as a pet animal and stubble burning [21, 1, 35, 2]. According to the criteria of the International Union for the Conservation of Natural Life and Natural Resources, the species categorizes as 'Vulnerable' on a global scale, and the population situation is also decreasing on a global scale [19]. *Testudo graeca* is listed in Appendix II (Strictly protected fauna species) of the Bern Convention on the Conservation of European Wildlife and Natural Habitats; and also listed in Appendix II of the CITES Convention on the International Trade in Endangered Species of Wild Flora and Fauna.

T. graeca is distributed throughout the world in Southern Europe, North Africa and Southwest Asia [8]. The species, which lives in stony and sandy habitats, is distributed in all regions with suitable habitats in Türkiye. There are some studies on the morphology of the *Testudo graeca* in Türkiye [3, 6, 31, 34], but the morphological characters of the populations in the Thrace Region have not been studied comparatively.

The aim of this study is to investigate whether there are intra-population sexual dimorphism, intrapopulation and inter-population morphological differences and similarities in *Testudo graeca* populations distributed in Thrace Region. With this study, the body condition data of the populations were revealed for the first time by using the Body Condition Index.

This study aims to provide additional information from previously unexplored regions for a globally protected species, *Testudo graeca* and provide comparative data for future studies.

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2. Materials and Methods

2.1 Study Areas

The Thrace Region is the part of Türkiye within the European continent covering an area of 23.764 km². There is Bulgaria on the north, the Black Sea on the northeast, Greece on the west, and the Aegean and Marmara Seas on the south. The region is separated from Anatolia by Bosphorus on the east and the Dardanelles on the south [38, 13].

Kırklareli station is located at an altitude of 390 m and consists of a large area and a habitat with shrubby vegetation where wetlands are frequent. The habitat of Tekirdağ station consisting of both groves and bushes and its elevation is 200

m. Çanakkale station is very close to the sea and consists of a dune-shrubs area with 5 m elevation. Unlike other stations, Edirne station has woodland with 50 m altitude was located between the highway on one side and railway on the other side. Adult *T. graeca* individuals were collected from four stations as Kırklareli/Karakoç, Çanakkale/Kavak Delta, Tekirdağ/Hereke, Edirne/Kapıkule (Figure 1). The necessary permissions have been obtained from the Local Ethics Committee of Animal Experiments of Çanakkale Onsekiz Mart University (decision no: 2020/08-04) for the analyses that carried out on animal specimens.

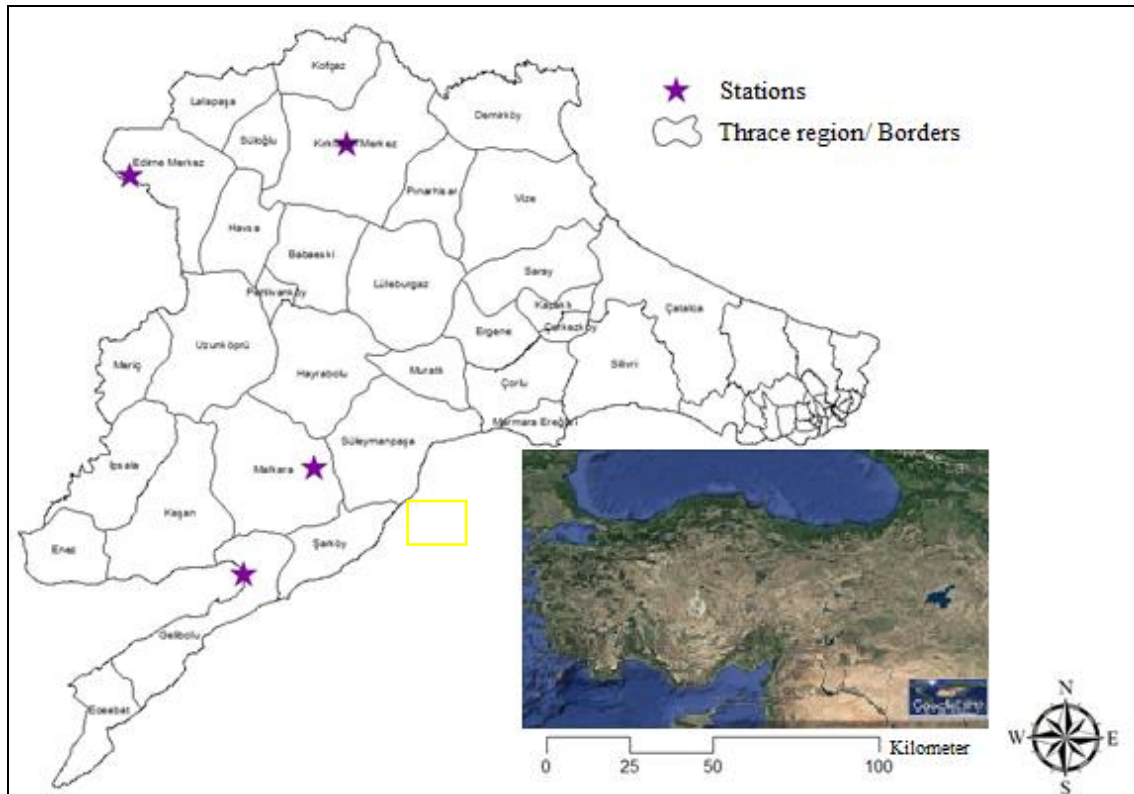


Fig 1: Stations where the specimens were caught.

2.2 Data Collection

Tortoises were collected by hand between April and September within the period of 2021–2022 and individually marked on the marginal scutes of the carapace [29]. All *T. graeca* specimens' sexes were determined using external morphological characteristics (e.g. concavity of plastron and longer tails in males). Juveniles (straight carapace length < 10 cm) which gender could not be determined were excluded from the analyses [36]. The morphological measurements of a total of 50 adult tortoises from Kırklareli station; a total of 26 adult tortoises from Çanakkale station, 25 adult tortoises from Tekirdağ station, and a total of 32 adult tortoises from Edirne station were studied. The body measurements of the animals were measured with digital caliper (Mitutoyo Corporation, Japan: 0.01 mm) and tortometer, and weights were determined with digital scale (Weight Lab Instruments: 0.01g) and analog scale. After morphological analyses were performed and photographs were taken, animal specimens were returned to the biotope to which they belonged.

