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Research Article

The Elemental Composition of Green Seaweed (*Ulva rigida*) Collected from Çanakkale, Turkey

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ABSTRACT

Seaweeds or marine algae are rich in terms of minerals. They are used as food source due to the quality of their biological content in many countries. In this study, the elemental composition of green seaweed (*Ulva rigida*) was determined seasonally. Sampling was carried out seasonally from Turkey's Çanakkale strait and the collected algae were analyzed both wet and dried according to the Nordic Committee on Food Analysis (method 186). According to the results; calcium, potassium, magnesium, sodium were found as macro elements and boron, barium, chromium, copper, iron, manganese, zinc as micro elements and determined within the legal limits stated by food codex. However, neither cobalt nor nickel as trace metals were detected in all groups. Moreover, lead and cadmium (which are considered hazardous) were also not detected. While Mg was found to be the highest macro element in all seasons in wet algae, the highest macro mineral varied in dried algae is Ca in spring, K in summer and Mg in both autumn and winter. Fe was found to be the highest micro mineral followed by B, Zn, Mn and Cu both by season and by dried or wet ones ($P<0.05$).

Keywords: Green seaweed, *Ulva rigida*, trace elements, Çanakkale strait, nutrient

INTRODUCTION

It is well known that the usage of macroalgae dates back many, many years. Native South Americans used to collect macroalgae in order to build food supplies and illness remedies (12000 years ago) (Ak, 2015; Dillehay et al., 2008). The utilization of algae takes part within the "Materia Medica" which belongs to Shen-Nung in B.C. 2700. However, algae products obtained by scientific methodologies are seen in last century (Sukatar, 2002). The use of Algae is particularly widespread in Southern Asia for nutrition, medicine and cosmetic industries, and fertilizer in agriculture (Atay, 1984; Kodalak, 2008). Sea lettuce is used as an additive for food and provender and is consumed in China, Japan, Korea, Indonesia, Malesia, France, United States, Canada and Scotland, freshly in salads and dried in soups, dishes and sauces (Mchugh, 2003). Also, they are considered as biologically substantial nourishments (Fleurence, 1999; Rohani-Ghadikolaei, Abdulalian, & Ng, 2012; Sánchez-Machado, López-Cervantes, López-Hernández, & Paseiro-Losada, 2004) and it is significant following fish in aquatic products (Dawczynski, Schubert, & Jahreis, 2007; Fleurence, 1999; Galland-Irmouli et al., 1999; Ortiz et al., 2006).

The Marine Strategy Framework Directive (MSFD) of the European Commission aims to deliver a good environmental status (GES) for the European marine environment by 2020. The eighth and ninth descriptor groups of this directive concern contaminants of fish and other seafood (Law et al., 2010; Swartenbroux et al., 2010). According to this directive, the toxic element compositions of the most commonly consumed fish and seafood species must be monitored in Mediterranean Sea. Therefore, the elemental composition of *Ulva rigida* is important in the usage of a food source. With that feature, *Ulva rigida* can also give an idea about the elemental pollution in the environment (Wan et al., 2017). Moreover, it can be used as an indicator species for lead (Haritonidis & Malea, 1999; Malea & Haritonidis, 2000) and aluminum (Favero, Cattalini, Bertaggia, & Albergoni, 1996). In this study, the elemental composition of *Ulva rigida* were evaluated considering MSFD instructions to highlight *Ulva rigida* as a valuable food source and provide information for further studies in the future.

MATERIAL AND METHODS

Material

In this research, green seaweed (*Ulva rigida*) was used. *Ulva rigida,* also known as sea lettuce, is a cosmopolite species and distributed along the Turkish coasts especially in shallow and rocky bottoms which are rich in nutrients such as nitrogen and phosphorus (Cirik, 2001; Cirik & Cirik, 1999). This algae's tallus size varied from 1-2 cm up to 30 cm and clings to the substrate with a short stem (Irkin, 2009). The green seaweed is shown in Figure 1.

Figure 1. Green seaweed (*Ulva rigida*) collected from Çanakkale, Turkey.

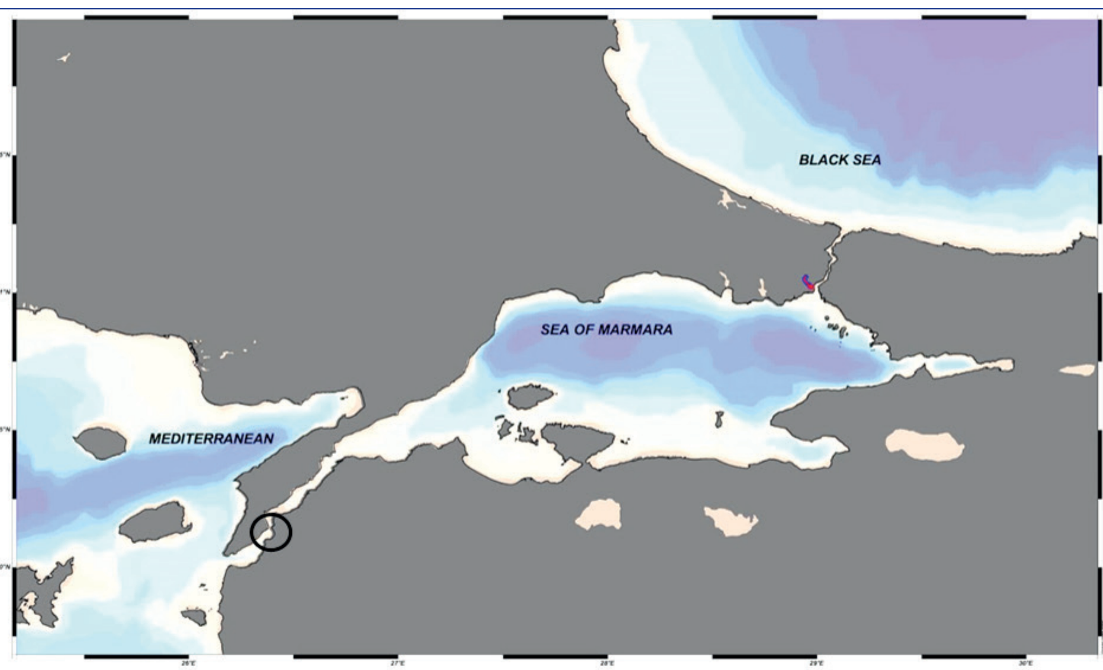

Figure 2. Sampling area in Çanakkale, Turkey. The map was created with Ocean Data View (ODV) Software (40°06'08.6"N, 26°23'13.7"E).

Sampling

Green seaweed samples weighing approximately 2 kg were collected from Kepez station in the Çanakkale strait in the Northern Aegean Sea, Turkey. Sampling was carried out seasonally/quarterly between February/2011 and February/2012. The sampling station of green seaweed (*Ulva rigida*) is shown in Figure 2 and the map used was created with Ocean Data View (ODV) software (Schlitzer, 2019). Samples were stored in 5-liter bottles of sea water taken from the sampling station and transferred to the laboratories in the Faculty of Marine Sciences and Technology in Çanakkale Onsekiz Mart University. Subsequently, the samples were cleaned of any unwanted substances that seaweed carries such as sand particles, epiphyte plants and other aquatic organisms. The sand removal process was carried out by scrubbing with a soft brush in salty water with 0.3% salinity. After this step, the green seaweed samples were separated into two groups. The element analysis was performed on the first group immediately. The second group was dried at 40 °C for 48 hours in a drying oven (Shin Saeng/ SDON-302 model). Finally, the dried samples were then analyzed.

Element Analysis

The element analyses were carried out according to the Nordic Committee on Food Analysis (method 18) (NMKL, 2007) with three parallel and three replicates. These algae are consumed both wet and dried and since some elements can be lost during the drying process, the analyses were carried out with both wet and dried samples. The VH6 Lab Single Element Atomic Absorbsion CRM standards were used in the analyses. Furthermore, the regulations recommended by the MSFD were applied to avoid secondary contamination in the sample preparations. In analysis, 0.5 mg of the samples were weighed using politetrafloroetilen plates (for microwave use) and they were digested with a 10 milliliter concentrated nitric acid (HNO_3) via Speedwave Berghof model microwave at 160 °C in gradually increasing heat conditions. After the samples were completely burned and had become clear mixtures, they were filtered and diluted with distilled water. In the burning process sequence, the mixtures were analyzed with the ICP-AES (Varian Liberty AX Sequential ICP-AES) in Çanakkale Onsekiz Mart University's Main Laboratory. The elements aluminum (Al), boron (B), barium (Ba), calcium (Ca), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), potassium (K), magnesium (Mg), manganese (Mn), sodium (Na), nickel (Ni), lead (Pb) and zinc (Zn) were analyzed. Finally, the data was analyzed and expressed as mg/g for macro elements and µg/g for micro elements on a wet matter basis.

RESULTS AND DISCUSSION

According to the results, four macro elements (calcium, potassium, magnesium, sodium), and seven micro elements (aluminum, boron, barium, chromium, copper, iron, manganese and zinc), were detected. The macro elements were expressed as mg/g and micro elements as µg/g. While magnesium was detected as the most abundant macro element in wet samples in autumn, it was detected as least abundant in summer (P<0.05). The statistical differences were determined between elements seasonally (P<0.05). The elemental composition of dried the seaweeds were

Table 1. Elemental composition of wet green seaweed (*Ulva rigida*)

Elements	Seasons			
	Winter	Spring	Summer	Autumn
Macro elements (mg/g)				
Ca	0.69 ± 0.00^{c}	3.23 ± 0.30^{a}	0.46 ± 0.02^{c}	1.11 ± 0.07^{b}
K	5.66 ± 0.03^{c}	6.09 ± 0.03^{b}	4.68 ± 0.12^{d}	7.18 ± 0.11^{a}
Mg	5.97 ± 0.06^{c}	8.41 ± 0.03^{b}	5.69 ± 0.08^{d}	8.92 ± 0.09^{a}
Na	$5.19 \pm 0.04a^{b}$	5.74 ± 0.24^{a}	4.44 ± 0.46^{b}	4.62 ± 0.40^{b}
Micro elements (µg/g)				
Al	89.00 ± 2.27^{b}	60.00 ± 0.72^{c}	44.93 ± 0.46^{d}	110.80 ± 0.20^{a}
B	17.67 ± 0.61^{c}	15.53 ± 0.31^{d}	52.27 ± 0.46^{a}	33.53 ± 0.61^{b}
Ba	0.53 ± 0.06^{b}	0.80 ± 0.00^{a}	0.67 ± 0.12^{ab}	0.80 ± 0.00^{a}
Co	< 0.035	< 0.035	< 0.035	< 0.035
Cr	< 0.010	0.20 ± 0.00^{c}	0.60 ± 0.00^{a}	0.20 ± 0.00^{b}
Cu	3.27 ± 0.76^{a}	3.00 ± 0.72^{ab}	2.00 ± 0.69^{ab}	1.33 ± 0.64^{b}
Fe	227.87 ± 3.41^{a}	188.20 ± 6.54^{b}	124.60 ± 0.87^{c}	225.07 ± 1.27^{a}
Mn	3.00 ± 0.00^{c}	3.07 ± 0.12^{c}	4.60 ± 0.00^{b}	5.40 ± 0.53^{a}
Ni	< 0.035	< 0.035	< 0.035	< 0.035
Zn	13.20 ± 0.20^{a}	8.47 ± 0.12^{b}	2.00 ± 0.00^{d}	4.40 ± 0.00^{c}
Toxic elements (µg/g)				
Cd	< 0.035	< 0.035	< 0.035	< 0.035
Pb	< 0.035	< 0.035	< 0.035	< 0.035

*Values are expressed as mean ±SD (n = 3), mean values in row with different superscripts were significantly different (P <0.05).

found to be similar to the wet ones. However, a relative increase was detected in both macro and trace element concentrations of dried samples due to the extraction of water from the samples during the drying process. The macro element composition of *Ulva rigida* is shown in Table 1.

Macro and micro elements accumulate in macroalgae with greater concentrations than the surrounding waters (Bonanno & Orlando-Bonaca, 2018). Iron was found as the most abundant trace element in both wet samples (with the amount of 227.87 µg/g in winter), and dried samples (with the amount of 574.53 µg/g in summer). A noticeable amount of Fe, Al and B were also found in the samples. The Mediterranean Sea is rich in terms of dissolved iron and aluminum (Chou & Wollast, 1997; Guieu et al., 2002) and these elements are usually accumulated in *Ulva rigida* (Favero, Cattalini, Bertaggia, & Albergoni, 1996; Malea & Haritonidis, 2000). Boron, which is found in high concentrations in sea water (Demey et al., 2014; Foster, Strandmann Pogge von, & Rae, 2010), is a mineral that has recently generated benefits for human health (Meacham, Karakas, Wallace, & Altun, 2010; Nielsen, 1997; Nielsen & Meacham, 2016) and it was found in all samples of our study. Also; zinc, manganese, copper and a small amount of chromium and barium were detected in *Ulva rigida*. Only chromium wasn't detected in winter. Chromium, which was detected as 0.20 µg/g in wet samples in fall, wasn't found in dried samples due to the dehumidification.

