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Research Article

A Preliminary Study on Using Rotifera Fauna to Determine The Trophic Level of The Büyükçekmece Reservoir (İstanbul, Turkey)

Zeynep Dorak[1]

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ABSTRACT

In this study, the abundance of rotifera fauna, in the Büyükçekmece Reservoir (İstanbul) and some physicochemical features of the reservoir, were investigated between May 2009 and February 2010. In terms of physicochemical conditions, the trophic state of the reservoir was determined as eutrophic (CTSI= 57.8). A total of 33 rotifera species were identified. *Keratella cochlearis* represented 40.62% of the total annual rotifera present, and was predominant. It was followed by *Polyarthra vulgaris* (10.14%), *Synchaeta oblonga* (9.06%), *Brachionus urceolaris* (5.58%), *Pompholyx sulcata* (5.21%) and *Epiphanes macroura* (%4.86), respectively. The contribution of the other rotifer species to the annual presence of rotifera was determined as being 24.52%. The dominance of these species was attributed to the eutrophic state of the reservoir, because *K. cochlearis*, *P. vulgaris, B. urceolaris* and *P. sulcata* are known as eutrophication indicator species, due to their saprobic valences. Also, the trophic state of the reservoir was found to be eutrophic according to the $Q_{B/T}$ index (= 3). According to the present data about rotifera species, and the abundance of them, the Büyükçekmece Reservoir was specified as eutrophic. However it is necessary to follow the conditions with periodic monitoring to observe the alterations in the Büyükçekmece Reservoir, in this respect the results of the present study would constitute an important baseline for subsequent studies.

Keywords: Zooplankton, indicator species, seasonal distribution, water quality, eutrophication

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INTRODUCTION

Rapid population growth and the development of industry has caused an increase in the need for drinkable tap water. However, usable water resources in Turkey are limited as well as around the world. Therefore, many reservoirs have been built for the supply of drinking water, irrigation, flood control, and energy generation in Turkey since the 1930s. Due to reservoirs being affected both by water level changes, sediment transport, the introduction of non-native species, and urbanization and industrialization, they are under the threat of eutrophication. Eutrophication causes a loss of biodiversity, and for this reason may destroy the balance of the food chain in aquatic systems (Brito et al., 2011). For this reason, the environmental conditions of reservoirs may affect diversity, density, biomass, and the spatiotemporal distribution of the zooplankton.

Zooplankton play a critical role in food and energy cycles in aquatic environments. Zooplankton groups grazing on phytoplankton, bacteria and detritus are significant protein sources for fish larvae, fish and aquatic invertebrates. The life cycles of zooplankton range from days to weeks (Brock et al., 2005). The feeding and reproduction forms of zooplankton vary among the groups (Hutchinson, 1967). Therefore their reactions to environmental conditions are different. Due to their quick responses to environmental alterations, zooplanktonic organisms, especially rotifers, are used as biological indicators (Ramadan et al. 1963; Gannon and Stemberger 1978; Sladecek 1983; Herzig, 1987; Saksena, 1987; Green 1993; Hanazato, 2001; Pereira et al., 2002; Jeppesen et al. 2011). Rotifers are small and have permeable integument (Arora and Mehra, 2003). They are able to reproduce in a short time (Snell and Janssen 1995), to give a quick response to the alterations in water quality by altering their species composition and abundance (Maley et al., 1988), and also to generate dense populations (Pace, 1986). Due to the above mentioned features, rotifers constitute the subject of this study.

This study focuses on rotifer taxa and their densities, which are a good biological indicator for determining water quality, and also aims to determine some limnological properties of the Büyükçekmece Reservoir. Another objective of the study is to compare the results with the previous study on biotic and abiotic variables of the reservoir performed by Aktan et al. (2006). Thus it is possible to evaluate the conditions of the reservoir and whether it has changed or not. To date, 417 rotifer species have been identified in Turkish freshwater resources (Ustaoğlu, 2015). The results of this study will also contribute to the knowledge of the inland water zooplankton diversity in Turkey. Also the data obtained will give insight to other planned studies.

MATERIAL AND METHODS

The Büyükçekmece Reservoir, which is located in the north west of Turkey and 50 km from the city centre of İstanbul (Soyer, 2003), was chosen as the study area. The Büyükçekmece Reservoir, which was constructed on a lake located at the mouth of the Karasu Stream, drains into the Sea of Marmara. As a result of the construction of the 11.4 m dam wall by the State Water System Services Department of Turkey (DSI) in the years 1983-1988 between the Sea of Marmara and the lake, the Büyükçekmece Reservoir lost its lagoon characteristic and it became a freshwater lake (Özuluğ, 1999). The lake meets the drinking and tap water requirements of İstanbul with 70 hm^3 water per year (Aktan et al., 2006).

The total water basin area of the Büyükçekmece Reservoir is 622 km^2 which has a 28.5 km^2-surface area, is 10 km long and 2.5 km wide (Soyer, 2003). The maximum depth of the lake is 7.15 m (Meriç, 1992). The main stream of this lake is the Karasu Stream which is located to the north of the lake. It has many tributaries such as Delice, Karamurad, Tavşan, Ayva, Akalan, Kestanelik and Öncürlü. The Keşliçiftiği (located on the west side of the lake) and Çekmece (located on the east side of the lake) Streams are also other sources (Özuluğ, 1999).

This study was conducted at 3 stations, which were selected as being representative of the Büyükçekmece Reservoir. The first station was selected from the area that is the most distant from the point that the Karasu Stream (the main source of the lake) flows into the lake (41.09095°N, 28.536003°E). The second station was selected from the middle of the lake (41.069596°N, 28.552753°E) and the third one was selected from the south side of the lake which is the closest part to the sea (41.047893°N, 28.569603°E) (Figure 1). The measured average depths of St. 1 and St. 2 were 3 m, and St. 3 was 5 m.

Figure 1. The Büyükçekmece Reservoir and sampling sites.

The sampling was conducted in May (2009), August (2009), November (2009) and February (2010) which were selected as being representative of each season. Dissolved oxygen (DO), water temperature, pH, electrical conductivity (EC) and salinity were measured *in situ* by a Hach Lange HQ 40d Multi-parameter instrument in order to determine the general limnological conditions of the reservoir. The water transparency of the reservoir was determined *in situ* using a Secchi disk. The trophic status of the lake was determined according to Carlson (1977), Chlorophyll *a* was determined according to Nusch (1980), and also total phosphorus was determined according to APHA AWWA WEF (1989). A non-parametric Kruskal-Wallis test was performed to determine the seasonal and spatial variations of the measured limnological variables.

Zooplankton was sampled with a closing net (55 µm mesh size, 9 cm diameter opening, 1 m length) vertically from the bottom to the surface and fixed with a 4% formaldehyde solution. The identification and classification of Rotifera species was performed on the isolated trophi of each individual according to the relevant taxonomic keys: Ruttner-Kolisko (1974), Pontin (1978), Koste (1978), Herzig (1987) and Sharma (1983). Species richness (S) of Rotifera was given as the total number of species at each station and season. The Relative abundance of Rotifera was calculated as individuals per litre (ind. L^{-1}). The individuals which have ≥ 5% proportion in total rotifera presence were considered as being dominant taxa. In order to determine the Rotifera trophic level of the reservoir the $Q_{Brachionus/Trichocerca}$ index was applied (Sladecek, 1983). The $Q_{B/T}$ index shows the rate of the number of *Brachionus* to the number of *Trichocerca*. The Q index is evaluated in three groups for the lake's trophic state, that Q=1 means oligotrophy, Q = 1.0-2.0 means mesotrophy, and Q>2 means eutrophy.

RESULTS AND DISCUSSION

The seasonal values of some of the main limnological parameters for each station, which were measured *in situ* in this study in the Büyükçekmece Reservoir, are shown in Table 1.

Table 1. Some limnological features of Büyükçekmece Reservoir

	Spring 2009			Summer 2009			Autumn 2009			Winter 2010		
	1st st.	2nd st.	3rd st.	1st st.	2nd st.	3rd st.	1st st.	2nd st.	3rd st.	1st st.	2nd st.	3rd st.
Temperature (°C)	17.1	15.2	14.9	25.9	25.5	25.1	18.6	18.1	17.1	6.6	6.2	5.5
DO (mg L^{-1})	10.48	11.59	11.25	7.66	7.20	8.26	8.19	9.32	9.83	9.57	9.63	10.57
pH	8.10	8.11	8.19	8.23	8.26	8.32	7.99	7.93	7.87	7.90	7.98	8.01
Salinity (ppt)	0.21	0.21	0.30	0.20	0.21	0.23	0.19	0.20	0.22	0.18	0.31	0.24
EC (25°C-µScm^{-1})	388.6	451.2	489.5	543.6	547.2	591.9	446.6	448.0	478.6	370.0	408.3	514.0
Secchi disk depth(m)	0.52	0.61	1.01	0.68	0.62	1.45	0.49	0.53	0.83	0.45	0.56	1.56
TP (µg L^{-1})	44.00	22.25	27.5	85.70	35.17	29.33	46.33	118.3	48.33	111.3	88.75	31.67
Chlorophyll a (µg L^{-1})	11.8	9.5	6.5	14.8	5.0	5.2	3.0	4.0	1.8	3.3	2.2	2.0

The annual average of the lake temperature was 16.3 ± 7.3°C and the temperature showed seasonal differences. The dissolved oxygen concentration (DO) reached its peak level due to the increase in water temperature and primary production in spring. The annual mean of the DO was measured as 9.5 ± 1.4 mg L^{-1}. The lake showed alkaline characteristics during the study period, and the mean pH was 8.1 ± 0.1. The annual mean salinity concentration, which had a freshwater characteristic after the dam construction, was 0.23 ± 0.04 ppt. The maximum conductivity values were measured in the summer period and the mean conductivity was 473.1 ± 67.6 µS cm^{-1}, annually. The annual average of the transparency (Secchi depth) was 0.8 ± 0.4 m in this shallow lake. Higher transparency values were detected in the areas that were closer to the seaside and deeper than the other stations (5 m). The annual average of the total phosphorus (TP) concentration was 54.81 µg L^{-1}. Higher Chlorophyll *a* (Chl *a*) concentration was found in the spring and summer periods where primary production increased with increasing temperatures. The annual average of Chlorophyll *a* was calculated as 5.76 µg L^{-1} (Table 1).

Table 2. Variance analysis results of the limnological variables of the Büyükçekmece Reservoir (Kruskal Wallis; $p < 0.05$).

Variable	By seasons	By stations
	Kruskal Wallis (p < 0.05)	
Water temperature (°C)	H = 10.202	H = 0.782
	p = 0.017	p = 0.677
DO (mg L^{-1})	H = 8.641	H = 1.654
	p = 0.034	p = 0.437
pH	H = 9.462	H = 0.154
	p = 0.024	p = 0.926
Salinity (ppt)	H = 1.605	H = 6.430
	p = 0.658	p = 0.140
EC (25 °C-µS cm^{-1})	H = 6.385	H = 3.500
	p = 0.094	p = 0.174
Transparency (m)	H = 1.667	H = 8.000
	p = 0.644	**p = 0.018**
Total Phosphorus (µg L^{-1})	H = 5.205	H = 2.577
	p = 0.157	p = 0.276
Chlorophyll a (µg L^{-1})	H = 8.436	H = 1.385
	p = 0.038	p = 0.500

Significant seasonal variations were observed between water temperature, dissolved oxygen, pH and Chlorophyll *a* concentration ($p< 0.05$). Significant spatial variations were determined for transparency values ($p< 0.05$) (Table 2).

The trophic status of the Büyükçekmece Reservoir was determined according to Carlson's Trophic State Index (1977) based on the Secchi disk depth (m), total phosphorus (µg L^{-1}) and the Chlorophyll *a* concentration (µg L^{-1}) values. The trophic status of the reservoir was determined as CTSI = 57.8 according to TSI(SD) = 63.7; TSI(TP) = 61.9 and TSI(CHL) = 47.8 values which were calculated based on annual averages.

Changes in the water level in the reservoirs, brought on by changes in the evaporation and precipitation amounts depending on seasonal conditions as well as the purpose and amount of water usage, are one of the most important factors in the role of aquatic organisms and biodiversity. The Büyükçekmece Reservoir is a very shallow reservoir and its deepest level was found to be 7.15 m in 1992 (Meriç, 1992), 6.9 m in 2006 (Aktan et al., 2006) and 5 m in this study. According to the Surface Water Quality Management Regulations it is reported that transparency <1.5 m indicates eutrophic conditions (Ministry of Forestry and Water Management, 2012). The average annual transparency (0.78 m) found in this study indicated eutrophic conditions. This decrease in transparency can be explained by the decrease in water depth of the reservoir over time due to its natural water usage conditions and seasonal increases in primary production. In this study, the Büyükçekmece Reservoir which was reported as being oligotrophic by Aktan et al. (2006) was found to be eutrophic (CTSI = 57.8).

A total of 33 rotifer species were identified, belonging to 17 families that were collected seasonally from 3 stations in Büyükçekmece Reservoir (Table 3). The distribution of the species by stations and seasons are given in Table 4.

When Rotifera fauna was evaluated in terms of the seasonal species richness, it was listed from the highest to lowest as: summer (32 species), autumn (22 species), spring (18 species) and winter (14 species) (Table 4). When the species richness was evaluated based on the stations, the highest species number was found in

Table 3. The taxonomic distribution of identified rotifers in the Büyükçekmece Resevoir.