2.3 Morphological Measurements and Indexes of Tortoises

Straight Carapace Length (SCL): Straight line measurement

by following the dorsal median line extending from the anterior end of the nuchal plate to the posterior of the supracaudal plate.; Curved Carapace Length (CCL): Curvilinear measurement taken between the nuchal plate and the supracaudal plate; Carapace Width (CW): Straight-line measurement between sixth marginals; Maximum Carapace Width (CW2): Straight-line measurement between eighth marginals (widest part of carapace); Plastron Length (PL): Measurement taken as a line from the notch between the gular plates to the notch between the anal plates; Maximum Plastron Width (PW2): Straight line measurement from the widest part of the lateral edges of the plastron; Plastron Width (PW1): a straight line measurement taken between sixth marginal plates; Carapace Height (CH): Vertical line measurement between the point where the plastron touches the ground and the 2nd or 3rd vertebral plates of the carapasa; Gular Suture Length (GSL): Measurement of linear length of suture between two gular; Humeral Suture Length (HSL): Measurement of the linear length of the suture between the two humeral plates; Pectoral Suture Length (PSL): Measurement of the linear length of the suture between two pectoral plates; Abdominal Suture Length (AbSL):

Measurement of the linear length of the suture between two abdominal plates; Femoral Suture Length (FSL): Measurement of the linear length of the suture between two femoral plates; Anal Suture Length (ASL): Measurement of the linear length of the suture between the two anal plates.

In addition, 14 morphometric ratios were examined in order to compare male and female individuals between populations and in the population (SCL/CCL, SCL/PL, SCL/PW1, SCL/PW2, PL/PW1, PL/PW2, SCL/CW, SCL/CH, SCL/HSL, SCL/AbSL, SCL/ASL, SCL/GSL, SCL/PSL, SCL/FSL). Body condition index (BCI) calculated as the ratio of body mass (g) to shell volume (cm³) estimated as the product of standardized CL, width, and height (in cm) [27]. Shell volume (SV) calculated using the formula SCL×CH×CW as cm³. Body mass was measured before the animals could urinate or defecate. Sexual dimorphism indice (SDI) were calculated using the method of Lovich & Gibbons (1992) [23].

2.4 Statistical Analyses

The data obtained from the morphometry of specimens were analysed by SPSS software (version 26). Kolmogorov

Smirnov Test for normality were used in analyses of the data. Comparisons between sexes and populations were made with Mann Whitney U Test for non-parametric data and Student-T test for parametric data. In all cases, p ≤ 0.05 value was considered statistically significant. In order to compare individuals between populations, ANOVA was applied for parametric data and Kruskal Wallis Test for non-parametric data. The Discriminant Analysis was applied to determine the morphological differences between the populations. Stepwise method was used to detect the characters that showing differences between populations. (F for entry: 3.84; F for removal: 2.71).

3. Results

In SSD calculations, it was found that SDI values were positive in Kırklareli (0.082), Çanakkale (0.125), Tekirdağ (0.089) and Edirne (0.080) populations. According to this data, it can concluded that all populations show female-biased sexual size dimorphism. It was found that all morphometric measurements of females were higher than males in all of the populations (Table 1).

Table 1: Descriptive statistics of morphometric measurements and ratios of all populations

KIRKLARELİ										
	Male (N: 25)					Female (N:25)				
	Min	Max	Mean	SE	SD	Min	Max	Mean	SE	SD
BW	560.00	1780.00	1174.80	64.869	324.347	510.00	2250.00	1563.20	89.464	447.322
SCL	14.50	21.10	18.33	0.375	1.877	12.50	23.60	19.85	0.534	2.672
CCL	18.00	27.20	23.32	0.468	2.342	17.50	28.50	25.26	0.520	2.604
CW	11.50	16.10	13.70	0.266	1.330	11.00	18.50	15.44	0.363	1.815
CW2	12.00	21.50	15.03	0.399	1.998	11.20	19.00	16.24	0.334	1.670
PL	11.79	20.40	15.14	0.375	1.875	11.00	23.00	17.86	0.517	2.586
PW2	9.80	17.00	12.69	0.295	1.478	9.16	17.50	14.12	0.379	1.895
PW1	10.19	16.50	12.39	0.278	1.391	9.58	16.50	14.10	0.356	1.783
CH	7.50	20.50	10.89	0.558	2.794	5.00	12.80	10.89	0.333	1.667
GSL	1.38	2.93	2.22	0.090	0.454	1.53	3.16	2.57	0.073	0.367
HSL	2.16	3.16	2.58	0.060	0.300	2.16	3.23	2.71	0.063	0.316
PSL	0.33	1.50	0.80	0.061	0.305	0.25	2.27	0.99	0.068	0.341
AbSL	3.39	5.97	4.95	0.128	0.643	4.16	7.31	6.02	0.159	0.798
FSL	1.45	4.49	2.13	0.117	0.586	1.31	3.00	2.28	0.064	0.323
ASL	1.39	2.28	1.75	0.047	0.238	1.64	2.98	2.38	0.084	0.422
BC (g/cm ³)	0.14	0.61	0.40	0.204	0.102	0.20	0.73	0.44	0.019	0.096
ÇANAKKALE										
	Male (N:15)					Female (N:11)				
	Min	Max	Mean	SE	SD	Min	Max	Mean	SE	SD
BW	780.00	2100.00	1089.13	88.199	341.596	880.00	2280.00	1565.45	125.077	414.834
SCL	16.00	21.20	18.14	0.395	1.531	17.00	23.50	20.42	0.617	2.048
CCL	19.50	28.00	22.51	0.656	2.543	21.20	27.50	25.15	0.626	2.078
CW	11.00	17.00	13.20	0.480	1.862	11.50	19.00	15.55	0.692	2.297
CW2	10.50	16.50	13.80	0.387	1.500	13.27	19.50	15.49	0.575	1.908
PL	11.64	17.00	13.42	0.353	1.367	13.62	20.00	16.76	0.680	2.258
PW2	9.93	13.86	11.17	0.298	1.156	10.34	17.00	12.97	0.535	1.776
PW1	10.38	14.74	11.57	0.310	1.200	10.94	16.50	13.04	0.474	1.572
CH	7.60	10.70	9.27	0.202	0.786	8.82	12.00	10.55	0.266	0.884
GSL	1.34	2.60	2.02	0.081	0.314	1.97	2.72	2.37	0.079	0.264
HSL	1.83	3.39	2.47	0.094	0.367	2.02	3.04	2.59	0.096	0.321
PSL	0.17	0.96	0.55	0.067	0.259	0.33	1.45	0.88	0.107	0.358
AbSL	4.20	6.24	4.79	0.137	0.531	4.96	7.42	6.02	0.246	0.817
FSL	1.40	2.45	1.82	0.086	0.336	1.81	2.52	2.20	0.068	0.228
ASL	0.87	1.97	1.51	0.070	0.274	1.44	2.55	2.04	0.107	0.355
BC (g/cm ³)	0.37	0.58	0.46	0.172	0.066	0.35	0.60	0.46	0.023	0.076
TEKİRDAĞ										
	Male (N:15)					Female (N:10)				
	Min	Max	Mean	SE	SD	Min	Max	Mean	SE	SD
BW	630.00	1615.00	1075.26	69.066	267.493	900.00	1790.00	1380.90	106.818	337.789
SCL	13.00	19.50	16.85	0.434	1.683	15.50	21.20	18.36	0.598	1.892