Two trace elements, cobalt and nickel were not detected in any samples during the whole year. Mediterranean waters are not rich in terms of nickel and cobalt (Achterberg & Van Den Berg, 1997; Swanner et al., 2014). However, according to other research using similar methods, these two elements were detected, albeit in small quantities) in other marine organisms caught from the Mediterranean Sea (Berik, Çankırılıgil, & Gül, 2017; Joksimovic, Tomic, Stankovic, Jovic, & Stankovic, 2011; Mutlu, Türkmen, Türkmen, Tepe, & Ateş, 2012; Türkmen, Türkmen, Tepe, & Çekiç, 2010). Consequently, we might suggest that the cobalt and nickel accumulate less in *Ulva rigida* compared to other elements. According to our analyses, cadmium and lead - among the most dangerous toxic elements - were not detected in green seaweed. Several studies showed that, *Ulva rigida* accumulates these toxic metals, especially lead, in significant amounts. (Haritonidis & Malea, 1999; Saeed & Moustafa, 2013; Ustunada, Erdugan, Yilmaz, Akgul, & Aysel, 2011). This research also showed that, the sampling station of *Ulva rigida* was more reliable in terms of lead and cadmium pollution having regard to these low values. The micro element composition of *Ulva rigida* is shown in Table 2.

As regards the elemental studies on sea lettuces in the Çanakkale Province, these are generally focused on iron (Fe) cadmium (Cd) lead (Pb) zinc (Zn) and copper (Cu) (Ozden & Tuncer, 2015; Ustunada, Erdugan, Yilmaz, Akgul, & Aysel, 2011). As for the present study, we can only compare the results with the previous studies in the Çanakkale Province, in terms of Cu, Fe and Zn. Ustunada, Erdugan, Yilmaz, Akgul, & Aysel (2011) studied the seasonal alterations in the content of Cd, Zn, Pb and Cu in *Ulva*

Table 2. Elemental composition of dried green seaweed (*Ulva rigida*)

Elements	Seasons			
	Winter	Spring	Summer	Autumn
Macro elements (mg/g)				
Ca	2.11 ± 0.07[b]	12.73 ± 0.08[a]	1.56 ± 0.02[c]	2.23 ± 0.03[b]
K	7.01 ± 0.01[c]	7.19 ± 0.02[b]	6.52 ± 0.08[d]	8.17 ± 0.01[a]
Mg	10.55 ± 0.06[a]	8.91 ± 0.04[c]	6.13 ± 0.08[d]	10.22 ± 0.03[b]
Na	6.27 ± 0.27[a]	6.31 ± 0.13[a]	5.83 ± 0.41[ab]	5.21 ± 0.41[b]
Micro elements (µg/g)				
Al	158.00 ± 3.80[c]	211.87 ± 2.66[a]	171.73 ± 6.01[b]	224.60 ± 6.10[a]
B	36.87 ± 0.42[c]	34.73 ± 0.12[d]	59.40 ± 0.69[a]	45.93 ± 1.21[b]
Ba	0.60 ± 0.00[d]	1.27 ± 0.12[b]	0.87 ± 0.12[c]	1.67 ± 0.12[a]
Co	< 0.035	< 0.035	< 0.035	< 0.035
Cr	< 0.010.	0.20 ± 0.00[a]	0.07 ± 0.12[ab]	< 0.010
Cu	6.33 ± 0.64[a]	4.13 ± 0.64[b]	1.00 ± 0.53[c]	1.93 ± 0.46[c]
Fe	293.93 ± 4.12[d]	461.47 ± 8.03[b]	574.53 ± 5.60[a]	399.87 ± 7.91[c]
Mn	5.47 ± 1.50[b]	10.07 ± 0.12[b]	10.27 ± 0.12[a]	6.93 ± 0.12[b]
Ni	< 0.035	< 0.035	< 0.035	< 0.035
Zn	20.13 ± 0.12[a]	17.60 ± 0.20[b]	13.80 ±0.00[d]	14.40 ± 0.20[c]
Toxic elements (µg/g)				
Cd	< 0.035	< 0.035	< 0.035	< 0.035
Pb	< 0.035	< 0.035	< 0.035	< 0.035

*Values are expressed as mean ±SD (n = 3), mean values in row with different superscripts were significantly different (P <0.05).

rigida samples, in six different locations of the Dardanelles (Çanakkale), and did not detect any of the elements in levels greater than 1 µg/g within any of the dry algae samples collected. However, Ozden and Tuncer (2015) did not detect the elements of Pb and Cu in levels above 1 µg/g in the dry samples of *Ulva rigida* collected seasonally from five different locations in the Dardanelles. They also reported that the seasonal average amounts of Zn and Fe were between 1.01-6.5 µg/g and 2.25-10.87 µg/g, respectively. The results of the element quantities in the present study were observed to be higher compared to the abovementioned studies, for example, Cu was between 1.00 and 6.33 µg/g; Fe, 294-575 µg/g; and Zn, 13.80-20.13 µg/g. It is generally considered that the differences in the results between this study and other studies stems from the sampling years and a dissimilarity in sampling locations. The Dardanelles, being a specific current system can contain different proportions of minerals during various years and stations due to taking nutrition particularly from the water bodies originating from the Black Sea. Furthermore, the magnitude of the algae is a distinctive feature in terms of mineral composition. Older algae have better ability of absorbing minerals from sea water.

According to legislation, the acceptable daily limits of copper is 0.5 mg/kg, and manganese is between 0.4-1.0 mg/kg of bodyweight (Codex Alimentarius, 2007; 2011). There are no legal limits for aluminum and barium in meat products but the EFSA (2013) stated that aluminum exposure should not exceed 1 mg/kg weekly for humans and the Codex Alimentarius Committee (1996) stated that the acceptable barium limit is 1 mg/l in drinking water. Nickel and chromium were found very low - just slightly higher than the detection limits. Additionally, certain beneficial elements, such as boron and zinc, should be present in foods in the amounts of 0.5-0.4 mg/kg and 15 mg/kg of body weight, respectively (Codex Alimentarius, 2007; Jopp, 2012; WHO, 2013).

CONCLUSION

In this research, the elemental composition of green seaweed (*Ulva rigida*) and level of food safety was evaluated. In sum, *Ulva rigida* is rich in terms of certain beneficial micro elements such as iron, boron and zinc – and within acceptable values. Furthermore, the elements lead and cadmium (considered as hazardous), were not detected. With these features and the supporting studies related to nutrient content for this species, *Ulva rigida* we can suggest that the seafood sector is a convenient and secure food source if it is collected from not-polluted and safe areas.

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Research Article

Age Structure and Growth Characteristics of the Endemic Fish *Oxynoemacheilus anatolicus* (Nemacheilidae) in Düğer Creek, Mediterranean region of Turkey

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ABSTRACT

The present study reports the age and growth properties of Burdur Loach, *Oxynoemacheilus anatolicus* Erk'akan, Özeren & Nalbant, 2008 caught from the Düger Spring Creek (Burdur-Turkey) and is currently listed as an endangered species. 100 specimens of *O. anatolicus*, which ranged in size between 2.5 and 8.6 cm in total length, 0.14 and 5.90 g in total weight, were collected during the study period. Of all the *O. anatolicus* examined, 5 were immature, 50 were female, and 45 were male. The overall sex ratio in the populations matches the expected value of 1:1 in a normal population. The otolith readings indicated the presence of five age classes (I-V). Length–weight relationships were fitted by the equation $W= 0.0082L^{3.0402}$ ($p<0.05$) for both sexes combined and this indicated that growth was positive allometric. The condition factor values were calculated and ranged from 0.64 to 1.19. The obtained data was compared with available results from close species. This study provided first baseline data related to length-weight relationship, age, sex ratio and condition factor for *O. anatolicus* – a species whose populations have been threatened due to various ecological changes in its habitats, leading to increased concern and the need for conservation.

Keywords: Freshwater, Endemic, Burdur Loach, Karstic spring

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INTRODUCTION

Anatolia is characterized by high levels of biodiversity and a high density of endemic species, Its geological history has played a key role in the diversification of freshwater fish species (Demirsoy, 2002; Kuru, Yerli, Mangıt, Ünlü, & Alp, 2014; Çiçek, Sungur Birecikligil, & Fricke, 2015; Çiçek, Fricke, Sungur, & Eagderi, 2018). The loach genus *Oxynoemacheilus* has undergone major diversification in Anatolia, where more than 30 species have been reported (Froese and Pauly, 2019).

Members of the genus *Oxynoemacheilus*, commonly known as stone loaches, are small fish living in the fresh waters of Asia and its islands, Europe, and northeast Africa. They inhabit a variety of water bodies ranging from mountain streams to salty rivers in dry lowlands (Jouladeh-Roudbar, Eagderi, & Hosseinpour, 2016). Most of them are very rare and have a limited distribution area. Despite the high diversity and endemism of *Oxynoemacheilus* genus in Turkey, knowledge about its biology and population dynamics are still limited. Most of the available studies have focused mainly on length-weight relationships (Gaygusuz et al., 2012; Erk'akan, Innal, & Özdemir, 2013, 2014; Innal, Özdemir, & Dogangil, 2015; Birecikligil, Çiçek, Öztürk, Seçer, & Celepoğlu, 2016; Özcan & Altun, 2016; Yazıcıoğlu & Yazıcı, 2016).

The Burdur Endorheic Basin has a great diversity of natural ecosystems including wetlands, warm and hot springs, and saline and freshwater lakes. Because of the introduction of alien or translocated fish species and building of dams for agricultural purposes, many endemic fishes have become rare and endangered here (Küçük, Gülle, Innal, & Güçlü, 2016; personal observation, Deniz Innal). The Burdur Endorheic basin provides an essential spawning and rearing habitat for many loach species, including the Burdur loach (Küçük et al., 2016). Burdur loach has been reported at input locations in Karamanlı Dam Lake (Erk'akan, Özeren, & Nalbant, 2008), Başpınar Creek (Küçük et al., 2016), Düger Spring (Freyhof, Erk'akan, Özeren & Perdices, 2011; Innal et al., 2017) and Pınarbaşı Creek (Innal & Giannetto, 2017).

While the subject's populations have been threatened due to various ecological changes in its habitats, leading to increased concern and the need for conservation, there is not sufficient information available about its biological features. This study provided first baseline data related to length-weight relationship, age, sex ratio and condition factor for *O. anatolicus*.

MATERIALS AND METHODS

The study was carried out in Düger Creek between March 2014 and December 2014 (6 sampling events). Düger Creek is a small, karst system in the southwest of Turkey, situated in the Düger Village (37°34'31.53"N 30°01'13.64"E-37°34'37.04" N 30°01'28.38"E) close to the city of Burdur (Burdur Endorheic Basin). Water quality parameters were measured at the surface at the start of each field trip. Temperature (°C), salinity, pH and dissolved oxygen (mg/l) concentration were measured using a YSI water meter (Professional Plus). A total of 100 *O. anatolicus* speciemens were collected using electroshock equipment.

After being caught, the fish samples were transported to the laboratory where their size (total length; cm, referred to as L in the text and weight; g, referred to as W in the text) were measured and weighed to the nearest 1.0 mm and 0.01 g, respectively. The otoliths of individuals were used for age determination (The roman numerals indicate a subjective classification of ages). Length-weight relationships were estimated for the total sample and separated by sex, according to the equations suggested by Ricker (1975), $W=aL^b$. Where W = mass in grams; L = total length in centimeters. a=constant; b=constant described as isometric or allometric growth type. The value of Condition factor, K was calculated following Froese (2006), $K = 100 * W/ L^3$. The slopes of length–weight regressions were compared to 3 using Student's t-test to ascertain if the species grew isometrically. Size-frequency distributions between sexes were conducted using the t-test and Kolmogorov-Smirnov two-sample test. A Chi-square test was used to identify the sex-ratio divergence from the expected value of 1:1 (male:female).

RESULTS AND DISCUSSION

Düger Creek is a natural karst spring system leading to Lake Burdur. The bottom is generally muddy or made up of small gravel. A range of water quality parameters of Düger Creek were measured (Figure 1).

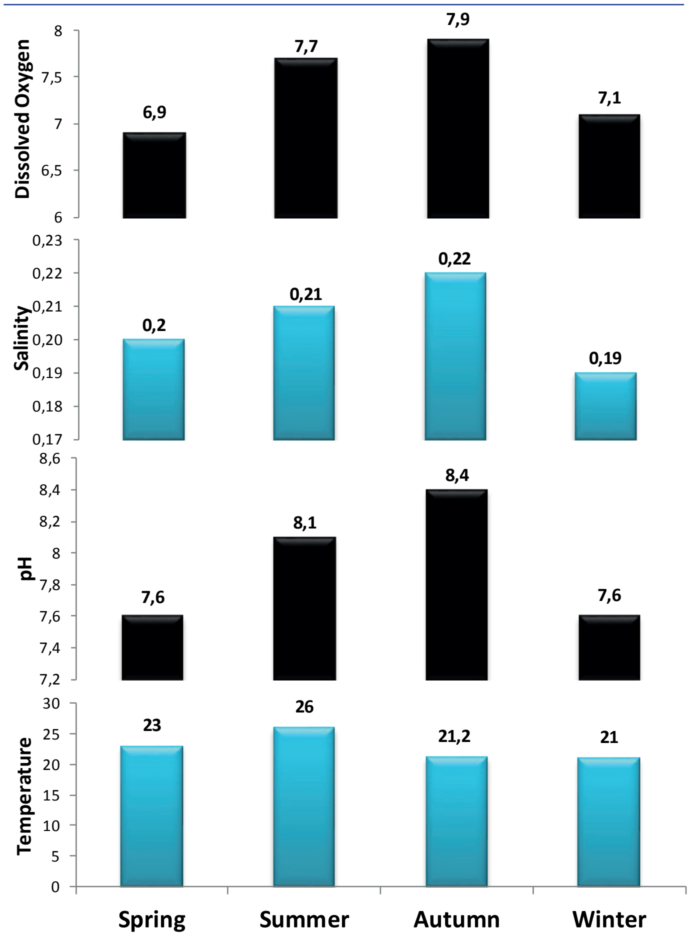

Figure 1. Water quality parameters of Düger Creek.