Familya	Tür
Brachionidae Ehrenberg. 1838	*Anuraeopsis fissa* Gosse. 1851
	Brachionus angularis Gosse. 1851
	B. budapestinensis Daday. 1885
	B. calyciflorus Pallas. 1766
	B. diversicornis (Daday. 1883)
	B. quadridentatus Hermann. 1783
	B. urceolaris (O.F.Müller. 1773)
	Keratella cochlearis (Gosse. 1851)
	K. quadrata (O.F.Müller. 1786)
Ascomorpha Perty. 1850	*Ascomorpha ecaudis* (Petry. 1850)
	A. saltans Bartsch.1870
Asplanchnidae Eckstein. 1883	*Asplanchna priodonta* Gosse. 1850
	A. sieboldi (Leydig.1854)
Lepadellidae Harring. 1913	*C. colurus* (Ehrenberg.1830)
Conochilidae Harring. 1913	*Conochilus unicornis* Rousselet. 1892
Dicranophoridae Harring. 1913	*Dicranophorus grandis* (Ehrenberg.1832)
Epiphanidae Harring. 1913	*Epiphanes macroura* (Barrois & Daday.1894)
Euchlanidae Ehrenberg. 1838	*Euchlanis dilatata* Ehrenberg.1832
Filiniidae Harring & Myers. 1926	*Filinia longiseta* (Ehrenberg.1834)
Gastropodidae Harring. 1913	*Gastropus stylifer* Imhof. 1891
Lecanidae Remane. 1933	*Lecane stichaea* Harring.1913
Notommatidae Hudson & Gosse. 1886	*Notommata copeus* Ehrenberg.1834
Philodinidae Ehrenberg. 1838	*Philodina gregaria* Murray. 1910
Synchaetidae Hudson & Gosse. 1886	*Polyarthra dolichoptera* Idelson.1925
	P. vulgaris Carlin.1943
	Synchaeta litoralis Rousselet.1902
	S. oblonga Ehrenberg.1831
	S. pectinata Ehrenberg. 1832
Testudinellidae Harring. 1913	*Pompholyx sulcata* (Hudson.1885)
	Testudinella patina (Hermann.1783)
Trichocercidae Harring. 1913	*Trichocerca cylindirica* (Imhof.1891)
	T. (Diurella) porcellus (Gosse.1886)
Trichotriidae Harring. 1913	*Trichotria tetractis* (Ehrenberg.1830)

the 3rd station (30 species) followed by the 2nd station (27 species) and the 1st station, respectively (Table 4).

In this study, the annual total number of the rotifer was found as 2855 ind. L^{-1}. The abundance determined in summer period contributed to 62% of the average annual abundance and followed by spring (20%), autumn (11%) and winter (7%) (Figure 2).

The highest rotifer abundance were found in the 1st station (1245 ind.L^{-1}) followed by the 3rd station (838 ind.L^{-1}) and the 2nd station (772 ind.L^{-1}) (Figure 3).

The average 40.62% of the total annual rotifera abundance was composed of *Keratella cochlearis* in Büyükçekmece Reservoir followed by *Polyarthra vulgaris* (10.14%), *Synchaeta oblonga* (9.06%), *Brachionus urceolaris* (5.58%), *Pompholyx sulcata* (5.21%) and *Epiphanes macroura* (4.86%). The abundance of the rest of the identified species was less than 3% individually and 24.52% in total (Figure 4).

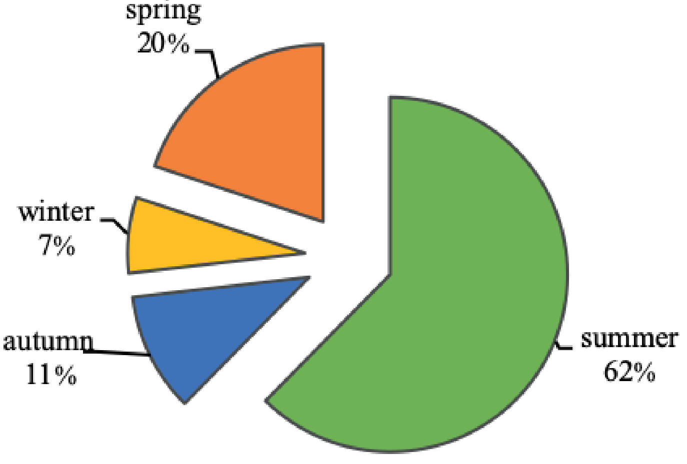

Figure 2. The seasonal distribution of rotifers.

Table 4. The spatiotemporal variation of rotifers in the Büyükçekmece Reservoir (sp: spring, su: summer, au: autumn, wi: winter).

	1st station				2nd station				3rd station			
	sp.	**su.**	**au.**	**win.**	**sp.**	**su.**	**au.**	**win.**	**sp.**	**su.**	**au.**	**win.**
Anuraeopsis fissa						+						
Ascomorpha ecaudis		+				+	+					
A. saltans			+			+	+				+	
Asplanchna priodonta		+		+	+	+	+	+		+		
A. sieboldi		+				+	+			+		+
Brachionus angularis	+	+					+					
B. budapestinensis	+	+	+			+	+			+	+	
B. calyciflorus	+	+			+	+	+		+	+	+	
B. diversicornis		+		+					+	+		+
B. quadridentatus		+				+				+		
B. urceolaris		+	+			+		+		+		
Colurella colurus			+		+	+	+			+	+	
Conochilus unicornis						+				+		
Dicranophorus grandis										+	+	
Epiphanes macroura		+	+	+	+	+	+	+	+	+	+	+
Euchlanis dilatata										+		
Filinia longiseta		+		+		+				+	+	+
Gastropus stylifer		+				+				+	+	+
Keratella cochlearis	+	+	+	+	+	+	+	+	+	+	+	+
K. quadrata	+	+			+	+			+	+		
Lecane stichaea										+		
Notommata copeus							+				+	
Philodina gregaria		+			+	+				+		
Polyarthra dolicoptera		+			+	+	+			+	+	
P. vulgaris	+	+	+		+	+	+	+	+	+	+	+
Pompholyx sulcata		+		+	+	+		+	+	+		+
Synchaeta littoralis			+		+	+	+	+			+	+
S. oblonga	+	+	+	+	+	+	+	+	+	+	+	+
S. pectinata		+	+	+		+	+	+		+	+	+
Testudinella patina		+		+	+	+		+			+	+
Trichocerca cylindrica		+	+			+	+		+	+	+	
T. porcellus	+	+								+		
Trichotria tetractis										+		
S	8	23	11	9	13	25	17	10	9	26	17	12

Table 5. The spatiotemporal distribution of dominant taxa (individual L^{-1}) (sp: spring, su: summer, au: autumn, wi: winter).

	1st station				2nd station				3rd station			
	sp.	**su.**	**au.**	**wi.**	**sp.**	**su.**	**au.**	**wi.**	**sp.**	**su.**	**au.**	**wi.**
B. urceolaris	-	99	3	-	-	33	-	3	-	21	-	-
E. macroura	-	15	2	16	1	43	2	10	2	3	30	17
K. cochlearis	429	311	9	3	24	125	4	1	5	238	6	1
P. vulgaris	5	56	2	-	20	72	12	3	1	111	6	1
P. sulcata	-	101	-	2	2	32	-	2	4	4	-	2
S. oblonga	1	2	44	2	2	5	44	70	4	18	55	13
Others	28	91	15	9	35	186	26	15	4	213	49	30
Total	463	675	75	32	84	496	88	104	20	608	146	64

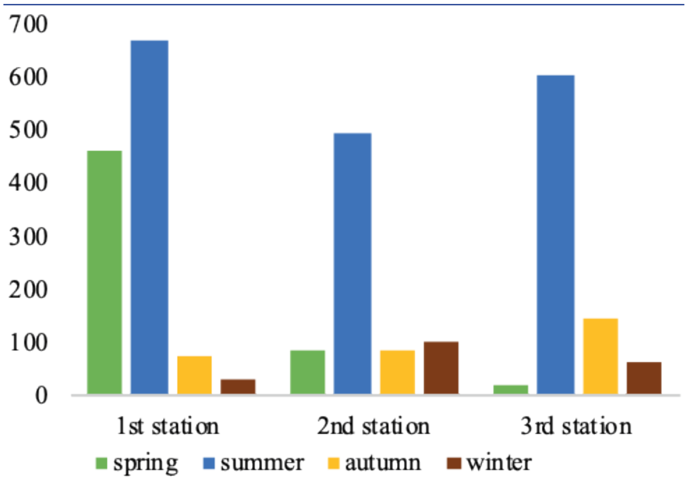

Figure 3. The spatiotemporal distribution of rotifers (ind. L^{-1}) (sp: spring, su: summer, au: autumn, wi: winter).

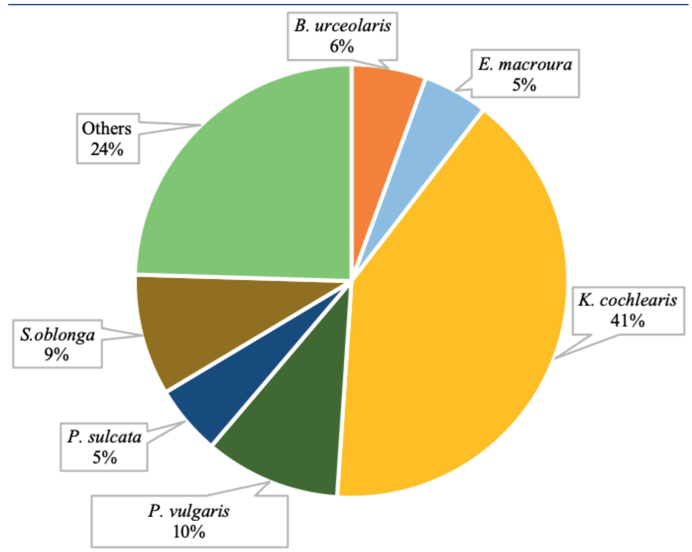

Figure 4. The annual distribution of dominant taxa (N%).

K. cochlearis, determined as the predominant species, was found at each station and in each season and the highest abundance values were detected in the 1st station, in spring (429 ind. L^{-1}) (Table 5). Moreover the species which had the relatively highest abundance were found as follows in the Rotifera community: *P. vulgaris* had the highest abundance in the 3rd station in the summer (111 individuals L^{-1}), *S. oblonga* in 2nd station in the winter (70 ind. L^{-1}), *B. urceolaris* and *P. sulcata* in the 1st station in the summer (99 ind. L^{-1} and 101 ind. L^{-1}, respectively) and *E. macroura* in the 2nd station in the summer (43 ind. L^{-1}) (Table 5).

The contribution of *K. cochlearis* which was one of the predominant species in the abundance of rotifera in the Büyükçekmece Reservoir throughout the year was 60.6%, 20.0% and 29.9% at the 1st, 2nd and 3rd stations respectively (Figure 5a). The contribution of *P. vulgaris* to the total abundance of rotifera was found to be 5% 13.9% and 14.3% at the 1st, 2nd and 3rd stations respectively. Whereas, the abundance of *S. oblonga* was found to be 3.9% (1st station), 15.7% (2nd station) and 10.7% (3rd station), *B. urceolaris* was found 8.2% (1st station), 4.6% (2nd station) and 3.5% (3rd station) throughout the year (Figure 5a). The contribution of *E. macroura* to the rotifer abundance was 2.6% (1st station), 7.3 (2nd station) and 6.1% (3rd station), while *P. sulcata* was found 8.3% (1st station), 4.6% (2nd station) and 1.2% (3rd station) throughout the year (Figure 5a). These spatial differences of the dominant spe-

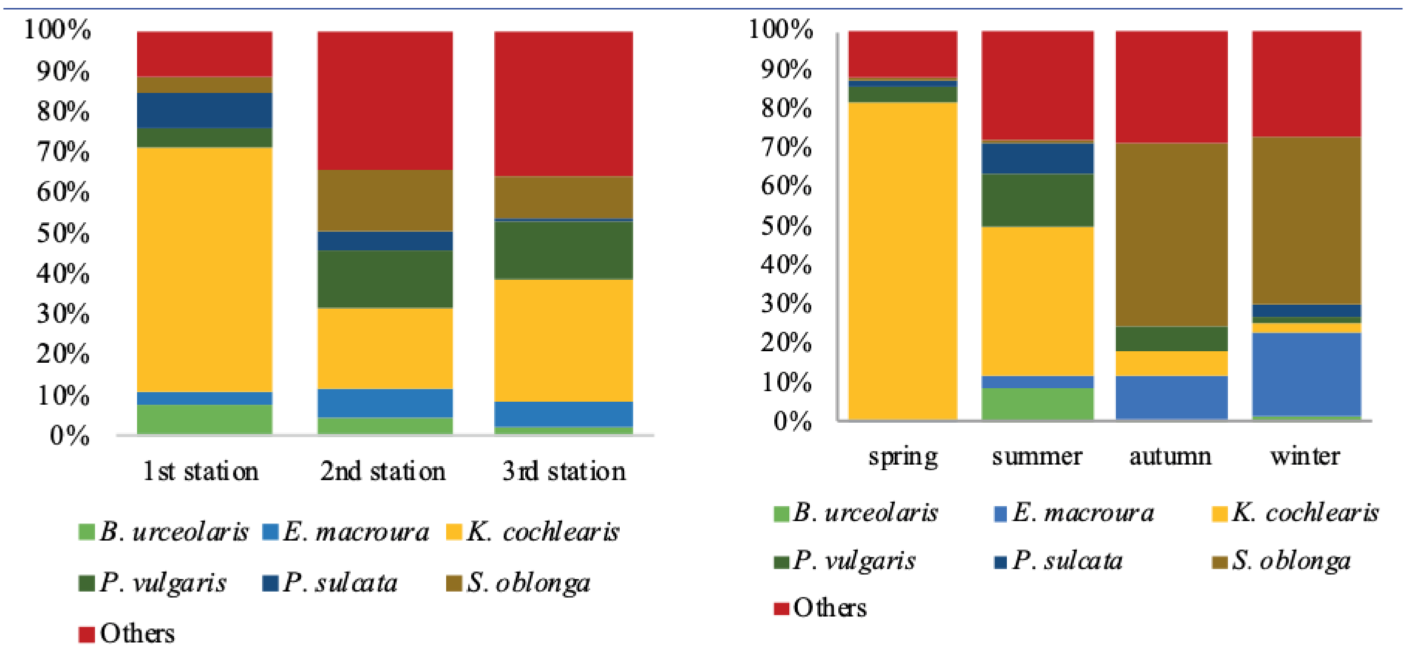

Figure 5. The spatial (a) and seasonal (b) distribution of rotifers in Büyükçekmece Reservoir.

cies may result from the distance to the streams' flow into the reservoir and the different depths of the stations.