CCL	18.60	26.00	22.39	0.519	2.012	21.30	26.40	23.62	0.585	1.851
CW	11.00	23.00	14.53	0.922	3.571	11.90	25.00	16.86	1.654	5.231
CW2	10.60	21.50	14.37	0.754	2.922	13.00	24.00	17.37	1.470	4.650
PL	11.33	14.92	13.52	0.238	0.924	13.27	19.50	16.09	0.649	2.054
PW2	9.47	12.73	11.54	0.247	0.958	10.72	15.50	12.78	0.505	1.598
PW1	9.78	13.18	11.69	0.250	0.968	10.49	16.15	12.95	0.567	1.794
CH	7.69	12.50	9.73	0.361	0.390	8.30	15.00	10.60	0.591	1.870
GSL	1.53	2.83	2.16	0.080	0.309	1.76	26.47	4.75	2.415	7.637
HSL	1.92	2.61	2.28	0.056	0.218	2.13	3.12	2.64	0.108	0.343
PSL	0.51	2.11	0.89	0.097	0.377	0.17	1.58	0.81	0.161	0.509
AbSL	4.18	5.37	4.65	0.100	0.389	4.62	6.40	5.66	0.212	0.671
FSL	1.66	2.24	1.94	0.053	0.207	1.17	2.55	2.00	0.145	0.460
ASL	1.29	1.71	1.49	0.031	0.123	1.21	2.78	2.13	0.149	0.471
BC (g/cm ³)	0.31	0.60	0.46	0.021	0.083	0.24	0.55	0.42	0.300	0.096
EDİRNE										
	Male (N: 11)					Female (N: 21)				
	Min	Max	Mean	SE	SD	Min	Max	Mean	SE	SD
BW	234.00	1822.00	899.63	172.875	573.364	276.00	1773.00	961.23	100.206	459.205
SCL	10.03	20.00	14.95	1.028	3.411	10.50	21.00	16.15	0.674	3.090
CCL	12.50	25.50	19.44	1.401	4.649	13.70	26.50	20.60	0.831	3.812
CW	8.24	14.90	11.32	0.647	2.148	7.60	16.00	12.40	0.457	2.096
CW2	7.81	15.30	11.73	0.726	2.409	8.50	18.80	13.30	0.563	2.582
PL	9.00	16.70	12.44	0.768	2.550	9.65	18.00	14.13	0.576	2.643
PW2	7.10	13.29	10.18	0.620	2.057	7.91	14.39	10.99	0.426	1.955
PW1	7.32	13.06	10.28	0.592	1.966	8.13	14.04	11.06	0.398	1.827
CH	5.34	10.20	7.63	0.527	1.750	5.17	11.00	8.22	0.366	1.678
GSL	1.17	2.95	1.96	0.178	0.593	1.36	5.27	2.13	0.176	0.807
HSL	1.76	2.78	2.26	0.108	0.359	1.49	3.51	2.55	0.112	0.514
PSL	0.33	1.13	0.67	0.079	0.263	0.35	1.01	0.73	0.037	0.171
AbSL	3.40	5.86	4.31	0.246	0.816	3.36	6.66	4.99	0.228	1.048
FSL	1.08	2.62	1.76	0.153	0.510	1.08	2.68	1.79	0.098	0.450
ASL	1.07	2.13	1.53	0.090	0.298	1.25	2.87	1.93	0.113	0.519
BC (g/cm ³)	0.49	1.03	0.58	0.045	0.150	0.32	0.68	0.51	0.015	0.069

3.1. Comparison of Morphometric Parameters of Male and Female Individuals in Populations

While CH, HSL and BC were not statistically different from the morphometric measurements taken from male and female individuals of Kırklareli population, all other measurements showed statistically significant differences. When the ratios were examined, 4 ratios showed statistically significant differences. The male and female individuals of Çanakkale population were examined, only HSL, PL and BC were not show statistically significant difference for the morphometric measurements, while all other measurements showed statistically significant differences. When the ratios were examined, it was determined that 4 morphometric ratios

showed statistically significant differences. When the male and female individuals of Tekirdağ population were examined in terms of morphometry, it was determined that 8 measurements and 5 ratios showed statistically significant differences. In female and male individuals of Edirne population, only ASL showed a statistically significant difference, while other measurements did not show significant difference. When the ratios are examined, it was determined that the 4 morphometric ratios showed statistically significant differences. All statistical findings were showed in Table 2 in detail.

Table 2: Statistical evaluations of measurements and ratios of male and female individuals in populations with Student's t-test and Mann-Whitney U tests (t: T value, df: Degree of Freedom, p: Significance, U: Mann-Whitney U value) *Statistical significant differences between male and female individuals

KIRKLARELİ					ÇANAKKALE					TEKİRDAĞ					EDİRNE				
	t	df	p	U		t	df	p	U		t	df	p	U		t	df	p	U
BW*	-3.515	48	0.001		BW*			0.005*	28.000	BW*	-3.515	48	0.001	-	BW	-0.331	30	0.743	
SCL*	-2.327	48	0.024		SCL*	-3.254	24	0.003*		SCL*	-2.327	48	0.024	-	SCL			0.311	90.000
CCL*			0.000	133.000	CCL*	-2.819	24	0.010*		CCL	-1.540	23	0.137	-	CCL			0.592	102.000
CW*	-3.857	48	0.000		CW*	-2.886	24	0.008*		CW	-	-	0.174	50.500	CW			0.216	84.500
CW2*			0.001	148.000	CW2*	-2.531	24	0.018*		CW2	-	-	0.062	41.500	CW2	-1.672	30	0.105	
PL*	-4.264	48	0.000		PL	-1.881	11.628	0.085*		PL*	-3.702	11.45	0.003	-	PL	-1.739	30	0.092	
PW2*	-2.974	48	0.005		PW2*	-3.134	24	0.005*		PW2*	-2.442	23	0.023	-	PW2	-1.085	30	0.286	
PW1*	-3.766	48	0.000		PW1*	-2.699	24	0.013*		PW1*	-2.033	12.52	0.032	-	PW1	-1.115	30	0.274	
CH			0.102	228.500	CH*	-3.902	24	0.001*		CH	-	-	0.173	50.500	CH	-0.934	30	0.358	
GSL*	-2.931	48	0.005		GSL*	-2.992	24	0.006*		GSL	-	-	0.166	50.000	GSL			0.513	99.000
HSL	-1.468	48	0.149		HSL	-0.894	24	0.380		HSL*	-3.222	23	0.004	-	HSL	-1.640	30	0.112	
PSL*	-2.061	48	0.045		PSL*	-2.725	24	0.012*		PSL	0.438	23	0.666	-	PSL	-0.724	14.560	0.481	
AbSL*	-5.202	48	0.000		AbSL*	-4.628	24	0.000*		AbSL*	-4.295	13.063	0.001	-	AbSL	-1.885	30	0.069	
FSL*			0.017	190.000	FSL*	-3.236	24	0.004*		FSL	-0.395	11.46	0.700	-	FSL	-0.159	30	0.874	
ASL*			0.000	68.500	ASL*	-4.315	24	0.000*		ASL*	-	-	0.001	16.000	ASL*			0.043	64.500
BC			0.399	269.000	BC	-0.101	24	0.920		BC	1.027	23	0.315	-	BC			0.065	69.000
SCL/CCL	0.289	48	0.773		SCL/CCL	-0.158	24	0.876		SCL/CCL	-1.852	23	0.077	-	SCL/CCL	-1.111	30	0.275	