O. anatolicus was observed in slow-flowing waters where the vegetation zone was dense. *Pseudophoxinus burduricus, Gambusia holbrooki, Oxynoemacheilus theophilii* and *Oxynoemacheilus anatolicus* were reported from Düger Spring (Innal et al., 2015; Innal et al., 2017). Within the sample area, bottom salinity ranged from 0.19–0.22 ppt, surface temperature ranged from 21°C–26°C, pH ranged from 7.6–8.4 and dissolved oxygen (mg/L) ranged from 6.9–7.9. This species is well adapted to the warm-water spring zone of Düger Creek.

Although a high species diversity of Genus *Oxynoemacheilus* exists in Turkey, little is known about their life history. The ecology of *O. anatolicus* has been reported in aquatic systems in terms of systematics (Erk'akan et al., 2008), distribution (Freyhof et al., 2011; Küçük et al., 2016; Innal & Giannetto, 2017) and parasites (Innal et al., 2017). This work, however, is the first study on age and growth for Burdur Loach in Turkey, so no comparison is possible with other studies of this species.

The sex and age compositions of *O. anatolicus* are shown in Table 1.

The 100 individuals of *O. anatolicus* used for the age determination consisted of 45 (45%) males, 50 females (50%) and 5 (5%) juveniles. The female–male ratio for all fish combined was 1.11:1

Table 1. The sex and age compositions of *O. anatolicus*

Age	Juvenile		Female		Male		Total	
	N	%	N	%	N	%	N	%
I	5	5	2	2	3	3	10	10
II			21	21	29	29	50	50
III			11	11	7	7	18	18
IV			15	15	4	4	19	19
V			1	1	2	2	3	3
Total	5	5	50	50	45	45	100	100

Table 2. Length frequency distribution of *O. anatolicus*

Length intervals (cm)	Age groups (in years)					Total
	I	II	III	IV	V	
2-2.9	3					3
3-3.9	7	13				20
4-4.9		20				20
5-5.9		17	6			23
6-6.9			12	3		15
7-7.9				16		16
8-8.9					3	3
Total	10	50	18	19	3	100
Range TL	2.50 - 3.40	3.20 - 5.60	5.20 - 6.80	6.20 - 7.90	8.40 - 8.60	2.5 - 8.6
Mean TL±SD	2.98 ± 0.25	4.49 ± 0.64	6.01 ± 0.48	7.24 ± 0.48	8.47 ± 0.12	5.26 ± 1.55
Range W	0.14 - 0.31	0.29 - 1.53	1.07 - 3.11	2.02 - 5.31	5.45 - 5.90	0.14 - 5.90
Mean W±SD	0.23 ± 0.06	0.86 ± 0.37	1.94 ± 0.55	3.36 ± 0.81	5.65 ± 0.23	1.61 ± 1.40

Table 3. Estimated length weight parameters of *Oxynoemacheilus* species

Species	Locality	b	a	r^2	TL(Min-Max)	W(Min-Max)	N	Reference
O. mesudae	Küfe Creek	2.628	0.0161	0.95	6.6 - 8.9	2.2 - 5.2	14	Erk'akan et al., 2014
O. evreni	Çayır Creek	2.788	0.0128	0.92	5.4 - 9.4	1.4 - 6.7	27	Erk'akan et al., 2014
O. theophilii	Bozçay Creek	2.898	0.01	0.94	3.1-5.6	0.25-1.18	10	Innal et al., 2015
O. samanticus	Karaboğaz Creek	2.919	0.00851	0.92	4.5 - 8.6	0.6 - 4.3	40	Erk'akan et al., 2014
O. angorae	Kılıçözü Stream	2.929	0.0098	0.96	3.5-9.8	0.38-6.58	103	Yazıcıoğlu & Yazıcı, 2016
O. theophilii	Dalaman Stream	2.989	0.011	0.93	6.4-7.9	2.51-4.88	10	Innal et al., 2015
O. anatolicus	Düger Creek	3.04	0.0082	0.98	2.5-8.6	0.14-5.90	100	PRESENT STUDY
O. theophilii	Cüneyt Creek	3.07	0.007	0.96	6.6-10.5	2.3-11	17	Innal et al., 2015
O. angorae	Kızılırmak River Basin	3.102	0.008	0.94	2.8-8.6	0.22-6.18	127	Birecikligil et al., 2016
O. theophilii	Düger Spring	3.188	0.007	0.94	3.9-5.8	0.56-2.09	13	Innal et al., 2015
O. eregliensis	Melendiz Creek	3.196	0.005	0.98	1.65-10.3	0.1-7.3	76	Erk'akan et al., 2013
O. angorae	Sögütözü Beynam	3.228	0.00622	0.99	4.4 - 8.3	0.8 - 6.6	24	Erk'akan et al., 2014
O. angorae	Balıklı Stream	3.237	0.006	0.88	4.7–7.3	0.86–3.56	30	Gaygusuz et al., 2012
O. simavicus	Karaçaltı Creek	3.261	0.0044	0.95	4.6-7.1	0.6-2.5	17	Erk'akan et al., 2014
O. theophilii	Yiğitler Creek	3.293	0.004	0.98	5.5-8.9	1.1-5.4	9	Innal et al., 2015
O. hamwii	Gölbaşı Lake	3.52	0.0021	0.96	5.0–8.8	0.6–3.65	28	Özcan and Altun, 2016

and Chi square test analysis conducted on sex ratio showed that the difference was not statistically significant (P>0.05). The ages of the captured specimens ranged from I to V years and the second group was dominant in the population, followed by age IV (19 %), III (18 %), I (10 %), and V (3 %) age groups.

Females were caught in higher numbers in this study. A higher proportion of females has also been reported for other members of the Nemacheliidae family, for species such as 1.0/0.63 (f/m) for *O. angorae* in Kılıçözü Stream (Yazıcıoğlu & Yazıcı, 2016). 1/0.81 (f/m) for *O. tigris* from Murat River (Koyun, Ulupınar, Mart, & Tepe, 2016).

Length frequency distribution of *O. anatolicus* is given in Table 2

The specimens of *O. anatolicus* ranged from 2.5 to 8.6 cm in total length and from 0.14 to 5.9 g in total weight. Total length ranged from 3.1 to 8.4 cm in males, from 3.1 to 8.6 cm in females and from 2.5 to 3 cm in juveniles. Weight ranged from 0.208 to 5.9 g in males, from 0.203 to 5.6 g in females and from 0.14 to 0.285 g in juveniles. The mean total length and weight of females were higher than males. No significant difference was observed in mean length and weight between sexes (P > 0.05).

The total length of *O. anatolicus* ranged from 2.5 to 8.6 cm, which fits well within the known values (Table 3) while the minimum length observed in this study was close to the value reported for *Oxynoemacheilus angorae* from the Kızılırmak River Basin (Birekcikliğil et al., 2016). The maximum length was closer to known reported values for some species; *Oxynoemacheilus angorae* from the Kızılırmak River Basin (Birekcikliğil et al., 2016) and Sögütözü Beynam (Erk'akan et al., 2014), for *Oxynoemacheilus hamwii* from Gölbaşı Lake (Özcan & Altun, 2016), for *Oxynoemacheilus mesudae* from Küfe Creek (Erk'akan et al., 2014), for *Oxynoemacheilus samanticus* from Karaboğaz Creek (Erk'akan et al., 2014), for *Oxynoemacheilus theophilii* from Yiğitler Creek (Innal et al., 2015). In population structure, female individuals of *O. anatolicus* showed wider length range, mean length and weight than males.

Length and weight frequency distributions and length-weight relationships $W = aTL^b$ (in g and cm) for *O. anatolicus* from Düger Creek are given in Figure 2.

Among all the individuals, dominancy was in the total length range of 3-6 cm and dominancy was in the weight range of 0.14-2 g (Figure 2). The length frequency distributions of males and females were not significantly different. Length–weight relationships was calculated using the data of 100 *O. anatolicus* specimens. This was found to be $W= 0.0082L^{3.0402}$(R^2=0.98) ($p<0.05$; 95% CI of b: 3.022-3.054) for all individuals. The calculated value of (b) exponent for female, male and combined sexes was 3.0286 ($p<0.05$), 3.0498 ($p<0.05$) and 3.0402 ($p<0.05$), respectively. These values indicate that the fish had positive allometric growth. "b" values of *O. anatolicus* were not significantly different between the sexes. The regression models in the study showed no differences in terms of growth patterns between males and females of *O. anatolicus*. The r value of 0.98 indicates a high correlation degree of length and weight.

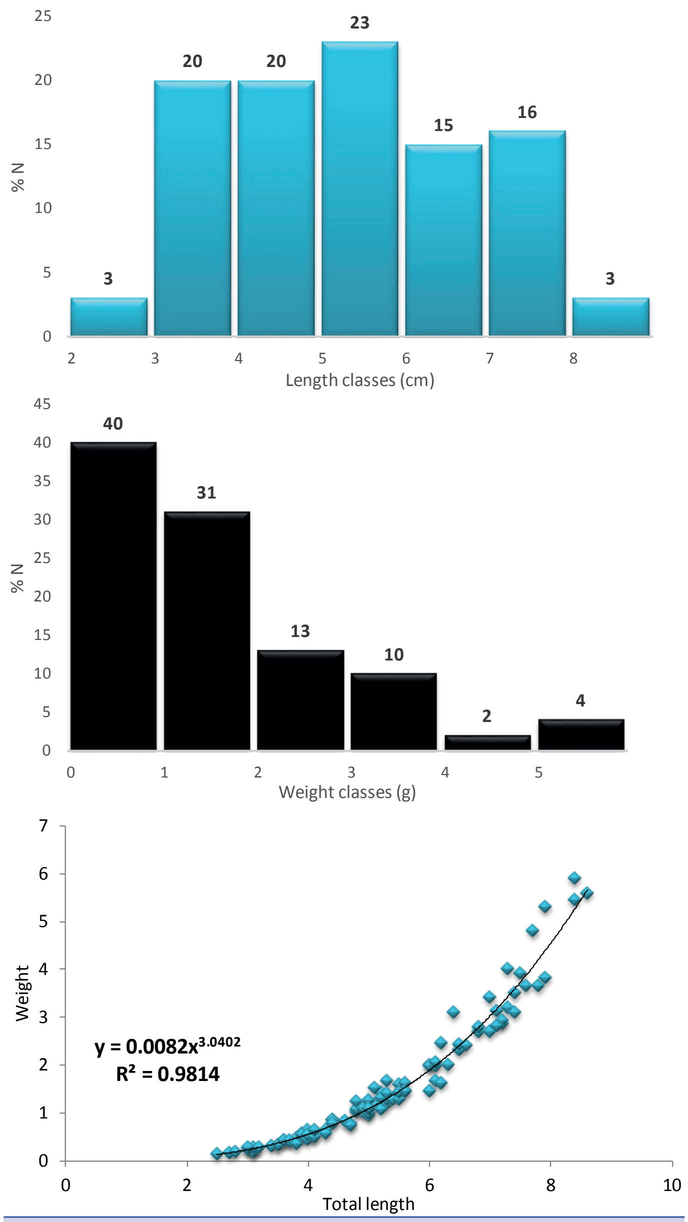

Figure 2. Length and weight frequency distributions and length-weight relationships for *O. anatolicus* from Düger Creek.

Length-weight relationship (LWR) parameters have basic uses in fish stock assessment and fisheries management (Froese, 2006). This paper provides the first published reference of the length-weight for *O. anatolicus*. Relationships between length and weight for species of *Oxynoemacheilus* genus have been described by several authors, and both isometric and allometric growth from various water bodies have been reported for species of *Oxynoemacheilus* genus (Table 3). The b value of *Oxynoemacheilus* species in Turkey has been shown to range from 2.63 to 3.52 (Table 3).