Whereas the dominant rotifer species in the summer and the spring periods was determined as *K. cochlearis* (37.9% and 80.9% respectively), *S. oblonga* was the most abundant of the rotifer species in the autumn and the winter (46.1% and 42.9%) (Figure 5b). While *P. vulgaris* (13.5%), *B. urceolaris* (8.6%), *P. sulcata* (7.7%) species contributed to the greatest share in the summer period *E. macroura* (20.2%) has the greatest contribution in winter in which these species were considered the predominant species (Figure 5b).

The variance analysis (Table 2) indicated a significant difference in the spring season. This situation can be explained by the high total of phosphorous levels detected in the autumn and the winter used by primary producers in spring, which resulted in an increase in Chlorophyll *a* concentration (Table 1). Moreover, an increase in the algal population contributed to an increase in dissolved oxygen levels (Table 1). As a result of the seasonal differences of these parameters in the reservoir, rotifer taxa reached a higher level of abundance in the spring and the summer periods than that of the autumn and the winter periods due to algal growth and an increase in water temperature (Table 5).

Although 50 reservoirs are there in Marmara Region, the zooplankton fauna was studied on only five (Kızıldamalar, Boğazköy, Süloğlu, Ömerli, Büyükçekmece) of them. The results of the Büyükçekmece and other reservoirs were evaluated together for a regional comparison.

The transparency was reported as ≤ 0.5 m both for Kızıldamalar (depth: 26 m) and Boğazköy Reservoirs (depth: 12 m). During the study period the water temperature was determined at higher levels in the Boğazköy Reservoir (25 °C). Whereas the dissolved oxygen concentration was measured as 7.61 mg L^{-1} for the Kızıldamalar Reservoir and 6.5 mg L^{-1} for the Boğazköy Reservoir. pH levels were in the alkaline range for both of them and electrical conductivity levels were 326 µS cm^{-1} and 594 µS cm^{-1} for the Kızıldamalar and the Boğazköy Reservoirs respectively. The total phosphorous concentration was reported as 54 µg L^{-1} for both reservoirs (Ergönül et al., 2016). It was concluded that the reservoirs showed eutrophic characteristics (Ergönül et al., 2016). Whereas 8 rotifer species were determined in Kızıldamalar Reservoir, 7 species were detected in the Boğazköy Reservoir. The shared species between Kızıldamalar, Boğazköy and Büyükçekmece Reservoirs were *A. fissa*, *B. angularis, P. dolichoptera, P. vulgaris* and *P. sulcata*. Additionally, *K. cochlearis* was found both in the Boğazköy and the Büyükçekmece Reservoirs. The Limnological conditions of Kızıldamalar and Boğazköy Reservoirs were quite similar to the conditions determined in the present study (Table 2). It has been concluded that the shared rotifer species in these reservoirs are tolerant to the current trophic conditions.

The physicochemical characterization of the Süloğlu Reservoir was not specified in a faunistic study carried out in March 2013 – February 2014 (Güher and Çolak, 2015). 32 rotifer species were identified in this study in which rotifer fauna was dominated by indicators of eutrophic water and the reservoir showed oligo-mesotrophic characteristics. 15 rotifer species namely *A. fissa, A. priodonta, A. sieboldi, B. angularis, B. budapestinensis, B. urceolaris, E. dilatata, K. cochlearis, K. quadrata, P. vulgaris, P. sulcata, S. pectinata, S. oblonga, T. patina* and *T.cylindirica* were found in both the Büyükçekmece and the Süloğlu Reservoirs. Although the dominant species differed according to the reservoirs eutrophication indicator taxon were detected in both of them.

The drinking water for the İstanbul Province in the Marmara Region is supplied by the Büyükçekmece, Ömerli, Darlık, Elmalı, Alibey, Terkos reservoirs and the Istranca streams (Pabuçdere, Kazandere, Sultanbahçedere, Büyükdere, Kuzuludere Dams, Elmalıdere Regulator, Düzdere Pond). Among these reservoirs only the Büyükçekmece Reservoir is a natural water basin. Although limnological research was carried out for most of these reservoirs, the studies on the zooplankton fauna were only conducted for the Ömerli Reservoir (Kaplan, 1989; Altınyurt, 2006; Tarkan, 2010; Dorak et al., 2019) and the Büyükçekmece Reservoir (Aktan et al., 2006).

In a study carried out at the Ömerli Reservoir in 2006 it was shown that the water temperature was 7–25°C, conductivity was 135–343 µS cm^{-1}, pH was 6.78–9.35 and the chlorophyll *a* concentration was 42-54 µg L^{-1} (Altınyurt, 2006). Altınyurt (2006) reported that the conditions which were classified as eutrophic (Tüfekçi et al., 2003) were better when compared with the previous results. In another study carried out at the same reservoir in 2010 the results also showed eutrophic characteristics (Tarkan, 2010). However, in a recent study conducted in 2019 the physicochemical characteristics of the Ömerli Reservoir were as follows; the average temperature: 26.2 °C, dissolved oxygen: 8.6 mg L^{-1}, pH: 8.5, conductivity: 320.4 µS cm^{-1}, transparency: 2 m, total phosphorous: 15.0 µg L^{-1} and chlorophyll *a* concentration: 11.1 µg L^{-1} and it was concluded that reservoir was in mesotrophic conditions (Dorak et al., 2019). 14 rotifer species found in this study were also detected at the Ömerli Reservoir namely *A. fissa, A. priodonta, A. sieboldi, B. angularis, B. calyciflorus, C. unicornis, K. cochlearis, K. quadrata, P. dolichoptera, P. vulgaris, P. sulcata, R. rotatoria, S. oblonga* and *T. cylindirica*. These species show reactions to the changes in water quality (Gannon and Stemberger, 1978; Sharma 1983; Sladecek, 1983; Saksena 1987).

The 33 species detected at the Büyükçekmece Reservoir (Table 3) are on the list of Turkish rotifer fauna (Ustaoğlu et al., 2012) and considered to be a common species in the world (Segers, 2007). 56 rotifer species were identified in a study carried out by Aktan et al. (2006) in Büyükçekmece Reservoir (June 2004 – June 2005). These species were similar to the species found in this study.

The species detected in this study *A. fissa, B. angularis, B. calyciflorus, K. cochlearis, K. quadrata, E. dilatata, T. cylindrica, T. porcellus, P. vulgaris, S. pectinata, S. oblonga* and *P. sulcata* are known as indicators of eutrophication (Ruttner-Kolisko, 1974; Koste, 1978; Saksena, 1987; Michaloudi, 1997). During the sampling period the share of each species was < 3% except *P. vulgaris, S. oblonga* and *P. sulcata*. Besides, the eutrophication indicator species *K. cochlearis, P. vulgaris* and *S. oblonga* dominated the community. Although *S. pectinata, P. dolichoptera* and *A. priodonta* which were identified as the dominant species for oligotrophic conditions (Ruttner-Kolisko, 1974) were found in almost each sampling period and stations and they had minor share in the rotifera community in the Büyükçekmece Reservoir.

K. cochlearis, which represented 40.62% of the total annual rotifer abundance in the Büyükçekmece Reservoir, is a biological indicator. It is eurythermal (Bath and Kaur, 1998) and tolerant to pollution and the accumulation of organic matter (Hulyal and Kaliwal, 2008). It also prefers alkaline waters (Siegfried et al., 1989; Mulani et al., 2009) and spreads worldwide (Pennak, 1978). The other dominant species *P. vulgaris* (10.14%) is a eutrophication indicator (Ruttner-Kolisko, 1974; Koste, 1978; Saksena, 1987; Michaloudi, 1997), and is eurythermal (Berzins and Pejler, 1989a) like *K.cochlearis*. These two dominant species are perennial (Kolisko, 1974), and also they can tolerate a wide range of oxygen concentrations (Berzins and Pejler, 1989b). Due to these specifications *K. cochlearis* and *P. vulgaris* were found in almost all of the reservoirs in the Marmara Region. Also, these species were found in many reservoirs from different geographical regions and lakes in Turkey (Kaya and Altındağ, 2007; Ustaoğlu et al., 2012; Apaydın Yağcı, 2014; Saler and Alış, 2014; Apaydın Yağcı et al., 2015; Ergönül et al., 2016; Dorak et al., 2017; Dorak, 2019; Dorak et al., 2019).

An index ($Q_{B/T}$), which is calculated by the ratio of the number of species belonging to the Brachionus genus to the number of species belonging to the Trichocerca genus, is used to interpret the trophic level of the reservoir (Sladecek, 1983). According to the index if the $Q_{B/T}$ ratio = 1 the reservoir is considered as oligotrophic if the ratio is in the range of 1-2 the reservoir is mesotrophic and if the ratio is > 2 the reservoir is considered as eutrophic. In this study, it was found that 6 species belonged to the *Brachionus* genus and 2 species belonged to the *Trichocerca* genus, and the $Q_{B/T}$ was calculated to be 3. In this study the contribution of *Trichocerca* species (*T. cylindirica* and *T. porcellus*) to the annual total presence of rotifer, was determined as 3.07%. The contribution of *Brachionus* species (*B. angularis, B. budapestinensis, B. calyciflorus, B. diversicornis, B. quadridentatus, B. urceolaris*) to the total amount of rotifera was determined as 7.98% during the year in which 5.58% belonged to *B. urceolaris*. It is known that the *Brachionus* species are less affected by algal blooms than other microcrustaceans (Ismail and Adnan, 2016) and the high abundance of these species is a good biological indicator for eutrophic waters (Attayde and Bozelli, 1998). Moreover they can tolerate pollution (Sladecek, 1983; Hra, 2011). *Brachionus* species were detected in each sampling period and station in the Büyükçekmece Reservoir. Also, they reached their highest abundance in the summer, when the total phosphorus and Chlorophyll *a* (as a primary production) concentrations were higher. The diversity, density and temporal distribution of rotifers was supported by the eutrophic state of the reservoir, and showed the strong relationship between water quality and rotifers.

CONCLUSION

Overall the trophic level of the Büyükçekmece Reservoir in terms of rotifer fauna should be evaluated considering the richness of species and the abundance of detected species (Bays and Crisman, 1983; Harman et al., 1995; González et al., 2011). According to the prevalence and dominance of the eutrophication indicator *K. cochlearis,* the species richness of *Brachionus* and the $Q_{B/T}$ index it was obvious that the trophic status of Büyükçekmece Reservoir was eutrophic. Moreover, CTSI values also supported the rotifer fauna results and indicated the eutrophication. The rapid change in the trophic level of the reservoir, which is described as oligotrophic in 2006 by Aktan et al., suggests that an action plan should be established in the Büyükçekmece Reservoir in terms of the water quality and biodiversity.

Conflict of interests: The author declares no conflict of interest.

REFERENCES

Aktan, Y., Aykulu, G., Albay, M., Okgerman, H., Akçaalan, R., Gürevin, C. & Dorak, Z. (2006). Büyükçekmece Gölü'nde aşırı artış gösteren fitoplankterlerin gelişimini kontrol eden faktörlerin araştırılması. Tübitak Projesi 2006; ÇAYDAG-103Y127, 112s.

Altınyurt, S. (2006). Ömerli Baraj Gölünde Zooplanktonların Mevsimsel Değişiminin Saptanması, Yüksek Lisans Tezi, Marmara Üniversitesi Fen Bilimleri Enstitüsü, İstanbul.

Apaydın Yağcı, M. (2014). Seasonal Variations in Zooplankton Species of Lake Gölhisar, a Shallow Lake in Burdur, Turkey. *Pakistan Journal of Zoology*, *46*(4), 927–932.

Apaydın Yağcı, M., Yılmaz, S., Yazıcıoğlu, O., & Polat, N. (2015). The zooplankton composition of Lake Ladik (Samsun, Turkey). *Turkish Journal of Zoology, 39*, 652–659. [CrossRef]

APHA APHA-AWWA WPCF (1989). *Standard methods for the examination of water and wastewater*. 17th ed., Washington DC., 1391 p.

Arora, J., & Mehra, N.K. (2003). Seasonal dynamics of rotifers in relation to physical and chemical conditions of the river Yamun (Delhi), India. *Hydrobiologia, 491*, 101–109. [CrossRef]

Attayde, J.L., & Bozelli, R.L. (1998). Assessing the indicator properties of zooplankton assemblages to disturbance gradients by canonical correspondence analysis. *Canadian Journal of Fisheries and Aquatic Sciences*, *55* (8), 1789–1797. [CrossRef]

Bays, J.S., & Crisman, T.L. (1983). Zooplankton and trophic state relationships in Florida lakes. *Canadian Journal of Fisheries and Aquatic Sciences*, *40*, 1813–1819. [CrossRef]

Bath, K.S., & Kaur, H. (1998). Seasonal distribution and population dynamics and rotifers in Harike reservoir (Punjab-India). *Journal of Environment and Pollution*, *5*(4), 249–252.