SCL/PL*	3.782	41.835	0.000		SCL/PL*			0.003*	26.000	SCL/PL*	3.153	23	0.004	-	SCL/PL*	2.431	30	0.021	
SCL/PW1*	2.780	48	0.008		SCL/PW1			0.568	71.500	SCL/PW1	0.392	23	0.699	-	Kdu/PW1	-0.306	30	0.762	
SCL/PW2	1.463	48	0.150		SCL/PW2	1.023	24	0.317		SCL/PW2	0.490	23	0.629	-	Kdu/PW2	-0.180	30	0.859	
PL/PW1	-1.500	48	0.140		PL/PW1*			0.008*	31.000	PL/PW1*	-2.243	11.284	0.046	-	PL/PW1*	-3.621	30	0.001	
PL/PW2	-3.153	48	0.003		PL/PW2			0.102	51.000	PL/PW2*	-2.984	23	0.007	-	PL/PW2*	-3.996	30	0.000	
SCL/CW	2.189	48	0.033		SCL/CW	1.368	24	0.184		SCL/CW	-	-	0.781	70.000	SCL/CW	0.401	30	0.691	
SCL/CH			0.393	268.500	SCL/CH	0.334	24	0.741		SCL/CH	-	-	0.934	73.500	SCL/CH	-0.230	30	0.819	
SCL/HSL	-0.886	38.686	0.381		SCL/HSL			0.243	60.000	SCL/HSL	1.280	23	0.213	-	SCL/HSL			0.275	88.000
SCL/AbSL*	3.813	48	0.000		SCL/AbSL*	3.515	24	0.002*		SCL/AbSL*	3.646	23	0.001	-	SCL/AbSL	1.561	30	0.129	
SCL/ASL*	5.842	48	0.000		SCL/ASL*	2.521	24	0.019*		SCL/ASL*	3.058	23	0.006	-	SCL/ASL*	2.518	30	0.017	
SCL/GSL			0.097	227.000	SCL/GSL			0.169	56.000	SCL/GSL	-	-	0.471	62.000	SCL/GSL			0.487	98.000
SCL/PSL			0.211	248.000	SCL/PSL			0.092	50.000	SCL/PSL	-	-	0.542	64.000	SCL/PSL	0.494	30	0.625	
SCL/FSL	0.646	33.792	0.523		SCL/FSL	1.588	24	0.125		SCL/FSL	-	-	0.912	73.000	SCL/FSL	-1.149	30	0.259	

3.2. Comparison of Morphometric Parameters of Male and Female Individuals Between Populations

When male individuals from all populations were compared, statistically significant differences were found in all body measurements except BW, GSL, FSL and PL/PW2 (p<0.05). In terms of morphometric measurements with significant difference, it was seen that male individuals in Kırklareli population had higher body measurements while Edirne individuals had the smallest measurements. In the morphometric measurements of females it was determined

that there is no statistically significant differences for HSL, PSL, SCL/CCL, PL/PW1, PL/PW2, SCL/CW, SCL/AbSL, SCL/ASL, SCL/PSL and SCL/FSL values (p>0.05). Results from pairwise analysis (Tukey’s) after ANOVA and Tamhane analysis after Kruskal Wallis in all groups showed that there were statistically significant differences between the groups as well. As a result of statistical analyses it was observed that female individuals in Kırklareli population had higher body measurements than female individuals, while Edirne individuals had the smallest measurements.

Table 3: Comparison of morphometric measurements and ratios of female individuals in between populations and male individuals in between populations by ANOVA analysis (df: Degree of Freedom, p: Significance) *Statistical significant differences between male and female individuals

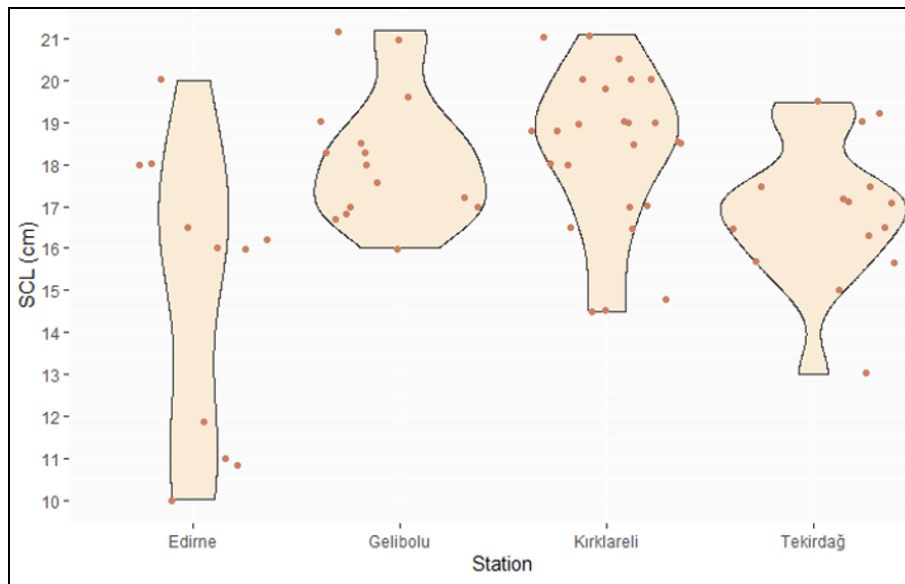
	Male						Female						
	ANOVA			Kruskal Wallis			ANOVA			Kruskal Wallis			
	F	DF	p	Chi-Square	DF	p	F	DF	p	Chi-Square	DF	P	
BW	1.421	3	0.245				BW*				17.707	3	0.001
SCL*				13.718	3	0.003	SCL*				22.125	3	0.000
CCL*	4.860	3	0.004				CCL*				23.419	3	0.000
CW*				10.144	3	0.017	CW*				20.284	3	0.000
CW2*				12.793	3	0.005	CW2*				17.439	3	0.001
PL*	7.396	3	0.000				PL*	8.740	3	0.000			
PW2*	8.904	3	0.000				PW2*	10.905	3	0.000			
PW1*	5.988	3	0.001				PW1*	11.351	3	0.000			
CH*				16.650	3	0.001	CH*	12.049	3	0.000			
GSL	1.326	3	0.274				GSL*				18.462	3	0.000
HSL*	4.263	3	0.008				HSL	0.683	3	0.566			
PSL*	3.677	3	0.017				PSL	2.456	3	0.071			
AbSL*	3.007	3	0.037				AbSL*	6.055	3	0.001			
FSL				5.732	3	0.125	FSL*	7.018	3	0.000			
ASL*				16.976	3	0.001	ASL*	3.997	3	0.011			
BC*	7.967	3	0.000				BC*	3.172	3	0.030			
SCL/CCL*	7.222	3	0.000				SCL/CCL	2.326	3	0.083			
SCL/PL*	9.387	3	0.000				SCL/PL*	5.926	3	0.001			
SCL/PW1*	5.244	3	0.003				SCL/PW1*	9.164	3	0.000			
SCL/PW2*	9.667	3	0.000				SCL/PW2*	10.223	3	0.000			
PL/PW1*	2.878	3	0.043				PL/PW1	0.384	3	0.765			
PL/PW2	1.004	3	0.397				PL/PW2	0.688	3	0.563			
SCL/CW*				8.155	3	0.043	SCL/CW				5.190	3	0.158
SCL/CH*				16.171	3	0.001	SCL/CH*	4.083	3	0.010			
SCL/HSL*	3.615	3	0.018				SCL/HSL*				20.625	3	0.000
SCL/AbSL*				8.615	3	0.035	SCL/AbSL	0.891	3	0.451			
SCL/ASL*	6.341	3	0.001				SCL/ASL	2.751	3	0.051			
SCL/GSL*				11.777	3	0.008	SCL/GSL*				9.627	3	0.022
SCL/PSL*				12.145	3	0.007	SCL/PSL				0.901	3	0.825
SCL/FSL*	4.100	3	0.010				SCL/FSL				2.507	3	0.474