Allometric growth of *Oxynoemacheilus* genus determined in this study was in accordance with results reported in earlier studies

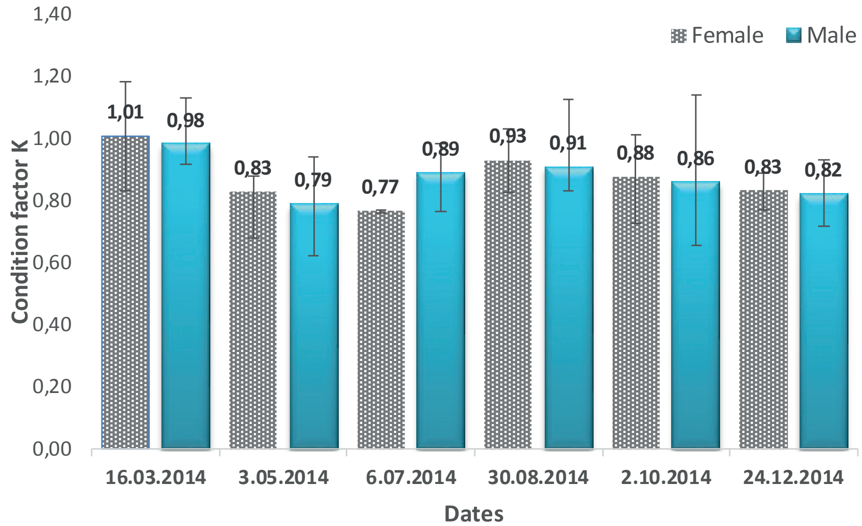

Figure 3. Seasonally condition factor of *O. anatolicus*.

(Gaygusuz et al., 2012; Erk'akan et al., 2013; Erk'akan et al., 2014; Innal et al., 2015; Birekcikligil et al., 2016; Özcan & Altun, 2016). The factors affecting the b value have been reported by various authors (Tesch, 1971; Moutopoulos & Stergiou, 2002; Froese, 2006). Variations in growth type and b values from different areas may be attributed to one or more factors, including different physico-chemical parameters of systems, flora and fauna compositions of systems. sampling designs, sampling properties and characters of species (sex, length range, diet, parasites).

Graphical presentations of the seasonal condition factor for *O. anatolicus* studied are shown in Figure 3.

Condition factor (K) values for female samples were generally higher than those of the males. The mean K values for female, male and combined sexes were 0.90, 0.86 and 0.88 respectively (Fig. 3). The results showed that there were no variations in condition factors between sexes of the *O. anatolicus* collected from Düger Creek. The condition factor of *O. anatolicus* showed seasonal variation - it was noticed that K was higher when fish entered into the maturation phase during the month of March, while for rest of the seasons K showed lower values.

The mean condition factor which is a measure of the suitability of the environmental factor for growth of the species obtained for this study was 0.88 and ranged from 0.64 to 1.19. Mean condition factor value was close to the value (0.86) documented by Yazıcıoğlu & Yazıcı, (2016) for *Oxynoemacheilus angorae* from the Kılıçözü Stream and also relatively lower than the value (0.94) reported by Birecikligil et al. (2016) for *Oxynoemacheilus angorae* from the Kızılırmak River Basin (Birekcikliğil et al., 2016). Differences in mean condition factors of males and females in this study were not statistically significant.

The Burdur Loach was listed as endangered as a result of dam construction and pollution (Freyhof, 2014). The species is sympatric with 3 native species; *Pseudophoxinus burduricus, Cobitis battalgili, O. theophili,* of which the first two are endemic to Anatolia. During the study period in Düger Creek, one alien species, *Gambusia holbrooki* was caught. An increasing population of *G. holbrooki* may threaten the population of *O. anatolicus*.

Anthropogenic water pollution is another important disturbance factor. The anthropogenic water pollution sources include human waste, ruminant animal farming and chicken egg industry discharges. Chemical pesticides, often used in agriculture, may constitute a high risk to *O. anatolicus*. In addition, the construction of roads for Marble Mining affects the habitat quality of Düger Creek. A minor threat is excessive water abstraction that alters the normal creek flow and may restrict the movement of the fish along the creek channel.

CONCLUSIONS

This study highlights that growth characteristics for Burdur Loach are not much different from species in the same genus (Table 3). Length-weight relationship exhibited positive allometric growth patterns in the *O. anatolicus* collected from Düger Creek. The overall sex ratio in the populations matched the expected value of 1:1 in a normal population. Condition factor values of *O. anatolicus* in Düger Creek were close to the reported values for other species of the same genus. The best conditions for the fish were recorded during the month of March.

Because of the threat to *O. anatolicus* populations by loss of suitable habitats, conservation efforts are required. Data on length-weight relationship, age, sex ratio and condition factor for Burdur Loach inhabiting Düger Creek have been presented in this paper for the first time.

It could be concluded that the findings of this study will contribute to the knowledge of bioecology of *O. anatolicus*. Further studies on the reproductive biology and conservation practices are urgently required for this endangered species.

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Ethics Committee Approval: This study was carried out in accordance with animal welfare and trial ethics. All procedures were performed in accordance with the Law on Veterinary and Medical Activities and National Animal Welfare Act.

Conflict of Interest: Author has no conflict of interest to report.

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Research Article

Length-Weight relationship of 13 fish species from the Lower Sakarya River, Turkey

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ABSTRACT

In this study, a total of 1935 fish samples were collected monthly between June 2017 and May 2018 belonging to 5 families; Cyprinidae, Siluridae, Percidae, Centrarchidae and Esocidae from the lower Sakarya River, Turkish shores of the western Black Sea. Estimation for *b* value of the length-weight relationship ranged between 2.87 (*Carassius gibelio*) and 3.41 (*Alburnus escherichii*). Length–weight estimates and TL_{max} value (18.2 cm) for *A. escherichii* are not available in Fishbase and are first given in this research. Eleven of the evaluated 13 species are commercial for the Sakarya River fishery. The results of this research could be useful for further fishery studies in the lower Sakarya River.

Keywords: Length–weight relationship, Sakarya River, allometric growth, cyprinidae

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INTRODUCTION

Rivers and natural lakes are important ecosystems of our world and cover approximately 2.5% of the earth's surface (Shiklomanov, 1999). Turkey's inland water resources potential can be considered as important because of its position in the world. Turkey has an important inland water fishery potential with 33 rivers (177714 km), 200 natural lakes (900118 ha), 159 dam lakes (342377 ha) and 750 ponds (15500 ha) (FAO, 2015). Despite this potential, the production of inland waters is quite low. Fishery production can be increased by converting un-utilized water resources into production areas or by allowing use. Therefore, there is a need for comprehensive and stock assessment researches on fish populations which have economic importance in our inland waters and other populations to which they are related and their ecological environments. Thus, maximum sustainable yield can be provided without destroying the ecological balance and damaging existing stocks.

As indicated in the many other studies, Length-Weight Relationships (LWRs) have an important role in fish stock management (Kalaycı, Samsun, Bilgin, & Samsun, 2007) and also they are useful for comparing life history and morphological aspects of different populations from other regions (Goncalves et al., 1997). LWRs explain the mathematical correlation between fish length and weight. These relationships are used for conversion of length observations to weight values to provide some measure of biomass (Froese, 1998). In fishery studies, length is easier to record than mass, therefore, if we have a length value, body weight could be determined (Harrison, 2001).

In this study, the Lower Sakarya River region, which is chosen as the study area, has economically benefited as well as being a significant protein source for the local people with its ecology and the fish species it hosts. In this respect, the sustainable management of fishing in the region has great importance. The aim of this study is to contribute to sustainable fisheries management and literature by revealing the growth characteristics of fish species which have economic importance in the region.

MATERIALS AND METHODS

This study was conducted between June 2017 and May 2018 on the lower Sakarya River, in Turkey. Three sampling locations were chosen in the Sakarya river, Pamukova (1), Adapazarı (2) and Karasu (3) (Figure 1). Data were collected monthly with trammel nets (inner panel: 52-72-88 mm, outer panel: 300 mm; stretched mesh sized), fyke net (140 mm stretched mesh sized, 5 m leader net) and electro shocker (SAMUS 1000; 500W). The sampling areas were sandy-muddy substrates and depths were between 3-10 meters.

The samples were taxonomically identified in the laboratory according to Kuru, (2004); Kottelat & Freyhof, (2007); Geldiay & Balik, (2009). Total lengths were measured with measurement boards (±0.1 cm) and weights were taken with a precision balance (±0,01 g).

The parameters *a* and *b* of relationships of the equation $W = aL^b$ (Ricker 1975) which is estimated through logarithmic transformation; $\log W = \log a + b \log L$

where W is weight (g), L is total length (cm), *a* is the intercept and *b* is the slope of the linear regression. Parameters *a* and *b* were calculated by least-squares regression, as was the coefficient of determination (R^2). 95% confidence limits (CI) of *b* was also estimated (Pauly, 1993). Growth was determined separately for each fish species based on length-weight relationship equations.

RESULTS AND DISCUSSION

A total of 1935 fish samples were collected in this study. 13 fish species belonging to five families, Cyprinidae (78.86%), Siluridae (10.96%), Percidae (5.53%), Centrarchidae (2.38%) and Esocidae (2.27%), were examined. Estimation for *b* value of the length-weight relationship ranged between 2.87 (*C. gibelio*) and 3.41 (*A. escherichii*). The growth type of *A. brama, A. escherichii, Barbus sp., C. carassius, L. gibbosus, R. rutilus, S. erythrophthalmus, V. vimba* was determined as positive allometry ($b>3$) and *C. gibelio, E. Lucius, S. glanis* was determined as negative allometry ($b<3$) whereas *B. bjoerkna* and *P. fluviatilis* showed isometry ($b=3$). Mean condition factor values ranged from 0.59 (*S. glanis*) to 2.27 (*L. gibbosus*). Sample size (N), minimum and maximum lengths, minimum and maximum weights, length-weight relationship parameters (*a* and *b*), standard error of *b* (S_b), the coefficient of determination (R^2), confidence interval (CI) of *b*, growth type of species are presented in Table 1. Additionally, the relationship be-

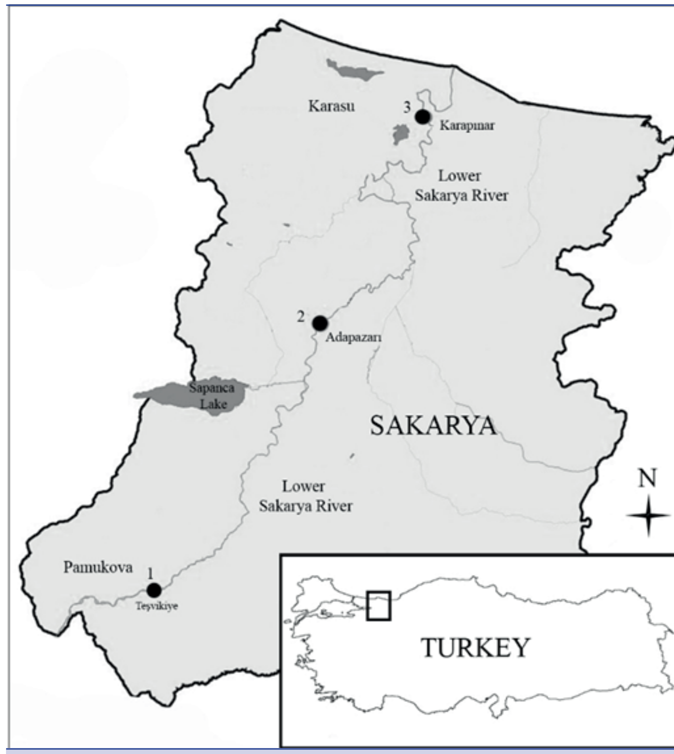

Figure 1. Study area.

Table 1. Estimated LWR parameters of 13 fish species from the Sakarya River, Turkey

Species	N	TL_{min}-TL_{max}	W_{min}-W_{max}	*a*	*b*	R^2	S_b	%95CI of *b*	Growth type
Abramis brama	143	14.3-53.7	33.35-1977.48	0.0074	3.12	0.97	0.05	3.04-3.21	+A
*Alburnus escherichii**	122	6.5-18.2	1.01-46.84	0.0026	3.41	0.98	0.06	3.34-3.50	+A
Barbus sp.	38	25.3-55.7	163.05-1911.43	0.0042	3.26	0.97	0.05	3.09-3.43	+A
Blicca bjoerkna	547	6.2-30.4	3.15-311.15	0.0101	3.07	0.94	0.07	3.01-3.14	I
Carassius carassius	38	16.1-25.3	83.83-295.94	0.0148	3.12	0.96	0.04	2.91-3.35	+A
Carassius gibelio	179	9.3-32.4	13.76-592.75	0.0264	2.87	0.97	0.06	2.80-2.94	-A
Esox lucius	44	27.2-59.8	153.16-1353.12	0.0097	2.91	0.93	0.06	2.66-3.14	-A
*Lepomis gibbosus**	46	3.9-14.7	0.83-75.74	0.0091	3.37	0.98	0.04	3.25-3.49	+A
Perca fluviatilis	107	11.4-28.7	20.45-370.51	0.0154	2.94	0.93	0.06	2.79-3.09	I
Rutilus rutilus	152	11.2-32.2	14.46-364.67	0.0053	3.27	0.97	0.06	3.20-3.36	+A
Scardinius erythrophthalmus	43	10.2-30.2	13.46-432.41	0.0088	3.15	0.99	0.03	3.05-3.25	+A
Silurus glanis	212	10.7-108.4	8.59-8536.4	0.008	2.91	0.98	0.05	2.87-2.96	-A
Vimba vimba	264	12.3-29.1	20.86-322.61	0.0083	3.09	0.96	0.05	3.02-3.17	+A