Berzins, B., & Pejler, B. (1989a). Rotifer occurrence in relation to temperature. *Hydrobiologia*, *175*, 223–231. [CrossRef]

Berzins, B., & Pejler, B., (1989b). Rotifer occurrence in relation to oxygen content. *Hydrobiologia*, *183*, 165–172. [CrossRef]

Brito, S.L., Maia-Barbosa, P.M., & Pinto-Coelho, R.M. (2011). Zooplankton as an indicator of trophic conditions in two large reservoirs in Brazil. *Lakes & Reservoirs: Research and Management*, *16*, 253–264. [CrossRef]

Brock, M.A., Nielsen, D.L., & Crossle, K. (2005). Changes in biotic communities developing from freshwater wetland sediments under experimental salinity and water regimes. *Freshwater Biology*, *50*, 1376–1390. [CrossRef]

Carlson, R.E. (1977). A Trophic State Index for Lakes. *Limnology and Oceanography, 22* (2), 361–369. [CrossRef]

Dorak, Z., Köker, L., Sağlam, O., Akçaalan, R., & Albay, M. (2017). Determination of zooplankton community structure, biomass and trophic state of a shallow turbid lake. *Fresenius Environmental Bulletin*, *26* (1a), 834–845.

Dorak, Z. (2019). Indicator zooplankton species and ecological requirements of zooplankton communities in man-made reservoirs. *Fresenius Environmental Bulletin*, *28* (3), 2185–2198.

Dorak, Z., Köker, L., Gaygusuz, Ö., Gürevin, C., Akçaalan, R., & Albay, M. (2019). Zooplankton biodiversity in reservoirs of different geographical regions of Turkey: composition and distribution related with some environmental conditions. *Aquatic Sciences and Engineering, 34*(1), 29–38. [CrossRef]

Ergönül, M.B., Erdoğan, S., Altındağ, A., & Atasağun, S. (2016). Rotifera and Cladocera fauna of several lakes from Central Anatolia, Marmara, and Western Black Sea regions of Turkey. *Turkish Journal of Zoology, 40*, 141–146. [CrossRef]

Gannon, J.E. & Stemberger, R.S. (1978). Zooplankton (especially crustaceans and rotifers) as indicators of water quality. *Transactions of the American Microscopical Society*, *97*, 1635. [CrossRef]

González, E., Matos, M., Peñaherrera, C., & Merayo, S. (2011). *Zooplankton Abundance, Biomass and Trophic State in Some Venezuelan Reservoirs*. Dr. Islam Atazadeh, editor. Biomass and Remote Sensing of Biomass. InTech pp. 57–74.

Green, J. (1993). Diversity and dominance in planktonic rotifers. *Hydrobiologia,* 255/256 (Dev. Hydrobiol. 83), 345–352. [CrossRef]

Güher, H. (2000). A Faunistic study on the freshwater Cladocera (Crustacea) species in Turkish Thrace (Edirne, Tekirdağ, Kırklareli). *Turkish Journal of Zoology, 24*, 237–243.

Güher, H. & Çolak, Ş. (2015). Süloğlu Baraj Gölü'nün (Edirne) zooplankton (Rotifera, Cladocera, Copepoda) faunası ve mevsimsel değişimi. *Trakya Üniversitesi Fen Bilimleri Dergisi, 16*(1), 17–24.

Hanazato, T. (2001). Pesticide effects on freshwater zooplankton: an ecological perspective. -*Environmental Pollution*, *112,* 1–10. [CrossRef]

Harman, C.D., Bayne, D.R., & West, M.S. (1995). Zooplankton trophic state relationships in four Alabama–Georgia reservoirs. *Lake and Reservoir Management*, 11, 299–309. [CrossRef]

Herzig, A. (1987). The analysis of planktonic rotifer populations: A plea for long-term investigations. *Hydrobiologia, 147*, 163–180. [CrossRef]

Hra, M. (2011). Seasonal and spatial distribution of *Brachionus* (Pallas, 1966; Eurotatoria: Monogononta: Brachionidae), a bioindicator of eutrophication in lake El-Manzalah, Egypt. *Biology and Medicine*, *3*(2), Special Issue, 60–69.

Hulyal, S.B., & Kaliwal, B.B. (2008). Water quality assessment of Almatti Reservoir of Bijapur (Karnataka State, India) with special reference to zooplankton. *Environmental Monitoring and Assessment*, *139*, 299–306. [CrossRef]

Hutchinson, G.E. (1967). *A Treatise on Limnology*. II. Introduction to Lake Biology and the Limnoplankton. Wiley, New York.

Ismail, A.H., & Adnan, A.A.M. (2016). Zooplankton Composition and Abundance as Indicators of Eutrophication in Two Small Man-made Lakes. *Tropical Life Sciences Research*, *27*(1), 31–38. [CrossRef]

Jeppesen, E., Nõges, P., Davidson, T.A., Haberman, J., Nõges, T., Blank, K., Lauridsen, T.L., Søndergaard, M., Sayer, C., Laugaste, R., Johansson, L.S., Bjerring, R., & Amsinck, S.L. (2011). Zooplankton as indicators in lakes: a scientific-based plea for including zooplankton in the ecological quality assessment of lakes according to the European Water Framework Directive (WFD). *Hydrobiologia, 676*, 279–297. [CrossRef]

Kaplan, H. (1989). Ömerli Baraj Gölü Zooplankton Gruplarının Mevsimsel Dağılımı, Yüksek Lisans Tezi, İstanbul Üniversitesi, Fen Bilimleri Enstitüsü.

Kaya, M., & Altındağ, A. (2007). Zooplankton Fauna and Seasonal Changes of Gelingüllü Dam Lake (Yozgat, Turkey). *Turkish Journal of Zoology*, *31*, 347–351.

Kolisko, W.R. (1974). *Planktonic Rotifers Biology and Taxonomy Biological Station*. Lunz of The Austrian Academy of Science, Stuttgart.

Koste, W. (1978). *Die Radertiere Mitteleuropas*. Ein Bestimmungswerk, Begründet Von Max Voigt. Überordnung Monogononta. 2 Auflage Neubearbeitet Von II. Tafelband. Berlin Stutgart, 234pp.

Maley, D.F., Chang, P.S.S., & Schindler, D.W. (1988). Decline of zooplankton populations following eutrophication of Lake 227, Experimental Lakes Area, Ontario – 1969-1974. Canadian technical report of fisheries and aquatic sciences, 1619, 29 pp.

Michaloudi, E. (1997). Composition, Abundance and Biomass of the Zooplanktonic Organisms In Lake Micri Prespa (Macedonia, Greece). Doctoral dissertation, Aristotle University, Thessaloniki 199 pp.

Meriç, N. (1992). Büyükçekmece Baraj Gölü Balıkları. Fırat Üniv. XI. Ulusal Biyoloji Kongresi, Elazığ.167–174.

Mulani, S.K., Mule, M.B., & Patil, S.U. (2009). Studies on water quality and zooplankton community of the Panchganga river in Kolhapur city. *Journal of Environmental Biology, 30*(3), 455–459.

Nush, E.A. (1980). Comparison of different methods for chlorophyll and phaeopigment determination. *Archiv für Hydrobiologie–Beiheft Ergebnisse der Limnologie, 14*, 14–36.

Ministry of Forestry and Water Management (2012). Yüzeysel Su Kalitesi Yönetimi Yönetmeliği. Ankara, Turkey: Resmi Gazete 28483.

Özuluğ, M. (1999). A taxonomic study on the fish in the basin of Büyükçekmece Dam Lake. *Turkish Journal of Zoology, 23*, 439–451.

Pace, M.L. (1986). An empirical analysis of zooplankton community size structure across lake trophic gradients. *Limnology and Oceanography*, *31*(1), 45–55.

Pennak, R.W. (1978). *Freshwater invertebrates of the United States.*2nd ed. New York: John Wiley & Sons.

Pereira, R., Soares, A.M., Ribeiro, R., & Goçalves, F. (2002). Assessing the trophic state of Linhos lake: a first step towards ecological rehabilitation. *Journal of Environmental Management*, *64*, 285–297. [CrossRef]

Pontin, R.M. (1978). *A Key to the Freshwater planktonic and Semi-Planktonic Rotifera of the British Isles*. Freshwater Biological Association Scientific Publication, No: 38.

Ramadan, F.M., Klimowicz, H., & Swelim, A.A. (1963). The pollutional effect of industrial waste on rotifers. *Polish Archives Hydrobiology*, *11*, 97–108.

Ruttner-Kolisko, A. (1974). *Plankton Rotifers Biology and Taxonomy*. Stutgart: Biological Station Lunz of the Austrian Academy of Science.146pp.

Saler, S., & Alış, N. (2014). Zooplankton of Hancağız Dam Lake (Gaziantep–Turkey). *Journal of Survey in Fisheries Sciences*, *1*(1), 36-45. [CrossRef]

Saksena, N.D. (1987). Rotifer as indicators of water qality. *Acta Hydrocim Hydrobiologia*, *15*, 481–485. [CrossRef]

Segers, H. (2007). Annotated checklist of the rotifers (phylum Rotifera) with notes on nomenclature, taxonomy and distribution. *Zootaxa*, *1564*, 1–104. [CrossRef]

Siegfried, C.A., Bloomfield, J.A., & Sutherland, J.W. (1989). Planktonic rotifer community structure in Adirondack, New York, U.S.A. lakes in relation to acidity, trophic status and related water quality characteristics. *Hydrobiologia, 175*, 33–48. [CrossRef]

Sharma, B.K. (1983). The Indian species of the genus *Branchionus* (Eurotatoria: Monogononta: Brachionida), *Hydrobiologia*, *104*, 31–39. [CrossRef]

Sladecek, V. (1983). Rotifers as indicators of water quality. *Hydrobiologia*, *100*, 169–201. [CrossRef]

Snell, T.W., & Janssen, C.R. (1995). Rotifers in ecotoxicology: a review. *Hydrobiologia*, *313/314,* 231–247. [CrossRef]

Soyer, E. (2003). Büyükçekmece Su Kaynağının Ozonlama Sonucu Bromat Oluşturma Potansiyelinin Araştırılması, Yüksek Lisans Tezi, İ.T.Ü. Fen Bilimleri Enstitüsü, İstanbul.

Tarkan, A.S. (2010). Effects of streams on drinkable water reservoir: an assessment of water quality, physical habitat and some biological features of the streams. *Journal of FisheriesSciences.com*, *4*(1), 8–19. [CrossRef]

Tüfekçi, V., Morkoç, E., Tüfekçi, H., Tolun, L., Telli Karakoç, F., Karakas, D., Olgun, A., & Aydöner, C. (2003). Ömerli Baraj Gölündeki Toksik Fitoplankton Türlerinin Tespiti ve Su Kalitesinin İyilestirilmesine Yönelik Çözüm Önerilerinin Belirlenmesi Projesi, Yer ve Deniz Bilimleri Arastırma Enstitüsü, TÜBİTAK-MAM, Gebze, Kocaeli.

Ustaoğlu, M.R., Altındağ, A., Kaya, M., Akbulut, N., Bozkurt, A., Özdemir Mis, D., Atasagun, S., Erdoğan, S., Bekleyen, A., Saler, S., & Okgerman, H.C. (2012). A Checklist of Turkish Rotifers. *Turkish Journal of Zoology, 36*(5), 607–622. [CrossRef]

Ustaoğlu, M.R. (2015). An Updated Zooplankton Biodiversity of Turkish Inland Waters. *Journal of Limnology and Freshwater Fisheries Research, 1*(3), 151–159. [CrossRef]

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Research Article

The Characterization and Activity of Protease Enzyme on Different Days of Tadpoles [*Pelophylax ridibundus* (Pallas, 1771)]

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ABSTRACT

In this study, protease enzyme activity of *Pelophylax ridibundus* (Pallas, 1771) tadpoles was determined during the larval period starting from 25 Gosner stage (1960). When the *P. ridibundus* tadpoles reached the 25 Gosner stage (1960) on the 22nd day, the sampling was continued until the metamorphosis was completed by sampling at 5-day intervals. Initial average weight and length of the tadpoles were 0.076 g and 6.42 mm, respectively. The tadpoles were fed with pellet feed the size of 2 mm and 39% crude protein content twice a day in the morning and afternoon. The differences in the protease activity between the 22nd day and the 62nd day of the metamorphosis were found statistically significant (P<0.05). It has been observed that the protease enzyme reached maximum level at the 32nd day. In the next stages, protease activity showed a tendency to increase and decrease up to metamorphosis. These results can be used as the basis for the most appropriate nutritional formulation for *P. ridibundus* in the larval stage.