It was determined that mean SCL value was 18.33 cm in males of Kırklareli population, 18.14 cm in males of Çanakkale population, 16.85 cm in males of Tekirdağ population, and 14.95 cm in males of Edirne population. According to these findings, the largest tortoises in terms of

SCL value were found in the Kırklareli population, and the smallest ones were in the Edirne population (Figure 2A). When the mean SCL values of the female individuals in the populations were examined, it was determined that females in Kırklareli population were 19.85 cm, females in Çanakkale

population were 20.42 cm, females in Tekirdağ population were 18.36 cm, and females in the Edirne population were 16.15 cm. Considering the SCL value, the largest female

tortoises were found in Kırklareli population, and the smallest tortoises were found in Edirne population as in males (Figure 2B).



A



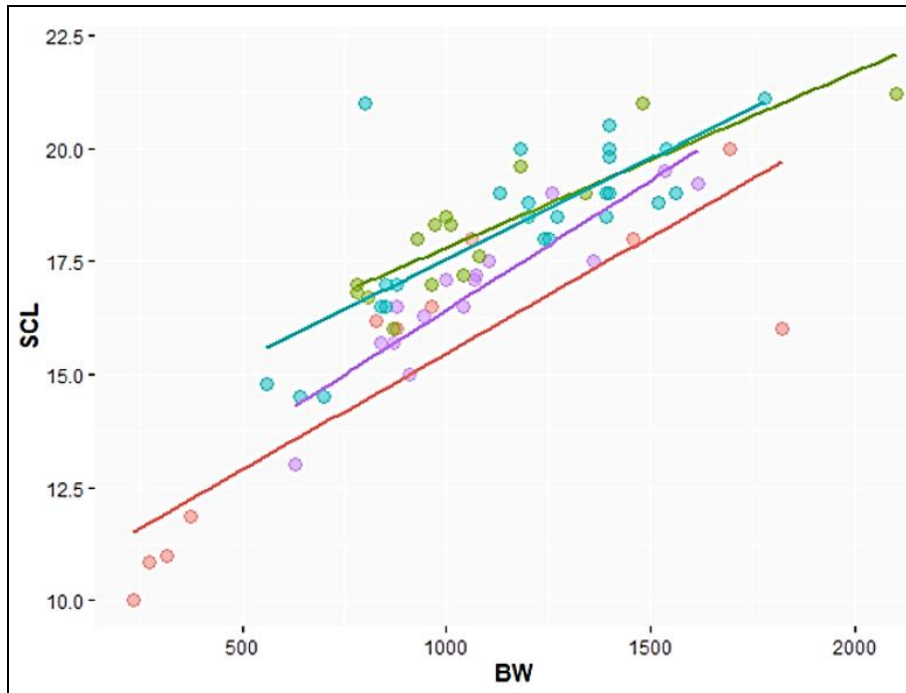
B

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

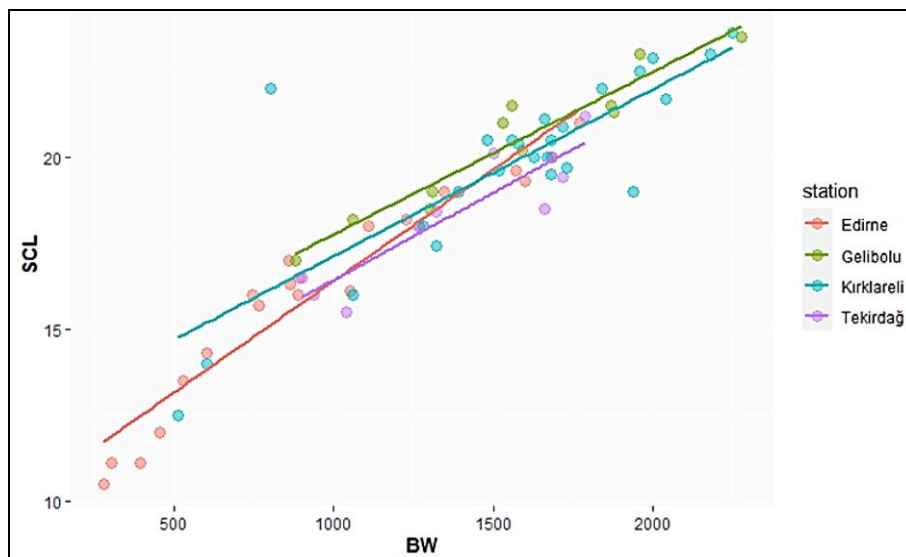
The mean BW value was 1174.80 g in males of Kırklareli population, 1089.13 g in males of Çanakkale population, 1075.26 g in males of Tekirdağ population and 899.63 g in male individuals of Edirne population. As a result of these informations, it is possible to say that male individuals in Kırklareli population were heavier than male individuals in other populations (Figure 3A).

When the mean body weights (BW) of female individuals between populations were compared; it was seen that the

females of Kırklareli were 1563.20 g, the females of Çanakkale were 1565.45 g, the females of Tekirdağ population were 1380.90 g and the female individuals of Edirne population were 961.23 g. As in the body weight comparison of male individuals, female individuals in Kırklareli population were heavier than female individuals in other populations (Figure 3B). The correlation between SCL and BW values that shows body sizes among populations were given in Figure 3.