*: Non commercial; +A: Positive Allometric; -A: Negative Allometric; I: Isometric

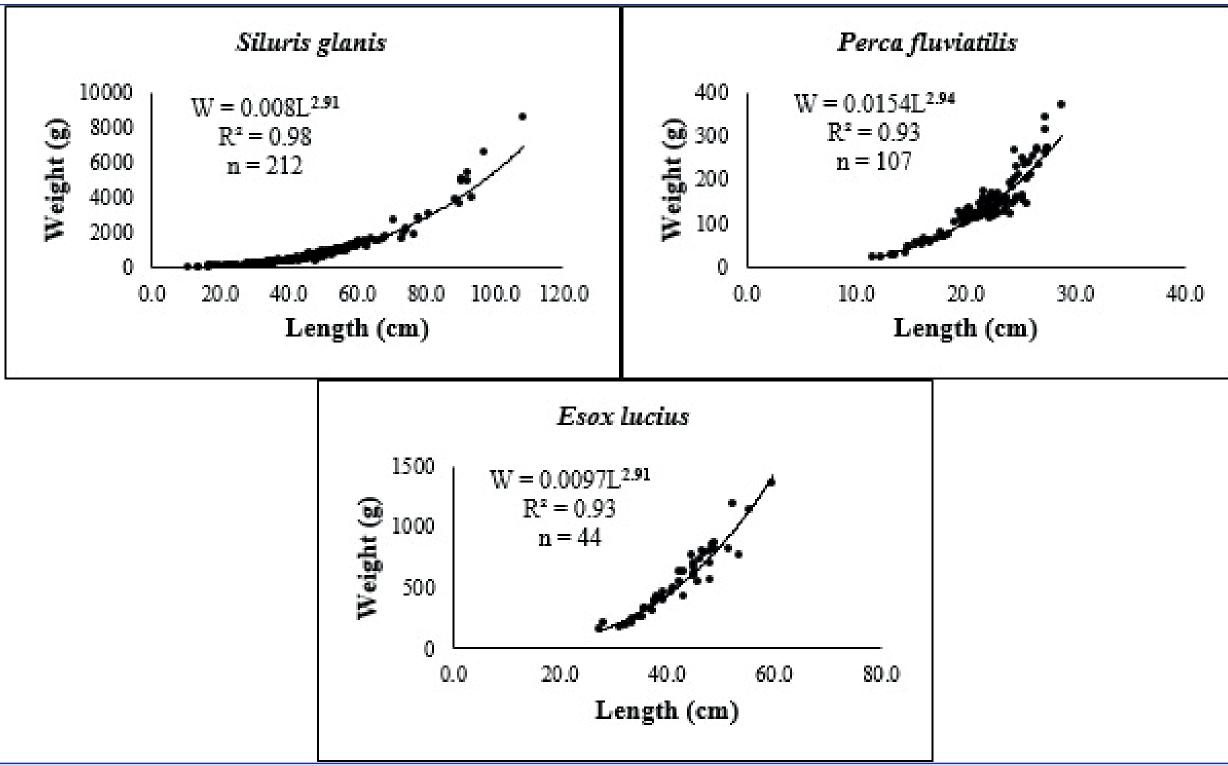

Figure 2. Length–weight relationships ($W=aL^b$) of three commercial fish species from the Sakarya River.

tween total length (TL) and total weight (W) were given for the most commercial fish species *S. glanis*, *P. fluvitilis*,, *E. lucius* (Figure 2).

The population parameters such as length-weight relationship (LWR) are one of the most useful parameters of fishery management and have importance in fisheries science. LWR is also important in fisheries management for comparative growth studies (Moutopoulos & Stergiou 2002; Tsoumani, Liasko, Moutsaki,, Kagalou, & Leonardos, 2006).

Length–weight estimates for *A. escherichii* are not available in the Fishbase database and it is first given in this research. Furthermore, the TL_{max} value (18.2 cm) of this study for *A. escherichii* was found to be the highest compared to the Fishbase database.

According to Froese (2006), *b* is expected to range from 2.5 to 3.5, all species analyzed being within this range. In this study, *A. brama*, *A. escherichii*, *Barbus sp.*, *C. carassius*, *L. gibbosus*, *R. rutilus*, *S. erythrophthalmus* and *V. vimba* showed positive allometric (b>3), *C. gibelio*, *E. lucius* and *S. glanis* showed negative allometric (b<3) and *B. bjoerkna* and *P. fluviatilis* (b=3) showed isometric growth. For the 13 species presented in this paper the *b* values were in general agreement with results obtained in other geographical areas (Saç & Okgerman 2016; Tarkan, Gaygusuz, Acıpınar, Gürsoy, & Özuluğ, 2006; Erguden & Goksu, 2009; Bobori, Moutopoulos, Bekri, Salvarina, & Munoz, 2010; Torcu Koç, Aka, & Treer, 2006). In contrast, Kahraman, Göktürk, & Aydın, (2014), studied in the same region, found positive allometric growth for *S. glanis*. These differences may be due to the fish condition, seasonality, sex, gonadal maturity, stomach fullness, length range, amount of sample and sampling method (Haimovici & Velasco, 2000; Teixeira, Silva, Fabré, & Batista, 2017). Thus, there is a need for all researchers worldwide to agree on a standardized fishing method to sample fish for LWR studies.

CONCLUSION

Consequently, the lower Sakarya River is important for the local fishery. Almost no recent information is available for the study area. According to our results, eleven of the evaluated the thirteen fish are commercially important for small-scale fishery. So, these parameters could be useful to maintain a more effective future stock management of the studied species in the lower Sakarya River.

Ethics Committee Approval: Legal research ethics committee approval permissions for the survey were obtained from the Adnan Menderes University, Animal Experiments Local Ethics Committee

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Conflict of Interest: The authors have no conflicts of interest to declare

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Research Article

Use of the Potential Ecological Risk Index for Sediment Quality Assessment: A Case Study of Dam Lakes in the Thrace Part of the Marmara Region

Cem Tokatlı[1]

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ABSTRACT

Ergene River Basin, which is known as a critically contaminated habitat, is located in the Thrace Part of the Marmara Region of Turkey. Altınyazı, Karaidemir, Kayalıköy, Kırklareli, Sultanköy and Süloğlu Dam Lakes are located in the Ergene River Basin in the Thrace Region, which has very large agricultural lands because of rich soil and many freshwater resources. They were constructed by DSİ (State Water Works) in order to provide irrigation and drinking water and flood protection. The aim of this study was to evaluate the sediment quality of these artificial lentic ecosystems by investigating a total of 25 essential and toxic element accumulations and evaluate the ecological risks of toxic metals on the reservoirs by using Potential Ecological Risk Index (R_I). Sediment samples were collected in the spring season (rainy) of 2018 from 15 stations and element concentrations were investigated by using an ICP-MS. According to the results of R_I, cadmium, lead and arsenic were found to be the highest ecological risk factors for the basin reservoirs.

Keywords: Thrace Region, Ergene Basin, Lentic Habitats, Toxic Metals, Sediment Indices

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INTRODUCTION

Rapid growth of population, developments of industry and lack of environmental awareness cause significant environmental problems and decrease the freshwater quality (Köse et al., 2014; Tokatlı et al., 2016). Lacustrine habitats (artificial or natural) are among the most vulnerable freshwater bodies to pollution due to their exposure to point (eg. municipal and industrial wastewater) and non-point (eg. run-off from agricultural land) contamination sources in their drainage basins (Çiçek et al., 2014; Tokatlı et al., 2017a).

It is clearly documented that sediment may pose a serious risk factor on the water quality through the complicated biogeochemical exchanges. Therefore, the investigation of the sediment quality is an essential and prime component of aquatic ecosystem assessment research (Farombi, et al. 2007, Yu et al. 2011; Çiçek et al., 2019). Many indices have been developed to evaluate the environmental and ecological risks of toxic elements in surface sediments and one of the most widely used sediment indices is Potential Ecological Risk Index (R_I) (Çiçek et al., 2013; Tokatlı et al., 2017b; Maanan et al., 2018).

The Thrace Region of Turkey, which is located on the north – west part of the Marmara Region, is known as an agricultural region and there are very large agricultural lands because of its quite rich soil and numbers of freshwater resources. The Ergene River Basin, which is the most important river basin of the Thrace Region, contains many industrial enterprises on its watershed and as well as the majority of these facilities are located on the upstream of the basin. Therefore, in addition to the agricultural pressure, industrial activities are also one of the significant pollution factors for the basin (Tokatlı, 2015; Sarı et al., 2016; Tokatlı and Baştatlı, 2016). Altınyazı, Karaidemir, Kayalıköy, Kırklareli, Sultanköy and Süloğlu Dam Lakes are located on the Ergene River Basin and they are the most important reservoirs of the Thrace Region. They were constructed by DSİ (State Water Works), on the Basamaklar, Poğaça, Teke, Şeytandere, Manastır and Süloğlu Streams respectively in order to provide irrigation and drinking water and also flood protection for the local settlements (http://www.dsi.gov.tr/). But as many freshwater ecosystems, these reservoirs are also being affected by especially agricultural and domestic pressure.

As many freshwater ecosystems, all these reservoirs are being adversely affected by especially agricultural and domestic pressure. The aim of this study was to reveal that pressure on these six significant artificial lentic habitats located on the Ergene River Basin by determining macro – micro element accumulations in sediment samples and evaluate the sediment quality by using Potential Ecological Risk Index.

MATERIALS AND METHODS

Study Area and Collection of Samples

Sediment samples were collected from 15 stations selected on the reservoirs in the rainy (spring) season of 2018. Topographic map of Ergene River Basin and Altınyazı, Karaidemir, Kayalıköy, Kırklareli, Sultanköy and Süloğlu Dam Lakes and selected stations on the reservoirs are given in Figure 1. Sediment samples were collected form the upper 10 cm of sediments with an ekman grab sampler in 1 L sterile glass bottles and kept at 4 ^{0}C until the chemical analysis.

Chemical Analysis

Sediment samples were dried for 3 hours at 105 ^{o}C. Samples were placed (0.25 gr of each sample) in Pyrex reactors of a CEM Mars Xpress 5 microwave digestion unit. $HClO_4$:HNO_3 acids of 1:3 proportions were inserted in the reactors respectively. Samples were mineralized at 200 ^{o}C for thirty minutes. Afterwards, the samples were filtered in such a way as to make their volumes to 100 ml with ultra – pure distilled water. The element levels in the sediment samples were determined by using the "Agilent 7700 xx" branded Inductively Coupled Plasma – Mass Spectrometer (ICP – MS) device at the Trakya University Technology Research and Development Application and Research Center (TÜTAGEM). The center has an international accreditation certificate within the scope of TS EN / ISO IEC 17025 issued by

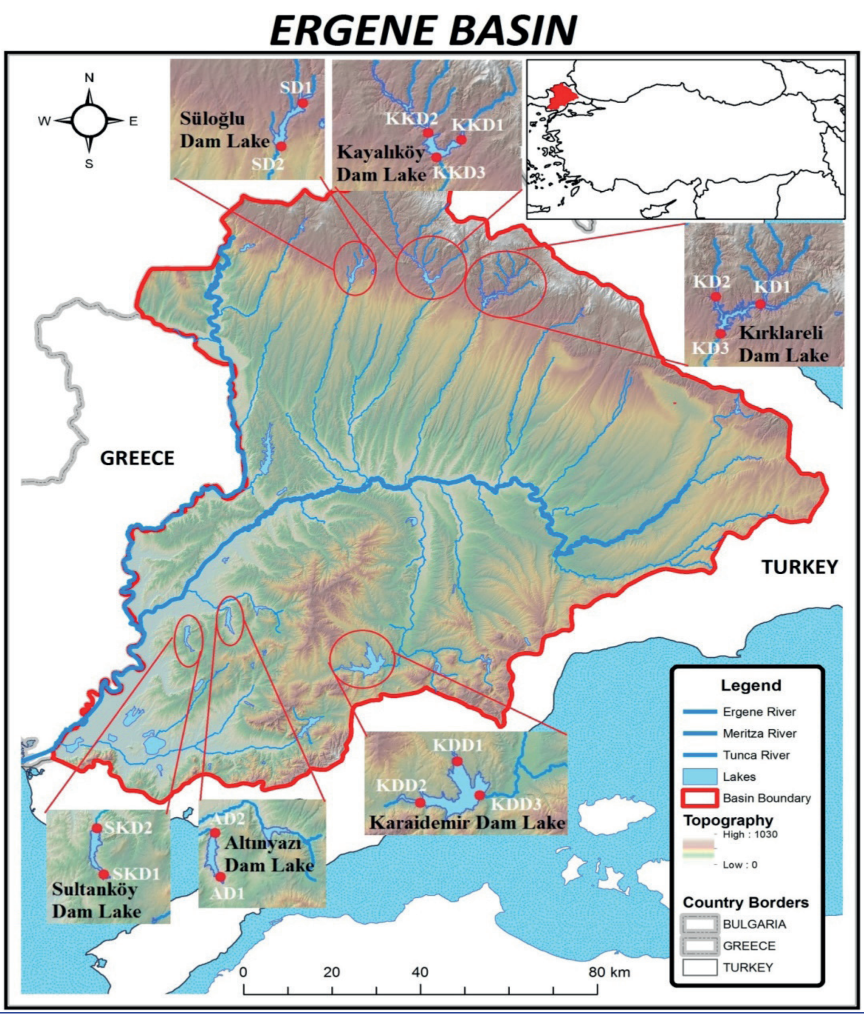

Figure 1. Topographic map of Ergene River Basin and selected stations.