Keywords: *Pelophylax ridibundus*, frog, acid protease, larval period, metamorphosis

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INTRODUCTION

Most adult amphibians are fed on insects, while a small part are carnivores because they eat live invertebrates. The anuran tadpoles are herbivorous and their diets may also include plant material as well as aquatic invertebrates. The functional development of digestive organs is very important in the digestibility of the tadpole. In particular, in the frog culture where artificial feeds with high protein values are preferred in their diet, the digestive enzyme system mainly contains protease, amylase and lipase (Klahan and Yuangsoi, 2012). In the larval period, which is the most important step in the feeding of frogs, there is little information about how these animals are fed. According to the needs of the larvae, the deficiency in feeding resulted in death with the emergence of larval diseases (Veiga et al., 1998; Seixas Filho et al., 1998). In other zoological groups, the relationship between the nutrition regime and the digestive system has been studied extensively and satisfactory results have been obtained by formulating the feed used to be manipulated (Seixas Filho et al., 2000). However, tadpole nutrition is far from establishing requirement standards that can be used by nutritionists. It is necessary to know the digestive physiology of these animals in order to identify the feed formulation in accordance with the nutritional requirements of the larvae at different stages of development. Furthermore, the effective use of the feed is directly related to the digestion process which is the basis of enzymes. In particular, the diets currently used in frog breeding have 40% crude protein content, but they contain the basic ingredients necessary for fish, but the needs for the tadpole frog is insufficient. In addition, nutritional habits and nutritional requirements of frogs vary at each stage of their development. Due to the structural changes that occur during the development of larvae, nutrients need to be higher and nutritional deficiencies should be avoided (Barbosa et al., 2005; Oliveira-Bahia, 2007).

Generally, the use of feeds with high crude protein values in frog cultivation has led to good performance both in the larval period (Carmona-Osalde et al., 1996; Albinati et al., 2000; Albinati et al., 2001; Hayashi et al., 2004) and in other developmental periods (Barbalho, 1991; Braga and Lima, 2001). In addition, 26.6% to 33.6% of crude protein levels were reported to be suitable for larval development (Barbosa et al., 2005), but the use of feeds with protein values of 22.5% may cause high mortality. For this reason, it is important to understand the relationship between the enzymes involved in digestion and the percentages of carbohydrates, proteins, and fats in the diet to increase meat production in frogs.

Studies report that adult amphibians fed with different diets do not exhibit any changes in the activity of intestinal enzymes, but alter the digestive performance of different diets used in feeding the tadpole (Toloza and Diamond, 1990; Sabat and Bozinovic, 1996). In addition, studies on the enzyme activity profiles of animals eating controlled diets are needed.

Although there are studies on the study of the enzymatic activity in amphibians (Etkin, 1968; Leone et al., 1976; Braga et al., 2004; Braga et al., 2006; Oliveira-Bahia, 2007), studies on the relationship between nutrition levels and growth in the literature have been reported to be inadequate (Barbosa et al., 2005). In some studies, the effects of some variables on larval growth, such as the period of light (Bambozzi et al., 2004), stock density (Hayashi et al., 2004) and protein levels (Carmona-Osalde et al., 1996) were investigated.

Metamorphosis, period of major post-embryonic transformations that involving morphological, physiological, biochemical, and behavioral changes. Also, changes the lifestyle of frog larvae. Metamorphosis in amphibians is the development of structures and functions that are important in the transformation of larval structures into beneficial structures in adults (Duellman and Trueb, 1986).

Morphological changes are observable changes, such as the formation of the lung, the development of the dermal glands of the eyelids, the formation of the mouth and tongue, and the differentiation of the digestive system (Bonneville, 1963; Bonneville and Weinstock 1970; Thibaudeau and Altig, 1988; Paulson and Robinson 1995; Rovira et al., 1993). Proteolytic enzymes play an important role in performing these morphological and physiological changes before and during metamorphosis. Proteolitic enzymes are used as energy reserves in metamorphosis as a result of feeding of living organisms. In addition, the feeding strategies formed by knowing the physiological events occurring in the larval period and the changes due to the days in the activities of these enzymes will accelerate the larval development and increase the survival rate.

The aim of this study was to determine the protease enzyme activity of *Pelophylax ridibundus* (Pallas, 1771) tadpoles fed with a protein ratio of 39% starting from 25 Gosner stage (1960) during the larval period. The results of the study will light on obtaining the most suitable feed ration for *P. ridibundus*, which is an economically important species.

MATERIAL AND METHODS

This study was carried out to determine protease enzyme activity on *P. ridibundus* tadpoles grown in the frog production facility of Aydıncık in Mersin, Turkey. Larval tadpole sampling was performed on the 22nd day with the Gosner 25 (1960) level at 5-day intervals and this process was continued until the metamorphosis was completed. In this study, 6 m² ponds were used in the cultivation of tadpole larvae. The water of the ponds was changed 50% once a day and the temperature of the ponds was measured as 23.0±1.0°C during the study period. Initial average weight and length of the tadpoles were 0.076 g and 6.42 mm, respectively. The tadpoles were fed with pellet feed the size of 2 mm and 39% crude protein content twice a day in the morning and afternoon (Table 1).

Table 1. Chemical analysis of formulated pellet food for *P. ridibundus* tadpoles

Content	Percent (%)
Moisture	4.54
Crude Protein	39
Fat	22.88
Ash	14.74

Basic composition: fish meal, chicken meal and fish oil.

Pellet food content analyzes used in the feeding study were conducted in Iskenderun Technical University Marine Sciences and Technology Faculty Aquaculture Laboratory. The tadpole samples for analysis were stored in the Hettich freezer at -80°C.

Determination of protease activities

Total protease activities of *P. ridibundus* tadpoles was measured as described by Walter (1984), using casein (10 mg ml^{-1}) in 50 mM Tris-HCl buffer at pH 9 as the substrate. The mixtures including extracts of tadpoles were incubated with the substrate and then the reaction was stopped by addition of 500 µl trichloroacetic acid (TCA) (120 g L^{-1}). The absorbance was recorded at 280 nm. All measurements were carried out in triplicate. The soluble protein concentrations of *P. ridibundus* tadpole were determined according to Brasford (1976).

Statistical methods

Data was analyzed by using SPSS 17.0 statistics software. Comparisons were made using a one-way ANOVA test. Then, a Post-Hoc Tukey multiple-comparison test was used for significant differences at the $P<0.05$ level.

RESULTS AND DISCUSSION

The results of the analysis of protease enzyme activities with *P. ridibundus* tadpoles are given in Table 2. The differences between the 22nd day of protease activity larvae and the 62nd day of the metamorphosis were found statistically significant ($P<0.05$). It has

Table 2. The changes observed in protease activities (mean±standard error (SE))

Day	Protease Activities (U/ml)
22	830.50 ± 64.19^{bc}
27	950.31 ± 62.31^{c}
32	1600.22 ± 12.61^{d}
37	675.76 ± 13.94^{b}
42	977.17 ± 14.79^{c}
47	392.08 ± 25.08^{a}
52	659.93 ± 40.72^{b}
57	739.36 ± 32.86^{b}
62	451.24 ± 17.38^{a}

In all lines, means with different superscripts are significantly different from each other (P<0.05)

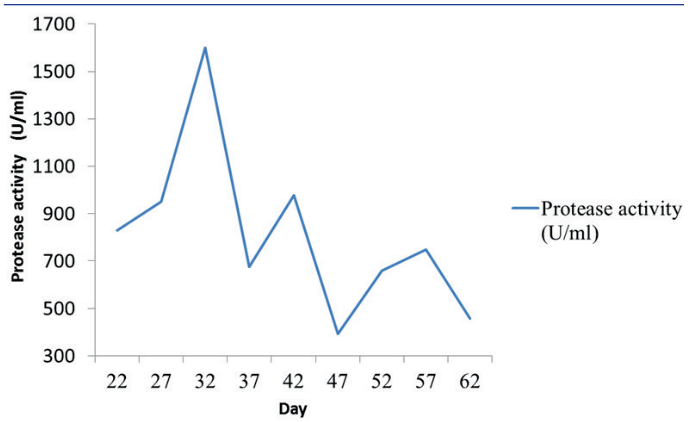

Figure 1. Protease activity on different days.

been observed that the protease enzyme reached maximum level at the 32nd day, increasing from the 25 Gosner stage (1960) (day 22). After that, the increases and decreases in protease enzyme activity were detected until metamorphosis (Figure 1).

Santos et al. (2016) with study *Lithobates catesbeianus* showed that the increase in the amount of digestive enzymes before metamorphosis is important to increase the amount of metamorphosis thanks to the increase in the energy needed for the growth of the living organism detected. In our study with *P. ridibundus* tadpoles, the highest protease activity was found on day 32 (1600.22±12.61 U/ml) since the beginning of nutrition that this increase continued until the metamorphosis and the digestive system were completed. With the growth slowed after 30 days, the amount of energy required for development will decrease and the enzyme activity will be physiologically limited by the tadpoles (Seixas Filho et al., 2010). During the study period 32-37. (675.76±13.94 U/ml), 42-47. (392.08±25.08 U/ml) and 57-62. (451.24±17.38 U/ml) days, the amount of protease was decreased.

Seixas Filho et al. (2010) reported that the tadpoles of *Rana catesbeiana* were fed with 28% crude protein, the amylase enzyme was more active between 30 and 45 days and the tadpoles were fed with mostly content of carbohydrate diets. In our study, a decrease in protease activity was observed in 32nd-37th days, although there was an increase again in protease activity from the 37th day (Figure 1). *P. ridibundus* tadpoles reached the metamorphosis stage on the 42nd day and the process ended on the 62nd day. As a result of our study, the amount of protease obtained from Oliveira-Bahia (2007) was similar to the results of the study.

The use of feeds with high crude protein values in frog culture has led to good performance in both larval stages (Carmona-Osalde et al., 1996; Albinati et al., 2000, 2001; Hayashi et al., 2004) and other developmental periods (Barbalho, 1991; Braga & Lima, 2001). In our study, tadpoles of *P. ridibundus* were fed with a pellet food containing 39% crude protein. Seixas Filho et al. (2010) reported that bullfrog tadpoles fed commercial frog feed with 28% crude protein content obtained good results in terms of enzyme activity.

Klahan and Yuangsoi (2012) reported that *Rana rugulosa* in 45-day tadpoles were more prone to protease activity than those with 60-day tadpoles. In our study, the 42-day *P. ridibundus* tadpoles (977.17±14.79 U/ml) were found to have more protease than the 62-day (451.24±17.38 U/ml) individuals. In this study, it was determined that the protease amount of *P. ridibundus* tadpoles (451.24±17.38 U/ml) decreased in the last period of the metamorphosis phase (62nd day). The reason for this decrease in the amount of protease is due to the maintenance of a number of morphological changes such as the consumption of metabolic energy in the loss of the tail and the tadpoles consuming a smaller amount of food in the last stages of metamorphosis than in previous periods (Gonçalves et al., 2015).

CONCLUSION

As a result, *P. ridibundus* tadpoles fed with 39% crude protein were found to have more protease activity at the beginning of the larval development period than in other periods. In our study, it was emphasized that appropriate dietary formulations should be formed so that it can be consumed effectively by frogs on different days of the larval period.

Ethics Committee Approval: This study was carried out accordance with animal welfare and the ethics of trial.

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

REFERENCES

Albinati, R. C. B., Lima, S. L., Tafuri, M. L., & Donzele, J. L. (2000). Digestibilidade aparente de dois alimentos protéicos e três energéticos para girinos de rã-touro (*Rana catesbeiana* Shaw, 1802). *Revista Brasileira de Zootecnia*, 29(6), 2151-2156. http://www.sbz.org.br/revista/artigos/2715.pdf

Albinati, R. C. B., Lima, S. L., & Donzele, J. L. (2001). Níveis de energia digestível na ração de girinos de rã-touro. *Revista Brasileira de Saúde da Produção Animal*, 2(2), 48-52. http://www.repositorio.ufba.br/ri/handle/ri/1840

Bambozzi, A. C., Seixas-Filho, J. D., Thomaz, L. A., Oshiro, L. M. Y., Braga, L. G. T., & Lima, S. L. (2004). Efeito do fotoperíodo sobre o desenvolvimento de girinos de rã-touro (Rana catesbeiana Shaw, 1802). *Revista Brasileira de Zootecnia*, *1*(1), 1–7. [CrossRef]

Barbosa, J. M., Silveira, A. M., & Gomide, C. A. (2005). Crescimento heterogêneo de girinos de rã-touro alimentados com diferentes rações. *Pesquisa Agropecuária Brasileira*, *40*(10), 1015–1019. [CrossRef]

Bonneville, M. A. (1963). Fine structural changes in the intestinal epithelium of the bullfrog during metamorphosis. *The Journal of cell biology*, *18*(3), 579–597. [CrossRef]

Bonneville, M. A., & Weinstock, M. (1970). Brush border development in the intestinal absorptive cells of Xenopus during metamorphosis. *The Journal of cell biology*, *44*(1), 151–171. [CrossRef]

Braga, L. G. T., & Lima, S. L. (2001). Influência da temperatura ambiente no desempenho da rã-touro, Rana catesbeiana (Shaw, 1802) na fase de recria. *Revista Brasileira de Zootecnia*, *30*(6), 1659–1663. [CrossRef]

Braga, L. G. T., Oliveira, M. D. A., Lima, W. C., & Euclydes, R. F. (2004). Atividade da tripsina em rã-touro na fase pós-metamórfica. *Revista Brasileira de Zootecnia*, *33*(4), 821–827. [CrossRef]

Braga, L. G. T., Oliveira, M. G. A., Lima, W. C., & Euclydes, R. F. (2006). F. Atividade enzimática da lipase em rã-touro na fase pós-metamórfica. *Scientia Agrícola*, *63*(5), 821–827. [CrossRef]

Brasford, M. M. (1976). A rapid and sensitive method for quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. *Anal. Biochem.*, *72*, 248–254. [CrossRef]

Carmona-Osalde, C., Olvera-Novoa, M. A., Rodriguez-Serna, M., & Flores-Nava, A. (1996). Estimation of the protein requirement for bullfrog (*Rana catesbeiana*) tadpoles, and its effect on metamorphosis ratio. *Aquaculture*, *141*(3-4), 223–231. [CrossRef]

Duellman, W. E., & Trueb, L. (1986). Biology of Amphibians. New York, United States of America, McGraw–Hill Press., 613 pp.