A



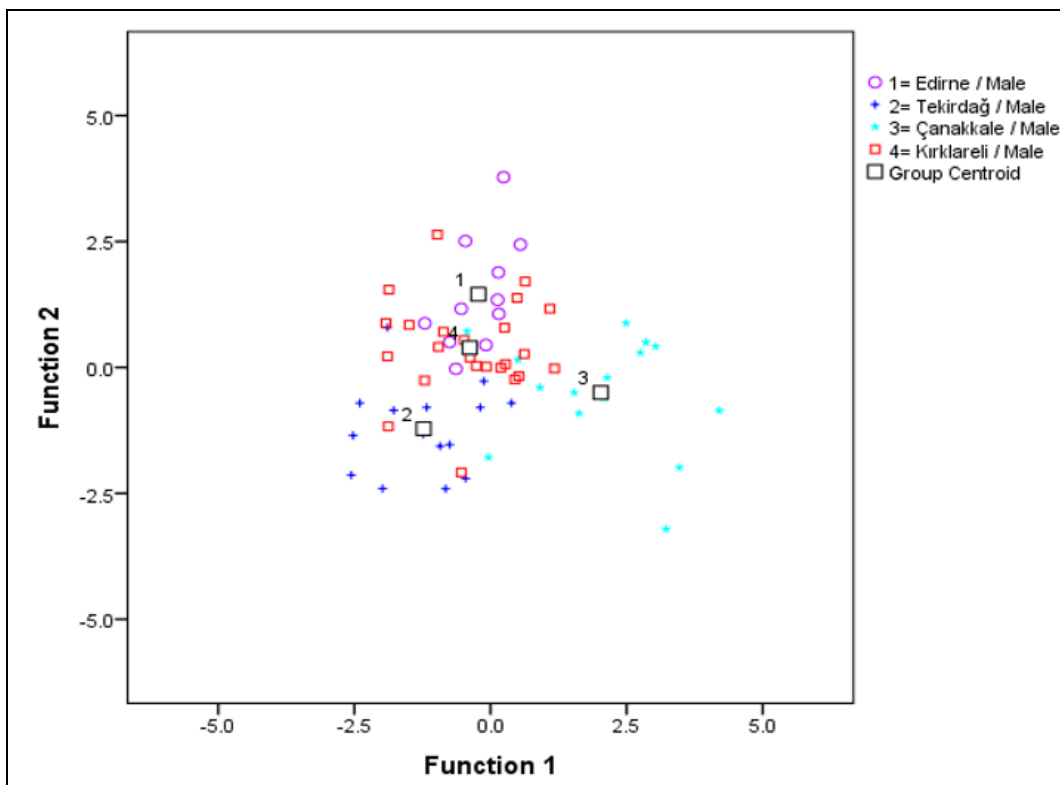
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Fig 3: Correlation of SCL and BW values in males (A) and females (B) between populations

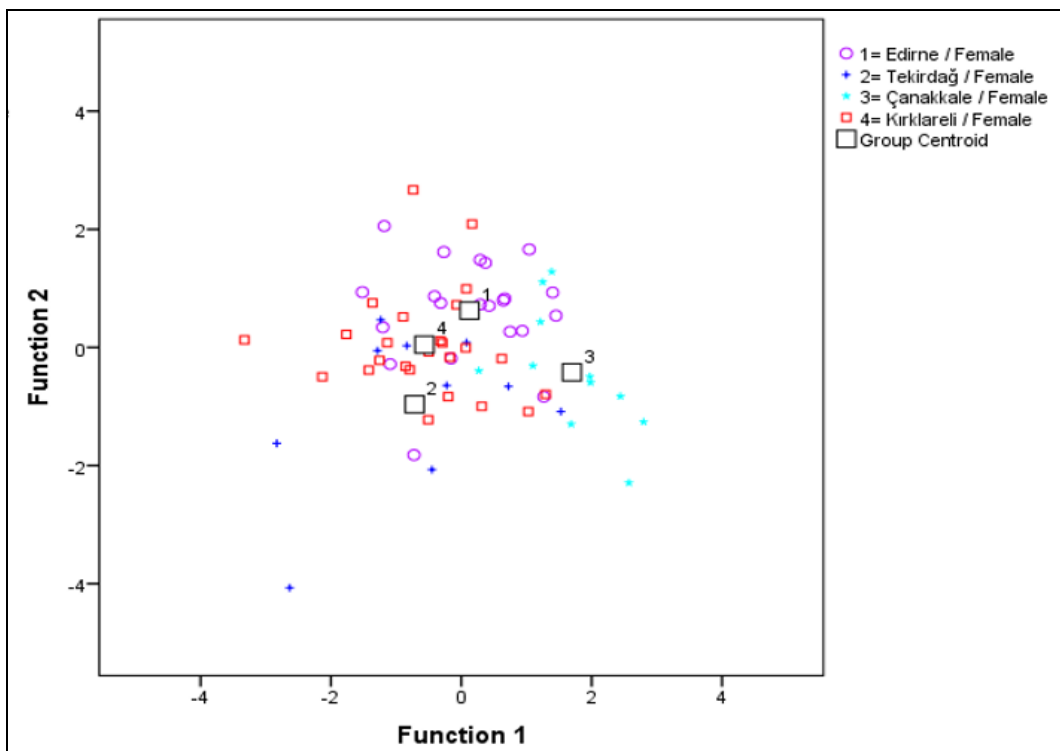
Discriminant analysis was applied to test whether there was a difference between tortoises in populations in terms of ratios and indices obtained from morphometric measurements in which differences were detected between males and females. As a result of the analysis, three functions were formed. While the first function explained 50.1% of the variance, according to this function the Çanakkale population was separated morphologically from other populations. According to the second function, which explained 30.1% of the variance, it was observed that male individuals in Tekirdağ and Edirne populations were separated from each other morphologically (Figure 4A). It was determined that the distinguishing characters for males were SCL/CCL ($F=7.22$,

$p=0.000$), SCL/PW2 ($F=9.66$, $p=0.000$), SCL/HSL ($F=3.61$, $p=0.018$) and BC ($F=7.96$, $p=0.000$).

When female individuals examined, the first function explained 58.7% of the variation and the second function explained 25.3%. Although there was not marked separation as in male individuals, it was observed that individuals in the Çanakkale population were separated from other populations according to the first function. According to the second function, the Tekirdağ population and the Edirne population are distinguished from each other (Figure 4B). It was determined that the distinguishing characters for females were SCL/PW1 ($F=9.16$, $p=0.000$) and SCL/CW ($F=4.73$, $p=0.005$) ratios.