TÜRKAK (representative of the World Accreditation Authority in Turkey). The element analyses were recorded as means triplicate measurements (EPA, 1998; 2001).

Potential Ecological Risk Index (R_I)

The Potential Ecological Risk Index was developed to evaluate the ecological risks in sediment samples in order to control the aquatic contamination. The methodology is based on the assumption that the sensitivity of the aquatic system depends on its productivity. According to the toxicity of toxic elements and the response of the environment, it was introduced to evaluate the degree of heavy metal pollution in sediments. The Potential Ecological Risk Index (R_I) can be calculated with the following formula (Hakanson, 1980);

$$RI = \sum E_r^i \qquad E_r^i = T_r^i \, C_f^i \qquad C_f^i = C_0^i / C_n^i$$

Where

"R_I" is calculated as the sum of all risk factors for heavy metals in sediments,
"E^i_r" is the monomial potential ecological risk factor,
"T^i_r" is the toxic response factor for a given substance (Table 3),
"C^i_f" is the contamination factor, "C^i_0" is the concentration of metals in the sediment and
"C^i_n" is a reference value for metals (Table 3).
The scale of "R_I" was given in Table 1.

Table 1. Scale used to describe the risk factors of E^i_r and R_I (Hakanson, 1980)

Assessment of potential ecological risk			
E^i_r	Potential ecological risk for monomial factor	R_I	Potential ecological risk for multinomial factors
< 40	Low ecological risk	< 95	Low ecological risk
40 – 80	Moderate ecological risk	95 – 190	Moderate ecological risk
80 – 160	Considerable ecological risk	190 – 380	Considerable ecological risk
160 – 320	High ecological risk	> 380	Very high ecological risk
> 320	Very high ecological risk		

Table 2. Macro – micro element accumulations in artificial lacustrine habitats in the Ergene River Basin

Elements (mg/kg)	Northern Dam Lakes								Southern Dam Lakes						
	Süloğlu		Kırklareli			Kayalıköy			Karaidemir			Altınyazı		Sultanköy	
	SD1	SD2	KD1	KD2	KD3	KKD1	KKD2	KKD3	KDD1	KDD2	KDD3	AD1	AD2	SKD1	SKD2
Li	35.4	94.4	97.3	115.4	80.0	148.9	199.9	345.1	113.5	149.6	56.3	162.1	225.5	104.6	103.7
Be	5.627	10.648	23.524	11.582	22.043	25.019	17.532	11.224	8.573	10.567	5.341	13.304	13.948	18.119	25.215
B	60.752	61.216	71.660	56.383	45.305	41.864	68.680	214.041	60.285	79.271	60.052	66.166	59.285	60.839	62.013
Na	2164	2526	1770	1905	1766	3503	66520	6454	1984	2778	1836	2788	4940	4454	6546
Mg	7128	35674	33100	25628	30043	60812	461190	146237	24480	72214	9210	76187	136871	57818	58488
Al	17011	98996	88745	92120	96885	204821	340876	173009	71847	116657	28218	95666	163288	138604	175258
K	6323	56044	34535	18592	39543	23928	55484	37016	32644	43227	9079	12240	17747	23371	34860
Ca	38058	56341	86844	28625	79668	119225	2550992	2452257	25136	83399	17020	667195	1717582	999325	593793
V	103.1	333.0	297.1	210.9	252.8	930.1	788.9	828.8	229.3	372.8	83.6	230.2	521.7	661.1	649.2
Cr	78.6	186.9	136.8	98.4	83.0	777.1	407.3	747.6	105.6	271.0	62.9	562.9	741.4	362.4	358.5
Mn	7252	15320	5145	5950	27466	50640	49649	28806	5249	21485	3165	11373	27047	37169	24108
Fe	24292	136429	198733	130505	169889	252457	322705	181380	121044	220464	37568	119719	232243	133792	114280
Co	63.9	99.2	107.8	77.8	158.4	725.9	1095.5	222.2	89.9	181.7	28.2	206.9	568.0	644.6	272.7
Ni	56.5	105.9	103.8	51.6	73.6	1519.5	4171.6	1094.7	69.6	309.4	28.5	1410.7	2417.7	1239.0	619.2
Cu	31.2	135.9	436.6	58.6	135.3	504.5	464.0	257.8	81.1	345.9	22.2	142.3	257.3	220.0	228.0
Zn	410	601	1254	585	716	891	1045	595	600	1178	321	696	850	564	612
As	18.623	20.341	28.661	21.710	729.450	89.164	53.428	40.698	12.181	33.600	9.372	13.653	42.091	69.270	59.219
Se	116	113	110	107	110	112	109	113	105	104	106	108	106	112	118
Sr	126	297	198	132	268	1117	10938	8000	128	625	93	1476	3381	1421	1405
Mo	48.205	47.912	47.325	46.616	52.408	46.586	47.070	212.363	45.042	47.974	45.111	43.762	44.164	43.571	45.329
Cd	1.170	2.225	12.517	1.788	3.818	6.235	5.144	7.594	1.428	3.577	0.585	1.772	3.320	3.181	2.995
Sb	0.461	0.845	2.052	0.427	0.534	0.660	0.463	183.661	1.182	1.187	0.441	0.471	0.335	0.562	0.671
Ba	709	2615	1252	499	3440	6796	9378	3311	731	3411	504	1124	3462	5688	4449
Tl	0.589	3.007	3.475	1.690	2.234	4.885	1.882	6.383	2.271	2.287	0.939	1.027	2.142	1.222	1.793
Pb	166	360	1764	355	529	1145	434	431	204	398	72	138	417	620	504

RESULTS AND DISCUSSION

Essential and toxic element accumulations detected in sediments of reservoirs located in the Ergene River Basin are given in Table 2. The Potential Ecological Risk Index monomial (E^i_r) and multinomial (R_I) for each station selected on the dam lakes located on the Ergene River Basin were identified and all the results are given in Table 3.

According to the results of monomial potential ecological risk index (E^i_r), all the investigated toxic elements posed "low ecological risk" on the reservoirs. The Potential Ecological Risk Index for monomial regulators indicted that the intensity of the investigated toxic metals can be followed as Cd > Pb > As > Cu > Cr > Zn. According to the results of multinomial potential ecological risk index (R_I), all the investigated stations exhibited "low ecological risk". The Potential Ecological Risk Index for multinomial regulators indicted that the ecological risks of the system can be followed as Kırklareli Dam Lake > Kayalıköy Dam Lake > Sultanköy Dam Lake > Altınyazı Dam Lake > Karaidemir Dam Lake > Süloğlu Dam Lake (Figure 2).

Cadmium is an agricultural origin toxic metal and it is known that it can be easily emitted to soil and water by using phosphate fertilizers. Cadmium, which may accumulate in aquatic organisms and agricultural crops, can also bind strongly to organic matter and be taken up by plant life and can be included in the food chain. It is clearly known that pesticides have a significant impact on lead and arsenic transition to the water, soil and sediment and also fertilizers contain significant quantities of zinc and copper (ATSDR, 2004; 2005a; 2005b; 2007). The Thrace Part of the Marmara Region is known as a significant agricultural zone in Turkey and has very large agricultural lands because of its rich soil and much ground – surface freshwater resources. In the present study, as a result Potential Ecological Risk Index, cadmium, lead and arsenic, which are known as agricultural origin toxicants, were found to be the most risky elements for the sediments of dam lakes located in the Ergene River Basin. The most significant anthropogenic sources of chromium in freshwater ecosystems is known as industrial activities, which are being intensively performed around the upstream of the Ergene River Basin (especially in the Çorlu and Çerkezköy Distrits) (ATSDR, 2000). According to the results of the Potential Ecological Risk Index, chromium did not pose a significant risk factor for the sediments of the investigated reservoirs. These results reflect that the dam lakes of the Thrace Region are not being affected significantly by the intensive industrial activities conducted around the Ergene River Basin.

In a study performed in the Gala Lake National Park (Meriç – Ergene River Basin) in Turkey, the Potential Ecological Risk Index was used to evaluate the sediment quality. As a result of this study, similar to the present study, cadmium was found to be the most risky element for the Gala Lake (Tokatlı, 2017). According to the results of another Potential Ecological Risk Index application conducted in Seydisuyu Stream Basin, similar to the results of the present study, chromium and cadmium were reported as the most risky elements for the Seydisuyu Stream Basin (Tokatlı et al., 2017b). Soliman et al. (2015) assessed the potential ecological risks of heavy metals in sediments of the Mediterranean coast in

Table 3. Toxic metal risk index values in sediments of the reservoirs

Dam Lakes	Stations	E^i_r						R_I	Multinomial Mean
		As	Cr	Cu	Pb	Zn	Cd		
Süloğlu	SD1	0.012	0.003	0.005	0.033	0.005	0.070	0.129	**0.192**
	SD2	0.014	0.006	0.023	0.072	0.008	0.133	0.255	
Kırklareli	KD1	0.019	0.005	0.073	0.353	0.016	0.751	1.216	**0.761**
	KD2	0.014	0.003	0.010	0.071	0.007	0.107	0.213	
	KD3	0.486	0.003	0.023	0.106	0.009	0.229	0.855	
Kayalıköy	KKD1	0.059	0.026	0.084	0.229	0.011	0.374	0.784	**0.654**
	KKD2	0.036	0.014	0.077	0.087	0.013	0.309	0.535	
	KKD3	0.027	0.025	0.043	0.086	0.007	0.456	0.644	
Karaidemir	KDD1	0.008	0.004	0.014	0.041	0.008	0.086	0.159	**0.208**
	KDD2	0.022	0.009	0.058	0.080	0.015	0.215	0.398	
	KDD3	0.006	0.002	0.004	0.014	0.004	0.035	0.065	
Altınyazı	AD1	0.009	0.019	0.024	0.028	0.009	0.106	0.194	**0.291**
	AD2	0.028	0.025	0.043	0.083	0.011	0.199	0.389	
Sultanköy	SKD1	0.046	0.012	0.037	0.124	0.007	0.191	0.417	**0.397**
	SKD2	0.039	0.012	0.038	0.101	0.008	0.180	0.378	
Monomial Mean		**0.055**	**0.011**	**0.037**	**0.100**	**0.009**	**0.229**		
$^*C^i_n$		15.00	60.00	30.00	25.00	80.00	0.50		
$^*T^i_r$		10.00	2.00	5.00	5.00	1.00	30.00		

*Reference values (C^i_n) and toxicity coefficients (T^i_r) values of heavy metals (Hilton et al., 1985)
E^i_r is the monomial and R_I is the multinomial heavy metal Potential Ecological Risk Index

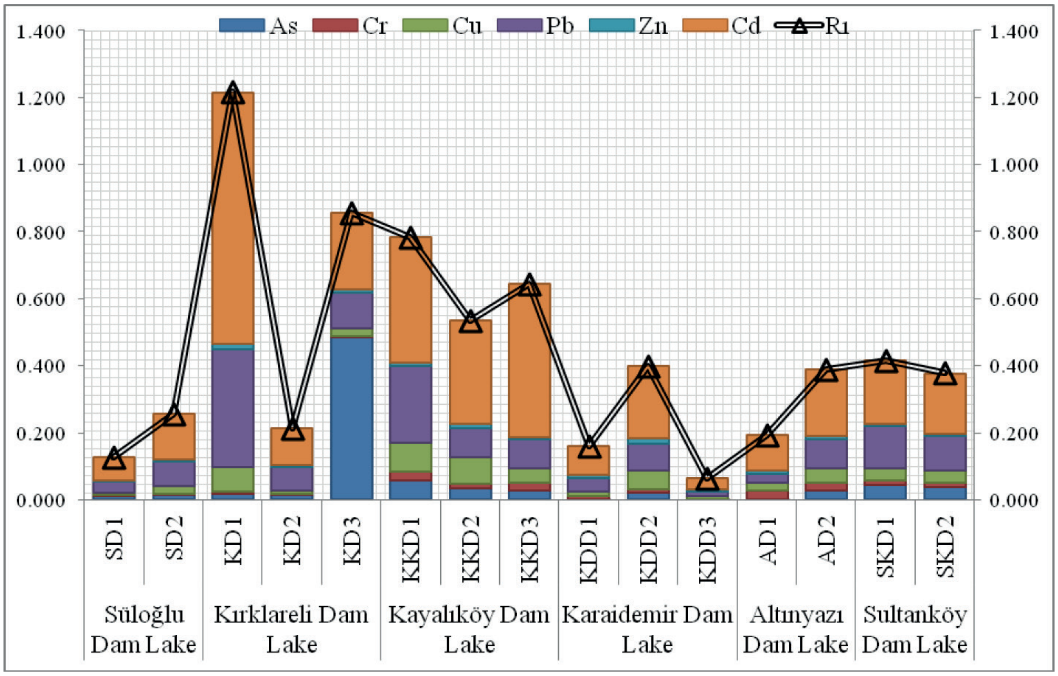

Figure 2. Values of Potential Ecological Risk Index.