Etkin, W. (1968). Hormonal control of amphibian metamorphosis. In Etkin, W. & Gilbert, L. I. (Eds.) In Metamorphosis: A Problem in Developmental Biology (pp. 314-348). Appleton, New York, Academic Press., 500pp.

Gonçalves, A. M., Santos, L. F., Santana, C. C., Colosio, R. R., & Pizauro, J. M. (2015). Activity of Tail Phosphatases: A Study during Growth and Metamorphosis of *Lithobates catesbeianus*. *Copeia*, *103*(3), 634–638. [CrossRef]

Gosner, K. L. (1960). A simplified table for staging anuran embryos and larvae with notes on identification. *Herpetologica*, *16*(3), 183–190.

Hayashi, C., Soares, C. M., Galdioli, E. M., Furuya, V. R. B., & Boscolo, W. R. (2004). Desenvolvimento de girinos de rã-touro (*Rana catesbeiana* Shaw, 1802) cultivados em diferentes densidades de estocagem em tanques-rede. *Revista Brasileira de Zootecnia*, *33*(1), 14–20. [CrossRef]

Klahan, R., & Yuangsoi, B. (2012). The Characterization and Activity of Digestive Enzymes in Different Sizes of Common Lowland Frog (*Rana rugulosa*). *International Journal of Environmental and Rural Development*, *3*(2), 114–120. http://iserd.net/ijerd61/IJERD%206-1-10.pdf

Leone, F., Lambert-Gardini, S., Sartori, C., & Scapin, S. (1976). Ultrastructural analysis of some functional aspects of *Xenopus laevis* pancreas during development and metamorphosis. *Development*, *36*(3), 711–724.

Oliveira-Bahia, V. R. L., (2007). Morfologia e enzimologia do sistema digestório dos girinos da rã-touro (*Rana catesbeiana*) durante o desenvolvimento e metamorfose (Master Thesis). Universidade Estadual Paulista, Jaboticabal, Brasil.

Paulson, P. E., & Robinson, T. E. (1995). Amphetamine-Induced time-dependent sensitization of dopamine neurotransmission in the dorsal and ventral striatum: A microdialysis study in behaving rats. *Synapse, 19*(1), 56–65. [CrossRef]

Rovira, J., Villaro, A. C., Bodegas, M. E., Valverde, E., & Sesma, P. (1993). Structural study of the frog *Rana temporaria* larval stomach. *Tissue and Cell*, *25*(5), 695–707. [CrossRef]

Sabat, Pablo., & Bozinovic, F. (1996). Dietary chemistry and allometry of intestinal disaccharidases in the toad *Bufo spinulosus. Rev Chil Hist Nat.*, 69, 387–391. http://rchn.biologiachile.cl/pdfs/1996/3/Sabat_%26_Bozinovic_1996.pdf

Santos, L. F. J. D., de Oliveira-Bahia, V. R. L., Nakaghi, L. S. O., De Stefani, M. V., Gonçalves, A. M., & Junior, J. M. P. (2016). Ontogeny of the Digestive Enzymes of Tadpoles of *Lithobates catesbeianus. Copeia*, *104*(4), 838–842. [CrossRef]

Seixas Filho, J. T., Mello, S. C. R. P., Silva, J. M. F., Tomas, J. E., & Melo, C. M. S. (1998). Efeito dos níveis de energia e proteína bruta no desempenho de girinos (*Rana catesbeiana* Shaw, 1802). *Revista Brasileira de Zootecnia*, 27(4), 664-669. http://www.sbz.org.br/revista/artigos/1840.pdf

Seixas Filho, J. T., Oliveira, M. G. A., Donzele, J. L., Gomide, A. T., & Menin, E. (2000). Atividade de lipase em quimo de três espécies tropicais de peixes Teleostei de água doce Lipase activity in the chime of three Teleostei freshwater fish. *Revista Brasileira de Zootecnia*, *29*(1), 6–14. [CrossRef]

Seixas Filho, J. T. D., Oliveira, M. G. A., Moura, G. D. S., Lanna, E. A. T., Garcia, S. L. R., & Lima, J. L. P. (2010). Influence of supplying bullfrog tadpoles with feed containing 28% crude protein on performance and enzymatic activities. *Revista Brasileira de Zootecnia*, *39*(1), 9–17. [CrossRef]

Toloza, E. M., & Diamond, J. M. (1990). Ontogenetic development of nutrient transporters in bullfrog intestine. *American Journal of Physiology-Gastrointestinal and Liver Physiology*, *258*(5), 760–769. [CrossRef]

Thibaudeau, D. G., & Altig, R. (1988). Sequence of ontogenetic development and atrophy of the oral apparatus of six anuran tadpoles. *Journal of Morphology*, *197*(1), 63–69. [CrossRef]

Veiga, A., de Miranda, R. G. B., & do Nascimento Santos, C. A. (1998). Efeito da granulometria da ração sobre o desempenho de girinos de *Rana catesbeiana. R. Bras. Zootec.*, 27(2), 224-230. http://www.sbz.org.br/revista/artigos/1860.pdf

Walter, H. E. (1984). Proteases and their inhibitors. 2. 15. 2 Method with haemoglobin, casein and azocoll as substrate. *Methods of enzymatic analysis*, *30*(5), 270–277.

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Research Article

The Effect of Seasons on Gill Net Selectivity

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ABSTRACT

In this study, the aim was to investigate the seasonal variations in the selectivity of striped red mullet (*Mullus surmuletus* L., 1758) captured by gill nets during the year in the north Aegean Sea. Fisheries' operations were carried out between March 2008 and August 2009. Gill nets with 18, 20, and 22 mm mesh sizes were used in the trials. These nets are widely used in the region. The SELECT method was used to determine the selectivity of gill nets. The deviances from the SELECT method revealed that lognormal models gave the best fits for all seasons. As a result of the calculations made according to the lognormal model, the modal lengths of the gill nets were calculated as the shortest in the spring season and the longest in the summer. The spread values of the selectivity curves of the experimental gill nets were determined the lowest in the winter season and the highest in the summer season. As a result of selectivity analysis, the differences between the spring and summer season modal lengths of the nets were calculated as 1.5 cm, 1.65 cm, and 1.82 cm for the nets with 18 mm, 20 mm, and 22 mm mesh sizes, respectively. The study results showed that the fishing season was important in gill nets selectivity.

Keywords: Seasons, gill net, selectivity, SELECT method, Aegean Sea

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INTRODUCTION

In terms of fishery management, to determine the selectivity of the mesh size of the fishing gear is extremely important knowledge (Millar and Holst, 1997). Fishery management based on mesh selectivity is implemented in gill net fisheries best. It has been reported that the mesh size, body shape, fish size, hanging ratio, the thickness, flexibility, and the visibility of the netting twine, fish behaviour affect the selectivity of gill nets (Clark, 1960; Hamley, 1975). As the most important factor that affects gill net selectivity is the mesh size (Von Brandt, 1975), the studies on this subject are more focused on this factor.

The body shape of the fish varies according to the feeding condition and the breeding season. Before breeding, fish are fed and fat in their habitat. When the breeding season begins after this feeding period, the body consumes the energy for the development of the gonads. Due to this situation, gill net selectivity may show significant changes due to feeding and reproduction in the body of the fish. Qeirrolo and Flores (2016) and Moth-Poulsen (2003) found that seasonal changes are important in selectivity. The effect of fish body shape on selectivity has also been studied in several studies, but seasonal changes have not been studied (Carol and Garcia-Berthou, 2007; Reis and Pawson, 1999).

Reis and Pawson (1999) said that gill nets can be said to be girth-specific fishing gear rather than species-specific fishing gear. Before the fish enter the spawning period, they are highly fed, their condition factor is quite high, and the fish are fat before the spawning. When the breeding season begins, they consume a lot of energy to develop their gonads using this condition. Body circumference may increase further due to the development of gonads according to the fish species.

Due to the increase in the circumference of the fish, the average length of fish caught in a net during the spawning season may be smaller than the average length of fish caught in the same net outside the spawning season. After reproduction, discharges of fish gonads and the decreasing condition factor of fish due to the consumption of energy to develop the gonads in spawning season cause the girth and length of the fish to be reduced. In this case, unlike the breeding season, the net with the same feature may catch the larger mean fish length than one in the breeding season.

The Striped red mullet is a major economic target species of Aegean Sea demersal fisheries (Arslan & İşmen, 2013; Torcu-Koç, Erdoğan, Üstün & Joksimoviç, 2015). Especially in the Aegean sea, this species is captured by fishermen throughout the year. In this study, it is aimed to investigate the changes in seasonal selectivity of striped red mullet (*Mullus surmuletus* L., *1758)*) in the gill nets that are commonly used in the northern Aegean Sea.

MATERIAL AND METHODS

This study was carried out between March 2008 and August 2009 in the commercial fishing areas on the coast of the North Aegean Sea (Figure 1).

In the trials, nine different gill nets with three mesh sizes (18, 20 and 22 mm) and three different hanging ratios (E= 0.4, 0.5 and 0.6) were used. Each of the nets used in the study had a twine thickness of 210 d / 2, a height of 40 meshes and a length of 80 m (E = 0.4), 100 m (E = 0.5), and 120 m (E = 0.6) according to the hanging ratios. Other than the hanging ratios and mesh sizes, all other features and specifications of the gill nets were identical. The nets were riggedin this way since a study on the effects of different hanging ratios on gill net selectivity was also conducted at the same time.

Fifty-nine fishing operations were carried out in total, including nineteen in summer, fifteen in autumn, six in winter, and nineteen in spring. Gill nets were deployed three hours before sunset and were removed from the sea at sunset. Similarly, the nets were set up two hours before sunrise and hauled from the sea an hour after sunrise. After the operation, the weights of fish were taken on scales having 0.01 g sensitivity and the total lengths (TL) of the fish were measured by millimetric measurement board.

Since there are three nets with different hanging ratios for the same mesh size, the data of striped mullets belonging to these nets were combined and used in selectivity analysis. PASGEAR software (version 2.10) was used in selectivity estimations (Kolding and Skålevik, 2011). This program uses the SELECT (Share Each Length's Catch Total) method, which contains five different models (Normal Location, Normal Scace, Log-normal, Gamma and Bi-modal) in the selectivity estimates of the gill nets (Millar, 1992; Millar and Holts, 1997; Millar and Frayer, 1999). The SELECT model is explained by the following equation

$n_{lj} \approx \mathrm{Pois}\,(p_j\, \lambda_l\, r_j(l))$,

where n_{lj} is the number of fish of length *l* caught in mesh size *j*, p_j is the fishing intensity, λ_l reflects the abundance of the length class *l*, $r_j(l)$ denotes the retention probability of length *l* fish in the *j*'th mesh size.

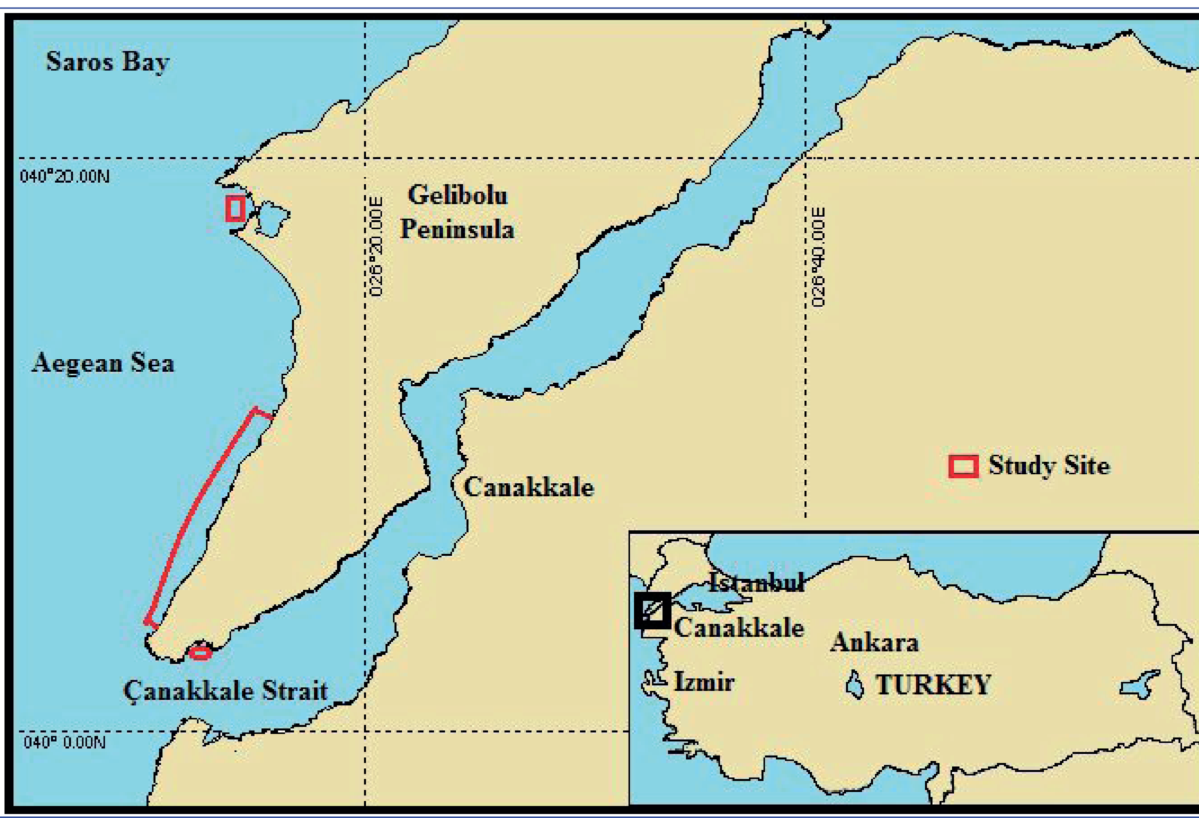

Figure 1. Study area.