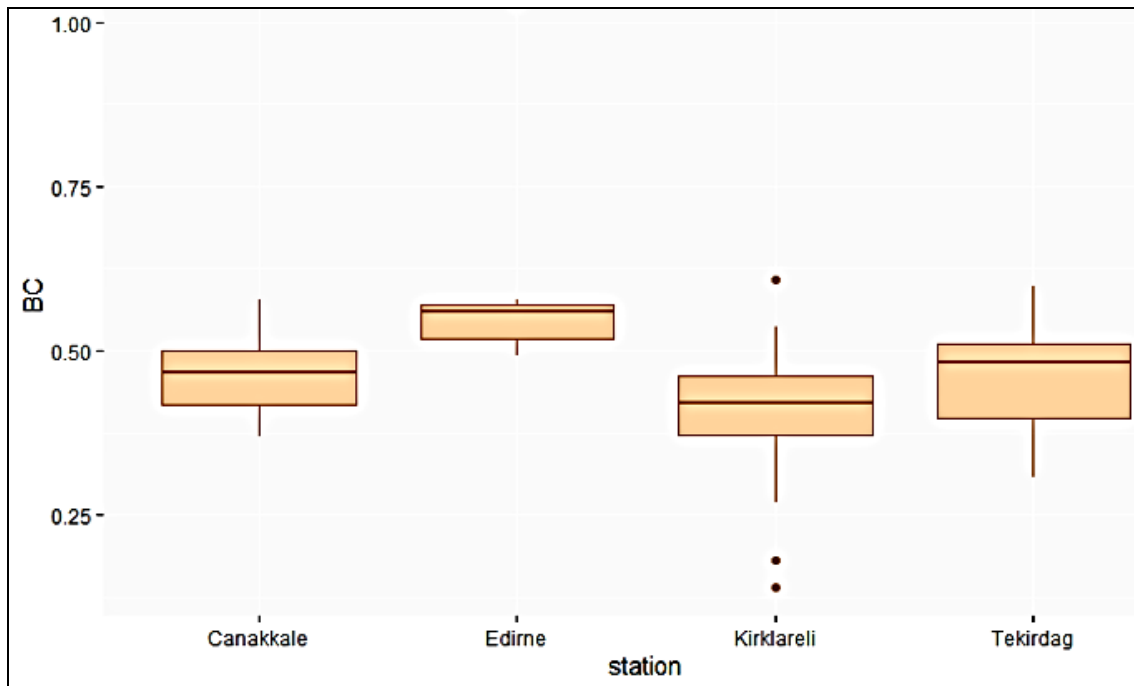
A



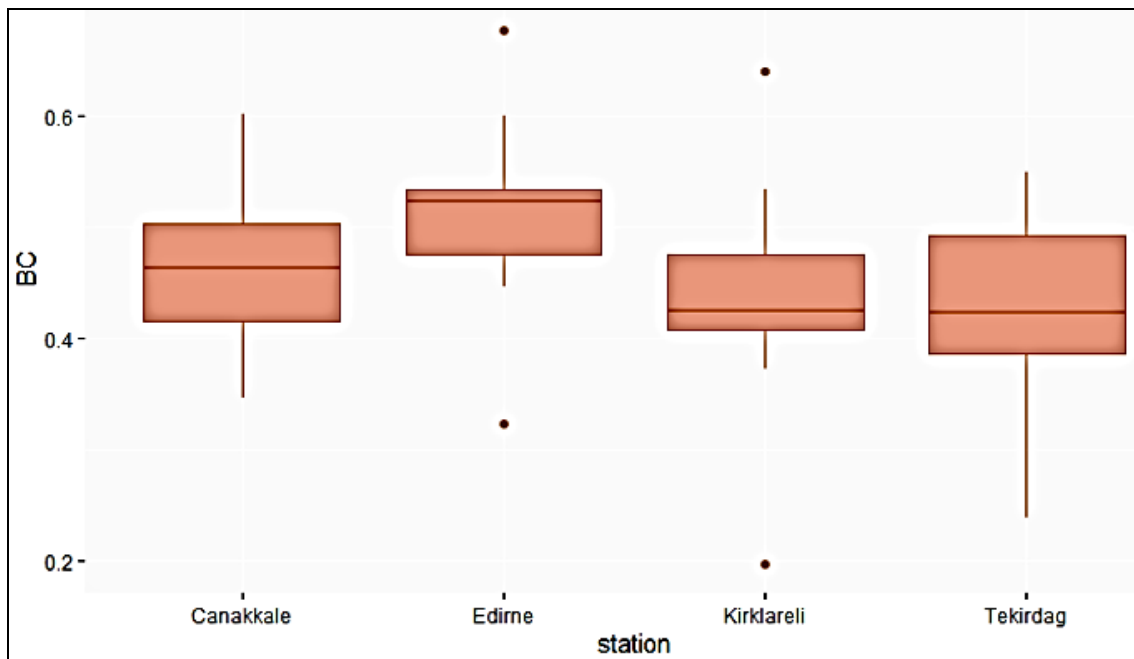
B

Fig 4: Results of discriminant analysis according to the differences in ratios and indices in male (A) and female (B) individuals among populations

While the mean BC values are between 0.40-0.58 in males, it ranges from 0.42-0.51 in females (Figure 5A-B).