Egypt and, similar to the present study, the risk assessment of this study showed that Cd had the highest ecological risk (Er = 21.52), followed by Pb (Er = 3.01), while Zn had the lowest risk (Er = 0.23).

In a study performed in Turkey, cadmium contents of different fertilizer samples taken from different fertilizer factories were investigated. It was reported that cadmium residues of many fertilizers used in Turkey were found to be over the limit values notified for fertilizers. It is known that phosphate rocks are the main ingredient of phosphate fertilizers and they are being imported from abroad to Turkey (Köleli and Kantar, 2005). Cadmium concentrations of these imported phosphate rocks are much more than what they should be. As a result of using phosphate fertilizers based of these imported phosphate rocks, significant amounts of cadmium are being accumulated on the land surface and also being moved to surface and groundwater resources (Emiroğlu et al., 2013).

The Thrace Region is known as one of the most productive lands in Turkey. Rice and sunflower are the two main crops produced in the region. Edirne City is also known as the most important city for rice production in Turkey. But unfortunately, agricultural applications carried out in the basin have been generally performed in the form of monoculture applications for many years (Helvacıoğlu et al., 2015). This situation causes the decrease of soil quality and increase in the use of fertilizers, and may be the reason for the detected quite high cadmium accumulations in regional sediments.

CONCLUSIONS

In this study, the Potential Ecological Risk Index was used to evaluate the sediment quality of the most significant artificial lacustrine habitats of the Ergene River Basin. According to results of Potential Ecological Risk Index, cadmium, lead and arsenic were found to be the highest ecological risk factors for the dam lakes and the ecological risk levels of the investigated reservoirs were recorded as; Kırklareli > Kayalıköy > Sultanköy > Altınyazı > Karaidemir > Süloğlu in general. The data of this research reveals that agricultural runoff caused by pesticide and fertilizer applications because of mainly monoculture practices conducted almost all around the region was the main ecological risk for the sediment qualities of the reservoirs located in the Ergene River Basin. Also, the present study clearly presents the necessity and availability of sediment indices on freshwater sediment quality assessment studies. In order to improve the sediment qualities of these significant artificial lentic ecosystems, monoculture practices in agricultural applications should be changed and the local people should be encouraged to use polyculture practices. Also, the uninformed use of chemical fertilizers and pesticides should be avoided by giving the necessary training to the farmers.

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Conflict of Interest: The author has no conflicts of interest to declare.

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Research Article

Diversity and Length-Weight relationships of Blenniid Species (Actinopterygii, Blenniidae) from Mediterranean Brackish Waters in Turkey

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ABSTRACT

This study aims to determine the species composition and range of Mediterranean Blennies (Actinopterygii, Blenniidae) occurring in river estuaries and lagoon systems of the Mediterranean coast of Turkey, and to characterise the length–weight relationship of the specimens. A total of 15 sites were surveyed from November 2014 to June 2017. A total of 210 individuals representing 3 fish species (Rusty blenny-*Parablennius sanguinolentus,* Freshwater blenny-*Salaria fluviatilis* and Peacock blenny-*Salaria pavo*) were sampled from five (Beşgöz Creek Estuary, Manavgat River Estuary, Karpuzçay Creek Estuary, Köyceğiz Lagoon Lake and Beymelek Lagoon Lake) of the localities investigated. The high juvenile densities of *S. fluviatilis* in Karpuzçay Creek Estuary and *P. sanguinolentus* in Beşgöz Creek Estuary were observed.

Various threat factors were observed in five different native habitats of Blenny species. The threats on the habitat and the population of the species include the introduction of exotic species, water pollution, and more importantly, the destruction of habitats. Five non-indigenous species (Prussian carp-*Carassius gibelio*, Eastern mosquitofish-*Gambusia holbrooki*, Redbelly tilapia-*Coptodon zillii*, Stone moroko-*Pseudorasbora parva* and Rainbow trout-*Oncorhynchus mykiss*) were observed in the sampling sites. In addition to these freshwater species, several lessepsian species (Keeled mullet-*Liza carinata*, Por's goatfish-*Upeneus pori*, Goldband goatfish-*Upeneus moluccensis*, Marbled spinefoot-*Siganus rivulatus*, *Sillago suezensis* and Yellowstripe barracuda-*Sphyraena chrysotaenia*) were observed in the sampling areas.

Keywords: Peacock blenny, Freshwater blenny, Rusty blenny, distribution, estuary

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INTRODUCTION

Blenniidae are one of the most abundant fish families inhabiting tropical and subtropical regions. The family consists of 58 genera and 397 species (Nelson, Grande, & Wilson, 2016). The blennids of the Mediterranean display a remarkable diversity with regard to habitat preferences, feeding habits, and behaviour (Patzner, Gonçalves, & Hastings, 2009).

Twenty species have been reported in the Eastern Mediterranean with 3 alien species included. Alien Blenny species were introduced to the Mediterranean-Black Sea Basin from the Suez Canal (Golani, Öztürk, & Başusta, 2006). As there is a low interest of commercial fishing of this family in the Turkish coast, there is no available data on the catch statistics of this species.

The biological data on the species, however, are scarce and limited to their distribution (Erazi, 1941; Steinitz, 1950; Aksiray, 1987; Çoker, 1996; Taşkavak, Bilecenoglu, Basusta, & Mater 2000; Bat, Gönlügür Demirci, & Öztürk 2006; Yılmaz, Barlas, Yorulmaz, & Özdemir 2006; Bilecenoğlu, Kaya, Cihangir, & Çiçek, 2014; Özgür-Özbek, Özkaya, Öztürk, & Golani, 2014), parasitology (Alaş, Öktener, Iscimen, & Trilles 2008; Özer, Özkan, Gürkanlı, Yurakhno, & Çiftçi, 2016) and evolution (Zander, 1972; Almada et al., 2009).

The parameters of the length-weight relationship (LWR) of the fish species are crucial in the fisheries' biology, supplying the information on several aspects of fish population dynamics (Bagenal & Tesch, 1978). The current knowledge on LWRs for Blennies is limited to six species, namely, *Aidablennius sphynx* (Özen, Ayyıldız, Öztekin, & Altın 2009), *Blennius ocellaris* (Çiçek, Avsar, Yeldan, & Ozutok, 2006; Sangun, Akamca, & Akar, 2007; Özaydın, Uçkun, Akalın, Leblebici, & Tosunoğlu, 2007; İşmen, Özen, Altınağaç, Özekinci, & Ayaz, 2007; İlkyaz, Metin, Soykan, & Kınacıgil 2008; Bok et al., 2011; Acarlı, Kara, & Bayhan 2014; Bilge, Yapıcı, Filiz, & Cerim, 2014), *Salaria pavo* (Özen et al., 2009; Bilge et al., 2014), *Parablennius sanguinolentus* (Keskin & Gaygusuz, 2010; Kara, Sağlam, Acarlı, & Cengiz, 2017), *Parablennius tentacularis* (Keskin & Gaygusuz, 2010), *Salaria fluviatilis* (İlhan, Ustaoğlu, & Berberoğlu 2013; Ergüden, 2016; Kara et al., 2017).

In both temperate and tropical habitats, the coastal lagoons and estuaries play a crucial role in the aspect of ecology and biology of the species (Bruno, Barbini, Diaz De Astarloa, Martos, & 2013). Status of Blennies fish composition in Brackishwater systems are still poorly understood. The current study aims to update the range and species composition of Blennids occurring in river estuaries and lagoon systems of Mediterranean coast of Turkey, and to characterise the length–weight relationship of specimens.

MATERIALS AND METHODS

A total of 15 sites (Yelkoma Lagoon Lake, Ceyhan River Estuary, Seyhan River Estuary, Göksu River Estuary, Paradeniz Lagoon Lake, Berdan River Estuary, Sultansuyu Creek Estuary, Hacımusa Creek Estuary, Karpuzçay Creek Estuary, Manavgat River Estuary, Köprüçay River Estuary, Beşgöz Creek Estuary, Kopak Creek Estuary, Beymelek Lagoon Lake and Köyceğiz Lagoon Lake), representing a variety of habitats (including mouths of rivers and creeks, coastal canals of rivers and lagoonal areas), were repeatedly surveyed from November 2014 to June 2017. Details (Type, substrate structure, macrophyte vegetation density, flow regime) of habitats were recorded. Sampling localities are given in the map (Figure 1), and sampling sites and descriptions are given in Table 1 and Table 2.

The ichthyofauna of the systems was sampled using a shore seine net (10 m long and 2 m high; 1.2 x 2 mm mesh size). Fish species were identified according to Aksiray (1987). The introduced and exotic taxa of the species were identified following İnnal & Erk'akan (2006). At each locality, the general observations on the population and its situation were also made. Specimens were weighed to the nearest 0.01 g total weight (W) and were measured to the nearest 0.1 cm in total length (TL). The a and b parameters were calculated by linear regression on the transformed equation: log(w) = log(a) + b log (L). For each species, the slopes of l ength-weight regressions were compared to 3 using student's t-test.

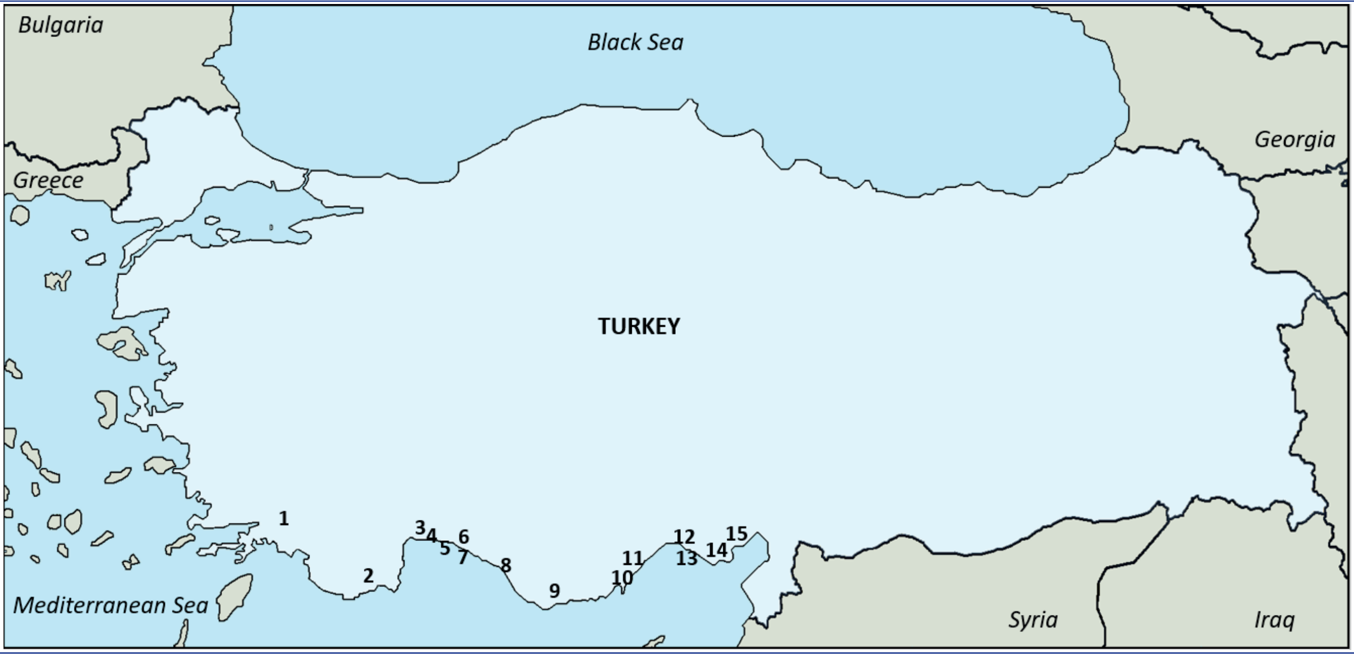

Figure 1. 1-Köyceğiz Lagoon Lake; 2- Beymelek Lagoon Lake; 3- Kopak Creek Estuary; 4- Beşgöz Creek Estuary; 5- Köprüçay River Estuary; 6- Manavgat River Estuary; 7- Karpuzçay Creek Estuary; 8- Hacımusa Creek Estuary; 9- Sultansuyu Creek Estuary; 10- Paradeniz Lagoon Lake; 11- Göksu River Estuary; 12- Berdan River Estuary; 13- Seyhan River Estuary; 14- Ceyhan River Estuary; 15- Yelkoma Lagoon Lake.