The log likelihood of the model is as:

$$\sum_l \sum_j \{n_l \log[p_j \lambda_l r_j(l)] - p_j \lambda_l r_j(l)\}$$

The equations for each of the models are as such:

$$\exp\left(-\frac{(L-k.m_j)^2}{2\sigma^2}\right)$$ for normal location shift in which means is proportional to mesh size,

$$\exp\left(-\frac{(L-k_1.m_j)^2}{2k_2^2.m_j^2}\right)$$ for normal scale shift,

$$\frac{1}{L}\exp\left(\mu+\log\left(\frac{m_j}{m_1}\right)-\frac{\sigma^2}{2}-\frac{\left(\log(L)-\mu-\log\left(\frac{m_j}{m_1}\right)\right)^2}{2\sigma^2}\right)$$ for log-normal,

$$\left(\frac{L}{(\alpha-1).k.m_j}\right)^{\alpha-1}\exp\left(\alpha-1-\frac{L}{k.m_j}\right)$$ for gamma, and

$$\exp\left(-\frac{(L-k_1.m_j)^2}{2k_2^2.m_j^2}\right)+c.\exp\left(-\frac{(L-k_3.m_j)^2}{2k_4^2.m_j^2}\right)$$ for bi-normal scale,

where *L* is the total length in cm, m_1 is the smallest mesh size, m_j is the mesh size *j*, *μ* is the mean size (length) of fish caught, *σ* is the standard deviation of the size of fish, and *k* is a constant. The decision on the most appropriate model fitting the data was evaluated by comparing the deviances of each model and by examining the residual plots.

Size distributions of fish caught in nets for all seasons are compared by using Kolmogorov-Smirnov Test. Before comparison with this test, the data of all the fish caught in the test nets for each season were combined. Comparisons with the Kolmogorov-Simirnov test were performed after this procedure. The nets with the same mesh size were not compared for different seasons.

RESULTS AND DISCUSSION

In the trials, a total of 1359 individual striped red mullet were captured by gill nets, including 263 in summer, 331 in autumn, 279 in winter, and 518 in spring. In the study, the minimum, maximum, and mean length and weight of the fish caught in the nets according to the seasons are given in Table 1. The total length frequency distributions of the catches according to the same mesh size with different seasons are displayed in Figure 2.

In the comparison of the deviances of the models, the lognormal model gave the best fit for all seasons (Table 2). Selectivity curves obtained from the SELECT method with the lognormal model of striped red mullet caught with gill nets of 18, 20, and 22 mm mesh sizes and seasons are presented in Figure 3.

The model lengths and spread values of the nets according to the seasons are given in Table 3.

The determined modal lengths of the different mesh sizes for red mullet were found to be lowest in the spring season and highest in the summer season. The spread value is the lowest in the winter and highest in the summer. For the gill nets with 18, 20, and 22 mm mesh sizes, the selectivity ranges were 14.48 – 19.22 cm, 16.1 – 21.36 cm, and 17.71 – 23.49 cm for the spring season, and 15.55 – 21.15 cm, 17.27 – 23.49 cm, and 19 – 25.84 cm, respectively. As a result of selectivity analysis, the differences between the spring and summer season modal lengths of the nets were calculated as 1.5 cm, 1.65 cm, and 1.82 cm for the nets with 18 mm, 20 mm, and 22 mm mesh sizes, respectively.

Table 1. The minimum, maximum and mean length and weight of the fish caught in the nets according to the seasons.

Meh Size (mm)	N	Minimum Length (cm)	Maximum Length (cm)	Mean Length (cm)	Minimum Weight (g)	Maksimum Weight (g)	Mean Weight (g)	Season
18	187	12,8	25,9	16,3±0,2	24	248	58,7±3	
20	168	13,4	26,6	17,7±0,2	30	246	73,8±3	Spring
22	163	14	31,2	19,07±0,2	16	464	94,5±4	
18	121	12,7	25,6	16,7±0,2	27	232	60,9±3	
20	73	10,4	30,6	18,6±0,3	25	387	86±6	Summer
22	69	14,6	25,2	19,7±0,3	40	238	102,3±5	
18	175	12,1	25,7	15,4±0,2	25	189	49,1±2	
20	89	9,2	27	18,3±0,3	10	272	87,4±5	Autumn
22	67	11	26,5	19,2±0,4	16	236	97,6±6	
18	152	13,8	25,1	16,3±0,1	31	256	52,2±2	
20	71	11,8	21,8	17,2±0,2	18	116	63,1±2	Winter
22	56	15,1	30,1	19,1±0,3	16	395	90,2±6	

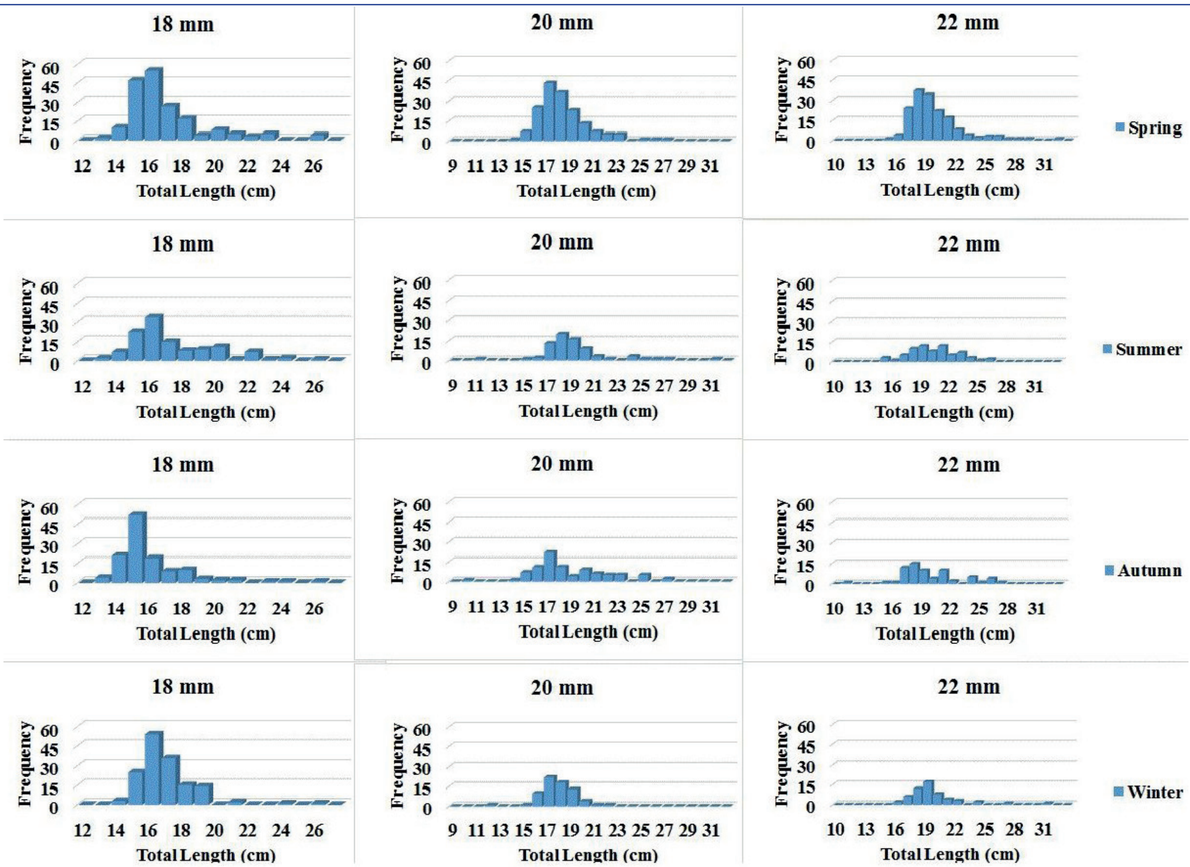

Figure 2. The total length frequency distributions of the catches according to same mesh size with different seasons.

Table 2. Selectivity model parameters according to seasons.

Model	Parameters	Modal Deviance	P-Value	Degrees of Freadom (Df)	Season
Normal location	(k, σ)=(9.395, 2.697)	113.534	0.0000001	39	
Normal scale	(k1, k2)=(9.609, 1.510)	137.153	0.0000001	39	
Lognormal	(μ1, σ)=(2.843, 0.136)	**99.088**	0.0000001	39	Spring
Gamma	(k, α)=(0.191, 50.356)	111.676	0.0000001	39	
Bi-modal	(k1, k2, k3, k4, w)=**No Fit**				
Normal location	(k, σ)=(10.248, 2.697)	78.531	0.000081	37	
Normal scale	(k1, k2)=(10.533, 1.542)	85.788	0.00001	37	
Lognormal	(μ1, σ)=(2.931, 0.147)	**73.201**	0.00036	37	Summer
Gamma	(k, α)=(0.221, 47.588)	76.553	0.00014	37	
Bi-modal	(k1, k2, k3, k4, w)=**No Fit**				
Normal location	(k, σ)=(9.783, 2.738)	92.129	0.000001	36	
Normal scale	(k1, k2)=(10.029, 1.382)	98.850	0.000001	36	
Lognormal	(μ1, σ)=(2.875, 0.138)	**84.142**	0.000010	36	Autumn
Gamma	(k, α)=(0.186, 53.638)	87.718	0.000003	36	
Bi-modal	(k1, k2, k3, k4, w)=**No Fit**				
Normal location	(k, σ)=(9.776, 2.093)	43.773	0.016	26	
Normal scale	(k1, k2)=(9.45, 1.063)	50.864	0.002	26	
Lognormal	(μ1, σ)=(2.88, 0.108)	**37.959**	0.061	26	Winter
Gamma	(k, α)=(0.114, 87.055)	41.481	0.028	26	
Bi-modal	(k1, k2, k3, k4, w)=**No Fit**				

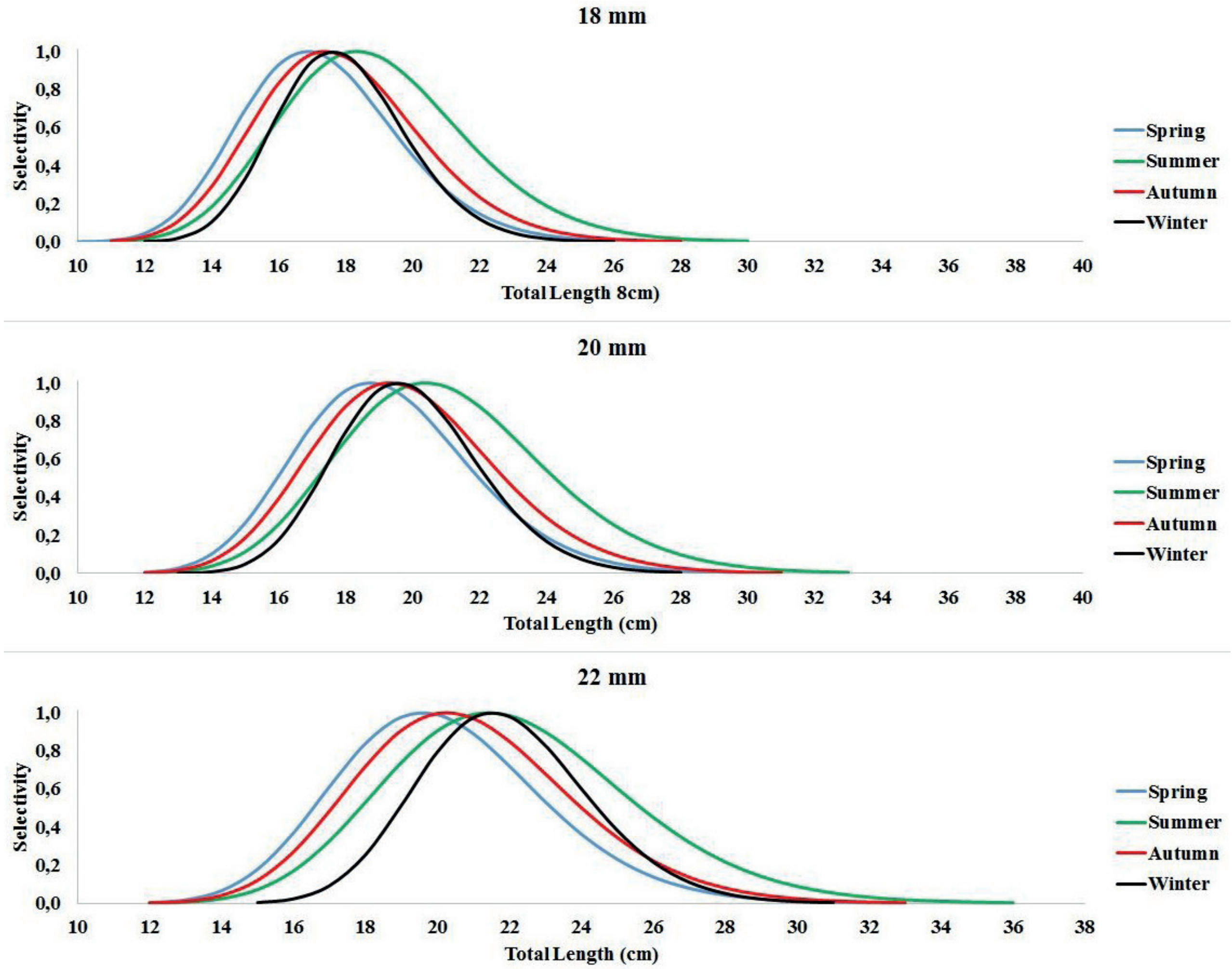

Figure 3. The comparison of the selectivity curve according to the seasons.