A

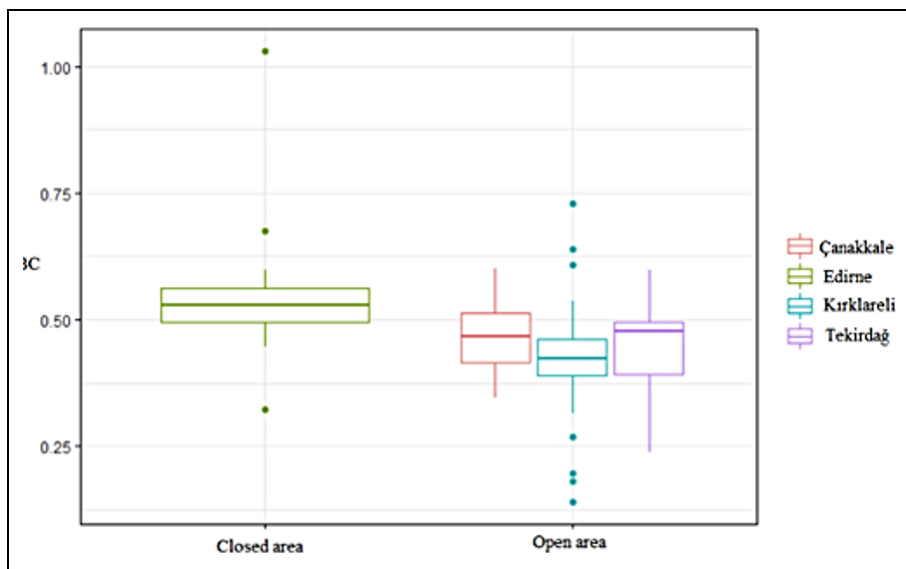


B

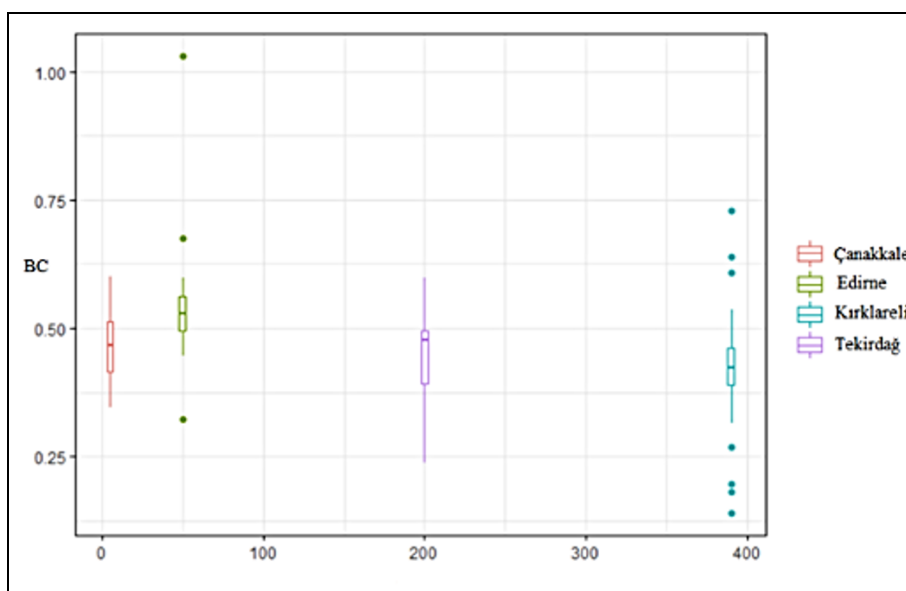
Fig 5: Comparison of Body Condition Indices (BCI) of males (A) and females (B) between four different populations.

It was examined whether the BC values of individuals in the populations were related to some habitat parameters. Edirne station was evaluated as closed area, Çanakkale, Tekirdağ and Kırklareli as open area, and as a result of this evaluation there was a statistically significant difference between closed and open areas for BC value ($p=0.000$) (Figure 6A). When the BC value was examined according to the elevation it was

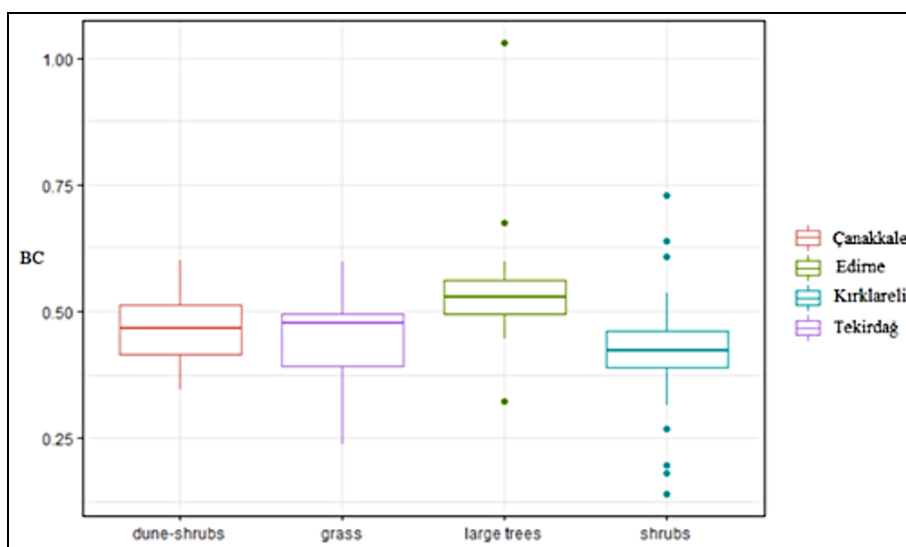
determined that there was a statistically significant difference between the stations ($p=0.000$) (Figure 6B). In addition, when the relationship of BC value of the populations between habitats was examined, it was determined that there were statistically significant differences between the habitats ($p=0.000$) (Figure 6C).



A



B



C

Fig 6: Relationship between BC values of populations and habitat parameters.

4. Discussion

This was the first comparative study of *Testudo graeca* morphologically with individuals taken from Thrace Region. In tortoises, SDI is the most widely used and accepted formula for calculating sexual size dimorphism (SSD) [23,28,10,14,24]. In SDI calculations, a negative value represents male-biased SSD, while a positive value represents female-biased SSD. As a result of the calculations made in present study, SDI values in all populations were determined as positive values representing female-biased sexual size dimorphism.

When the SCL values of male and female individuals in same population were compared, there was a statistically significant difference. As stated in previous studies, female individuals in present study were larger than males in all populations [36, 33, 9, 25, 30]. The fact that female individuals have larger body measurements than male individuals is associated with fertility [7]. Also it is known that the smaller body sizes of the males allow their movements to be faster, thus providing an advantage in seeking females to mate [5].

SCL value that expresses body size in tortoises, was compared with each other for male individuals between four different populations and significant differences were found. At the same time, it was found that the SCL value in female individuals showed differences between populations. In these 4 populations examined, it is possible to say that the largest individuals in both male and female individuals were found in Kırklareli population and the smallest individuals were in Edirne population. It was reported in previous studies that elevational differences plays a role in differing the body sizes of some tortoise species [37]. In this study, it was determined that the largest individuals were found at high altitudes. However, since the effect of geographical variation on *Testudo graeca* species has not been adequately studied, it cannot be said that the size differences are definitely dependent on elevation. In addition, as a result of the observations made in the habitat where the Kırklareli population is located, it was observed that the individuals were spread over a wide area and their access to food and water sources was easier. It is thought that Edirne population has smaller individuals due to the fact that habitat of Edirne population was between highway and railway, individuals were trapped in this area and the water resources was formed from seasonal water bodies.

Türkozan *et al.*, (2004) [32], in their study conducted on the Western Taurus Mountains, were determined that the distinguishing characters in *Testudo graeca* populations were SCL/CH and SCL/PL for male individuals; SCL/NL, SCL/FSL and PL/PW2 for females. In the present study, it was concluded that the distinguishing characters in males were SCL/CCL, SCL/PW2, SCL/HSL and BC; while SCL/PW1 and SCL/CW were in females.

Body condition values in all populations were presented for males and females. Nagy *et al.*, (2002) [27] found the lowest BC value as 0.6 cm³ and the highest as 0.7 cm³ and the mean as 0.64 cm³ in the *Gopherus agassizii* species in their study. In present study, it was seen that the mean BC values were lower, but a comparison could not be made because there was no study using the Body Condition Index in *Testudo graeca* in the literature.

5. Conclusion

In this study, morphometric measurements and ratios of 4

different populations distributed in the Thrace region were examined comparatively. Morphologically significant differences were detected between males and females in all populations, and females were found to be larger than males. When the populations were compared with each other, it was determined that the largest tortoises were found in Kırklareli and the smallest tortoises were in Edirne population, for both males and females. In addition, with this study, body condition data of *Testudo graeca* populations were revealed for the first time using the Body Condition Index.

6. Acknowledgement

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