Table 1. Sampling sites with its coordinates

No	Locality	Coordinates	
1	Köyceğiz, Köyceğiz (Muğla)	36°57'30.45"N	28°40'30.46"E
2	Beymelek, Demre (Antalya)	36°16'26.25"N	30° 3'15.01"E
3	Kopak, Aksu (Antalya)	36°51'7.27"N	30°52'1.87"E
4	Beşgöz, Serik (Antalya)	36°51'21.89"N	30°56'39.81"E
5	Köprüçay, Serik (Antalya)	36°49'46.82"N	31°10'26.82"E
6	Manavgat, Manavgat (Antalya)	36°44'18.42"N	31°29'38.43"E
7	Karpuzçay, Manavgat (Antalya)	36°42'56.84"N	31°33'00.95"E
8	Hacımusa, Gazipaşa (Antalya)	36°15'45.14"N	32°16'46.54"E
9	Sultansuyu, Anamur (Mersin)	36° 2'15.42"N	32°49'8.11"E
10	Paradeniz, Silifke (Mersin)	36°18'27.51"N	34° 0'39.00"E
11	Göksu, Silifke (Mersin)	36°17'46.24"N	34° 2'42.75"E
12	Berdan, Tarsus (Mersin)	36°44'53.83"N	34°53'29.27"E
13	Seyhan, Tarsus (Mersin)	36°43'44.41"N	34°54'37.71"E
14	Ceyhan, Karataş (Adana)	36°34'10.83"N	35°33'36.15"E
15	Yelkoma, Yumurtalık (Adana)	36°42'27.30"N	35°40'36.72"E

Table 2. Habitat description of sampling sites

Locality	Type	Substrates	Macrophyte vegetation	Flow velocity
Köyceğiz, Köyceğiz (Muğla)	Coastal lake	gravel-silt-sand	Medium	Steady
Beymelek, Demre (Antalya)	Coastal lake	silt-sand	Low	Steady
Kopak, Aksu (Antalya)	Open creek estuary	silt-sand	Low	Slow
Beşgöz, Serik (Antalya)	Open creek estuary	silt-sand	Medium	Slow
Köprüçay, Serik (Antalya)	Open river estuary	gravel-silt-sand	Low	Fast
Manavgat, Manavgat (Antalya)	Open river estuary	silt-sand	Low	Fast
Karpuzçay, Manavgat (Antalya)	Closed creek estuary	silt-sand	Low	Slow
Hacımusa, Gazipaşa (Antalya)	Open creek estuary	gravel-silt-sand	Low	Slow
Sultansuyu, Anamur (Mersin)	Open creek estuary	gravel-silt-sand	Low	Slow
Paradeniz, Silifke (Mersin)	Coastal lake	silt-sand	Low	Steady
Göksu, Silifke (Mersin)	Open river estuary	silt-sand	Low	Fast
Berdan, Tarsus (Mersin)	Open river estuary	silt-sand	Low	Slow
Seyhan, Tarsus (Mersin)	Open river estuary	silt-sand	Medium	Fast
Ceyhan, Karataş (Adana)	Open river estuary	silt-sand	Medium	Fast
Yelkoma, Yumurtalık (Adana)	Coastal lake	silt-sand	Low	Steady

RESULTS AND DISCUSSION

Brackishwater systems of the Mediterranean encompass diverse habitat types and provide nursery grounds for a number of Blennid species. A total of 210 individuals representing 3 fish species [*Parablennius sanguinolentus* (Pallas, 1814), *Salaria fluviatilis* (Asso, 1801) and *Salaria pavo* (Risso, 1810)] were sampled from five (Beşgöz Creek Estuary, Manavgat River Estuary, Karpuzçay Creek Estuary, Köyceğiz Lagoon Lake and Beymelek Lagoon Lake) of the localities investigated.

One hundred and seven individuals of *P. sanguinolentus* were found at Beşgöz Creek and Manavgat River Estuary, 100 individuals of *S. fluviatilis* were found at three localities (Karpuzçay Creek Estuary, Manavgat River Estuary and Köyceğiz Lagoon Lake), 3 individuals of *S. pavo* were found in one locality (Beymelek Lagoon Lake). As can be seen in Table 3, the sample size ranged from 3 individuals for *S. pavo* to 87 for *P. sanguinolentus*.

The high juvenile densities recorded for *S. fluviatilis* in Karpuzçay Creek Estuary and *P. sanguinolentus* in Beşgöz Creek Estuary suggest that Beşgöz and Karpuzçay Estuaries provide an important nursery grounds for these species. Nursery areas may be attractive to Blenny species because they provide high food availability and low predation pressure (Martinho et al., 2007; Francis, 2013). Several factors may affect the distribution of Blenny species at the examined stations such as life history, hydrological conditions, predation, prey availability, and anthropogenic impacts.

Table 3. Locality, sample size and size range (cm, TL; g, W) of species

Species	Locality	N	TL (Min-Max)	W (Min-Max)
S. pavo	Beymelek	3	8.6-9.2	4.0-5.9
S. fluviatilis	Karpuzçay	74	2.5-7.5	0.15-4.94
	Köyceğiz	15	2.8-5	0.15-0.85
	Manavgat	11	2.1-5	0.075-0.99
	All populations	100	2.1-7.5	0.075-4.94
P. sanguinolentus	Beşgöz	87	2.1-4.2	0.072-0.83
	Manavgat	20	1.7-5.0	0.032-0.85
	All populations	107	1.7-5.0	0.032-0.85

Table 4. Length–weight parameters a and b values of species (Growth pattern; N: negative allometry; P: positive allometry; I: Isometry)

Species	Locality	a	b	95% CI of b	t-test	Growth pattern	R^2
S. pavo	Beymelek						
S. fluviatilis	Karpuzçay	0.0095	3.077	3.0629-3.0943	$p<0.05$	P	0.99
	Köyceğiz	0.0082	2.869	2.8232-2.9133	$p<0.05$	N	0.97
	Manavgat	0.0074	2.963	2.8996-3.0323	$p=0.279$	I	0.99
	All populations	0.0062	3.308	3.2755-3.3339	$p<0.05$	P	0.96
P. sanguinolentus	Beşgöz	0.0047	3.655	3.629-3.6728	$p<0.05$	P	0.96
	Manavgat	0.0069	3.0078	2.9347-3.058	$p=0.903$	I	0.99
	All populations	0.006	3.367	3.3379-3.3942	$p<0.05$	P	0.95

Very little information is available on the ecology of most of the Blenny species, which do not have commercial fishery value. Length–weight parameters a, b and the correlation coefficient values are given in Table 4.

The total length of 2.1- 7.5 cm with the mean value of 4.34 cm for *S. fluviatilis*, the total length of 8.6- 9.2 cm with the mean value of 8.93 cm for *S. pavo* and the total length of 1.7- 5.0 cm with the mean value of 2.82 cm for *P. sanguinolentus* were recorded. Also, the weight of 0.075- 4.94 g with the mean value of 1.07 g, 4.0 -5.9 g with the mean value of 4.67 g and 0.032 -0.85 g with the mean value of 0.23 g for *S. fluviatilis*, *S. pavo* and *P. sanguinolentus* were recorded, respectively. *Salaria pavo* was however, excluded because of the inadequate sample size.

The slope b value of the length-weight relationships for *S. fluviatilis* from all localities was 3.308 (100 individuals). The slope b value of the length-weight relationships for *P. sanguinolentus* investigating all localities was 3.367 (107 individuals). The correlation coefficient values ranged from 0.95-0.99. The values of parameter b for the localities evaluated was found to be within the expected range of 2.5-3.5 as described by Froese (2006), with Beşgöz as an exception. The parameter b value for Beşgöz was found to be 3.638. The maximum length of *Parablennius sanguinolentus* found in the current study was smaller than other studies (Keskin & Gaygusuz, 2010; Liousia et al., 2012). Outside of b value from its normal range (2.5-3.5) could be due to the small length range (2.1-4.2 cm) of *P. sanguinolentus,* the data were not representative for big size individuals. Manavgat population of *P. sanguinolentus* has an isometric growth type while Beşgöz population has a positive allometric growth type.

Among the populations of *S. fluviatilis* analyzed, one population (Manavgat River Estuary) showed isometry, two populations (Karpuzçay Creek Estuary and Köyceğiz Lagoon Lake) showed allometry. Of the "b" value for seven populations of *S. fluviatilis* reported by İlhan et al., 2013, among the population analyzed, one population (Doğu Akdeniz) showed negative allometry, five populations (Marmara, Küçük Menderes, Antalya, Seyhan and Ceyhan populations) showed Isometry and one population (Batı Akdeniz) showed positive allometry. Variations of growth types reported by the current study and previous reports may be due to physico-chemical and biological parameters of systems and studied methods (time, sampling equipments, length range, gonadal maturity, sex, preserved techniques).

Although *S. fluviatilis* in Turkey shows a large distribution in aquatic systems such as coastal lagoons, estuaries and freshwater systems, *P. sanguinolentus* and *S. pavo* are restricted to only marine habitats. However, there has not been sufficient data about threats to the latter two species in previous studies. Threat status of these species are of the least concern (Di Natale et al., 2014 a, b).

S. fluviatilis was reported from drainage of the Aeagean, Black Sea and Mediterranean regions of Turkey (Geldiay & Balık, 1996; Demirsoy, 2002; Bostancı, Darçın, & Helli, 2016). However , *S. fluviatilis* was commonly reported in sea level habitats . Alp & Kara

Table 5. Alien fish species of localities

No	Species	Family	Köyceğiz	Beymelek	Beşgöz	Manavgat	Karpuzçay
Native Blenny species							
1	*Salaria pavo*	Blenniidae		√			
2	*Salaria fluviatilis*	Blenniidae	√			√	√
3	*Parablennius sanguinolentus*	Blenniidae			√	√	
Alien species							
1	*Coptodon zillii*	Cichlidae	√				
2	*Carassius gibelio*	Cyprinidae			√	√	
3	*Pseudorasbora parva*	Cyprinidae			√	√	
4	*Liza carinata*	Mugilidae			√	√	
5	*Upeneus moluccensis*	Mullidae				√	
6	*Upeneus pori*	Mullidae				√	
7	*Gambusia holbrooki*	Poeciliidae	√	√	√	√	√
8	*Oncorhynchus mykiss*	Salmonidae				√	
9	*Siganus rivulatus*	Siganidae		√	√	√	
10	*Sillago suezensis*	Sillaginidae			√	√	
11	*Sphyraena chrysotaenia*	Sphyraenidae				√	

(2007) reported that this species is present in Turkey from high mountain creeks up to 750 meters . *S. fluviatilis* is found in Mediterranean freshwater systems with small and localized populations (Vinyoles, Cote, & De Sostoa, 2002). In Mediterranean habitats in which *S. fluviatilis* occurs, the water pollution, eutrophication, deterioration of the quality of the water, gravel extraction, loss of habitat, the existence of exotic species, and construction of dams and river channelization have affected the survival of this species (Crivelli, 2006; Vinyoles, De Sostoa, Casals, & Bianco 1991; Ferrito & Tigano, 1996; Vinyoles & De sostoa, 2007; Laportea, Bertolo, Berrebi, & Magnan, 2014).

Five brackishwater systems throughout the Turkish coast have been classified as nurseries for three Blennid fish species (*S. fluviatilis, P. sanguinolentus* and *S. pavo).* The results of this study indicate that Blenny species are threatened and under significant danger from many anthropogenic activities.

Eleven fish species from nine families were identified as being alien to the 5 brackishwater systems surveyed in this study (Table 5). Ten non indigenous species (*Gambusia holbrooki*, *Liza carinata*, *Upeneus pori*, *Siganus rivulatus*, *Sillago suezensis*, *Oncorhynchus mykiss*, *Sphyraena chrysotaenia*, *Carassius gibelio*, *Upeneus moluccensis* and *Pseudorasbora parva*) were observed in the same habitat with *Parablennius sanguinolentus* and *Salaria fluviatilis* in Manavgat River Estuary in the current study.

S. fluviatilis was also observed in Köyceğiz lagoon and Karpuzçay Creek, both of which have been subjected to agricultural activity. *Coptodon zillii* and *Gambusia holbrooki* in Köyceğiz Lagoon and *Gambusia holbrooki* in Karpuzçay Creek shared the same habitats with *S. fluviatilis*.

Six non indigenous species (*Carassius gibelio, Pseudorasbora parva, Liza carinata, Gambusia holbrooki, Siganus rivulatus* and *Sillago suezensis)* were observed in the same habitat with *Parablennius sanguinolentus* in Beşgöz Creek Estuary in the current study.

Furthermore, the freshwater supply of Beşgöz Creek and Karpuzçay Creek had greatly decreased in recent years due to agricultural irrigation. Municipal waste waters have been discharged into Beşgöz Creek, Köyceğiz Lagoon and Manavgat River.

CONCLUSIONS

P. sanguinolentus, S. pavo and S. fluviatilis were collected in five brackishwater systems in the Mediterranean Coast of Turkey (Beşgöz Creek Estuary, Manavgat River Estuary, Karpuzçay Creek Estuary, Köyceğiz Lagoon Lake and Beymelek Lagoon Lake). The high juvenile densities recorded for *S. fluviatilis* in Karpuzçay Creek Estuary and *P. sanguinolentus* in Beşgöz Creek Estuary suggest that Beşgöz and Karpuzçay Estuaries provide an important nursery grounds for these species. Various threat factors were observed in five different localities which are the habitat of Blennid species.

The current study supplies some fundamental information about the distribution and L ength-weight relationships of brackishwater Blenny species and can be helpful for the future studies in the region.

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Ethics Committee Approval: This study was carried out in accordance with animal welfare and the ethics of trial. All procedures were performed in accordance with the Law on Veterinary and Medical Activities and National Animal Welfare Act. Therefore ethics approval was not required.

Conflict of Interests: The author declares that there are no conflicts of interest.

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