Table 3. The model lengths and spread values of the nets accordinto the seasons.

Meh Size (mm)	Modal Length (cm)	Spread Value (cm)	Selectivity Range (cm)	Season
18	16.85	2.37	14.48 – 19.22	
20	18.73	2.63	16.1 – 21.36	Spring
22	20.6	2.89	17.71 – 23.49	
18	18.35	2.8	15.55 – 21.15	
20	20.38	3.11	17.27 – 23.49	Summer
22	22.42	3.42	19 – 25.84	
18	17.39	2.48	14.91 – 19.87	
20	19.32	2.76	16.56 – 22.08	Autumn
22	21.26	3.03	18.23 – 24.29	
18	17.61	1.94	15.67 – 19.55	
20	19.56	2.16	17.4 – 21.72	Winter
22	21.52	2.37	19.15 – 23.89	

A statistically significant difference was found between the size distributions of fish caught in the nets for all seasons (P<0.05).

It was observed that the model sizes calculated from the fish caught in the nets according to the seasons are at the lowest value in the spring season, and the highest value is calculated in the summer season. İlhan et al. (2009) stated that the reproduction of striped red mullet occurred in the spring season in their study in İzmir Bay. Torcu-Koç et al. (2015) found that the breeding season of this fish in Edremit Bay, which is close to the study region, was in April-September and that the breeding peaked in July. Arslan and İşmen (2013) reported that the reproduction took place in April and May in the Saroz Bay. According to previous studies, it has been reported that the breeding season of this fish species occurs mostly in April and May and may be seen in some regions in summer (Torcu-Koç et al., 2015). As a result of the experiments, the modal lengths of the nets calculated according to the seasons are the smallest in the spring season and can be explained by the increase in the body girth of the fish due to reproduction. The fact that most of this fish species completed the breeding season in summer caused the fish to fall in average body girth. This situation caused the modal lengths of the nets to increase compared to other seasons. According to these results, the high spread value indicates that reproduction is at the beginning of summer. At the beginning of the summer season, the presence of fish that have not yet completed their reproduction has increased the length variance of the fish caught in the nets. This may have caused the spread value calculated for the summer season to be high.

The average total lengths of the fish caught in the experimental nets were determined to be the lowest in winter and the highest in summer. In the experiment, it was expected that it would be the lowest in spring because of this gonad growth. In the winter season, only fishing operations were carried out at one station in February due to weather conditions. This situation may have caused the average total length of fish to be low in winter.

Qeirrolo and Flores (2016), Moth-Poulsen (2003) found that seasonal changes are important in selectivity. In some studies, although the difference in seasonal selectivity is not significant, in our study, selectivity differences between seasons were found to be particularly significant in summer (P<0.05). Study results are similar to Qeirrolo and Flores (2016), Moth-Poulsen (2003).

In recent studies, length at first maturity of this fish for female and males were determined 13.7 cm and 13.2 cm respectively in the Saroz Bay (Arslan and İşmen, 2013), 11.9 cm for females and males on the Mediterranean coast of Egypt (Amin, Madkour, Abu El-Regal & Moustafa, 2016), and 16.6 cm for all individuals in Canary Islands (Pajuelo et al., 1997). When the results of the study were examined, it was seen that the selectivity ranges of experimental nets were larger than the length at first maturity. However, when smaller than 18 mm mesh sizes (17, 16 mm and smaller) were used, it was observed that it could give rise to dangerous results for its fish stocks.

CONCLUSION

Study results showed that seasonal changes are important in selectivity. But further studies are needed. If other studies have similar results, seasonal changes should be taken into account in management arrangements related to gill net selectivity.

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

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REFERENCES

Amin, A. M., Madkour, F. F., Abu El-Regal, M. A. & Moustafa, A.A. (2016). Reproductive biology of *Mullus surmuletus* (Linnaeus,1758) from the Egyptian Mediterranean Sea (Port Said). *International Journal of Environmental Science and Engineering*, 7, 1–10.

Arslan, M. & İşmen, A. (2013). Age, growth and reproduction of *Mullus surmuletus* (Linnaeus, 1758) in Saros Bay (Northern Aegean Sea). *Journal of Black Sea/Mediterranean Environment*, *19*(2): 217–233.

Clarke, J. R. (1960). Report on selectivity of fishing gear. *International Commission for the Northwest Atlantic Fisheries Special Publication*, *2*, 27–36.

Carol, J. & Garcia-Berthou, E. (2007). Gillnet selectivity and its relationship with body shape for eight freshwater fish species. *Journal of Applied Ichthyology*, *23*, 654–660. [CrossRef]

Hamley, J. M. (1975). Review of gillnet selectivity. *Journal of the Fisheries Research Board of Canada*, *32*, 1943–1969. [CrossRef]

İlhan, D. U., Akalın, S., Özaydın, O., Tosunoğlu, Z. & Gurbet, R. (2009). Growth and reproduction of striped red mullet (*Mullus surmuletus* L., 1758) in Izmir Bay (In Turkish). *Ege Journal of Fisheries and Aquatic Sciences*, *1*, 01–05.

Kolding, J. & Skålevik, Å. (2011) PasGear 2. A database package for experimental or artisanal fishery data. Version 2.5. available at http://www.imr.no/forskning/utviklingssamarbeid/eaf_nansen_programmet/pasgear_2/en

Millar, R. B. (1992). Estimating the Size-Selectivity of Fishing Gear by Conditioning on the Total Catch. *Journal of the American Statistical Association*, *87*, 962–968. [CrossRef]

Millar, R. B. & Holst, R. (1997). Estimation of gillnet and hook selectivity using log-linear models. *ICES Journal of Marine Science*, *54*, 471–477. [CrossRef]

Millar, R. B. & Fryer, R. J. (1999). Estimating the size-selection curves of towed gears, traps, nets and hooks. *Reviews in Fish Biology and Fisheries*, *9*, 89–116. [CrossRef]

Moth-Poulsen, T. (2003). Seasonal variations in selectivity of plaice trammel nets. *Fisheries Research*, *61*, 87–94. [CrossRef]

Qeirrolo, D. & Flores, A. (2016). Seasonal variability of gillnet selectivity in Chilean hake *Merluccius gayi gayi* (Guichenot, 1848). [CrossRef]

Pajuelo J. G. Lorenzo, J. M. Ramos A. G. & Méndez-Villamil, M. (1997). Biology of the red mullet *Mullus surmuletus* (Mullidae) off the Canary Islands, Central-East Atlantic. *South African Journal of Marine Science*, *18*(1), 265–272. [CrossRef]

Reis, E. G. & Pawson, M. G. (1999). Fish morphology and estimating selectivity by gillnets. *Fisheries Research*, *39*, 263–273. [CrossRef]

Torcu-Koç, H. Erdoğan, Z. Üstün, F. & Joksimovic, A. (2015). Some biological parameters of the striped red mullet (*Mullus surmuletus* L.) from the Bay of Edremit (Northern Aegean Sea, Turkey). *Acta Adriatica*, *56*(2), 223–232.

Von Brandt, A. (1975). Enmeshing nets: gillnets and entangling nets - the theory of their efficiency. *European Inland Fisheries Advisory Commission Technical Paper*, *23*(Supplement 1), 1, 96–116.

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Research Article

Benthic Diatom Composition of Iztuzu Coastal Lake, Dalyan (Aegean Sea, Turkey)

Aydın Kaleli[1]

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ABSTRACT

Coastal lakes are shallow lakes that have variable characteristics through fluctuations and marine winds. In this study, benthic diatom composition in the coastal lake of Iztuzu, Dalyan of Muğla was investigated from the material collected in 2011 and 2015. Little research has been done on coastal lakes and lagoon diatom flora in Turkey; this study contributes a total of 49 taxa identified to species level and 9 of the taxa for the first time recorded for diatom flora of Turkey. The most abundant taxa were; *Cocconeis placentula* Ehrenberg, *Diploneis bombus* (Ehrenberg) Ehrenberg, *Mastogloia* sp. and *Chamaepinnularia alexandrowiczii* Witkowski, Lange-Bertalot and Metzeltin. The results reveal a habitat-specific flora for Iztuzu Lake and give an aspect of understanding the marine-brackish distribution of diatoms in coastal lakes and lagoons. The results extend the knowledge of marine and brackish diatoms in Turkey and could provide data for similar lagoon and lakes which are under protection.

Keywords: Benthic, diatoms, coastal lake, Iztuzu, Dalyan, Turkey

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INTRODUCTION

Diatoms are unicellular silicious photosynthetic algae and distributed to a wide range of areas where water exists; from marine coasts to high mountain lakes and springs, cave entrances to thermal springs and even as epibionts on marine mammals (Denys, 1997; Aysel, 2005). Diatoms are also good indicators of ecological changes in lakes and streams, which are used to monitor the status of the location with a supplement of physiochemical parameters (Şanal & Demir, 2018).

Coastal lakes have very dynamic hydrology and are affected by variable environmental conditions. Marine winds, sea spray or sea flooding cause mixing events which result in high productivity in these lakes (Hansson & Håkansson, 1992). Salinity can change more in some lakes where there are stream openings and freshwater inputs (Gasparon & Burgess, 2000). The surrounding environment could influence coastal lakes and lagoons. Salinity and water temperature differences in the lagoon and lakes of the Black Sea and the Mediterranean Sea affects flora and fauna as well (Yerli, 1999). Coastal lakes and lagoons are important habitats due to the rapid changes in salinity and productivity, in response to an ideal location to observe ecological changes; however, the mentioned reasons make these areas sensitive to pollution. There were several studies in the lakes and lagoons, e.g., taxonomic studies including the discovery of new diatoms (Giffen, 1967; Riaux-Gobin & Compère, 2009) and diatoms used as environmental indicators (Desianti et al., 2017).

Several studies were carried out on the benthic and planktonic flora of diatoms in coastal lakes and lagoons in Turkey. Sıvacı, Yardım, Gönülol, Bat & Gümüş (2008) studied the benthic algae composition of Sarıkum Lagoon; epipelic algae was studied at Balık and Uzun Lagoon (Gönülol, Ersanlı & Baytut, 2009), while Soylu, Maraşlıoğlu & Gönülol (2011) focused on the epiphytic diatoms of Liman Lake in the Black Sea coasts. In the Sea of Marmara region, Polge, Sukatar, Soylu & Gönülol (2010) studied epipelic algae diversity of Küçükçekmece Lagoon. The Aegean Sea and the Mediterranean Sea coastal lake and lagoon planktonic and benthic diatom community was a subject of several studies (Egemen et al., 1999; Çevik, Polat & Dural, 2008; Aslan et al., 2018).

This study aims to reveal the diatom biodiversity of Iztuzu Coastal Lake in Dalyan; contribute to the knowledge of diatom flora of Turkey. The study documents diatoms and its distribution in a protected and undisturbed area and aims to provide data for further studies, particularly in the coastal lakes and lagoons of Turkish coasts.

MATERIALS AND METHODS

Iztuzu Lake (Tuz Lake) located in the southwest of Muğla Province at southeast Aegean Sea coasts of Turkey. The hills surround the lake on the east, and the lake is 100 meters inside of the shore of Iztuzu beach. The depth of the lake reaches approximately a meter and has a sand bottom structure (Figure 1). Iztuzu beach is one of the most important nesting locations for loggerhead sea turtles with high numbers of nests and hatchlings in the Mediterranean Sea (Margaritoulis et al., 2003). Beach is under the protection, and conservation studies are carried out by Dekamer (Sea Turtle Research, Rescue and Rehabilitation Center) (Başkale & Kaska, 2005; Kaska, Başkale, Katılmış, Sözbilen & Azmaz, 2016). Sampling was performed in 2011 and 2015, in 2011 samples were taken from the sand at the bottom of the lake at station 1, and the rocks and stones were scrapped in 2011 and 2015 from all stations. Environmental parameters were measured by Hach HQ40d in 2015; Salinity was 23.4 psu, conductivity was 40.8 mS/cm, and the water temperature was 30.2 °C.

The Samples were treated with 10% HCl, boiled with 35% H_2O_2 to remove the organic material and washed with distilled water several times (Swift, 1967). Permanent slides were prepared with air-dried cleaned valves and mounted with Naphrax®. Light microscopy observations were performed with Nikon Eclipse C*i*-E microscope. At least 200 valves were counted in each material.

Terminology and the taxonomical classification followed Round et al. (1990), DiatomBase (Kociolek et al., 2019) and AlgaeBase (Guiry & Guiry, 2019). Diatom identification was performed according to the following research; Peragallo & Peragallo (1897-1903), Hendey (1964), Giffen (1967, 1976), Simonsen (1987), Snoeijs (1993), Snoeijs & Balashova (1998), Witkowski, Lange-Bertalot & Metzeltin (2000), Louvrou (2007), Wachnicka & Gaiser (2007), Hofmann, Werum & Lange-Bertalot (2011), Loir & Novarino

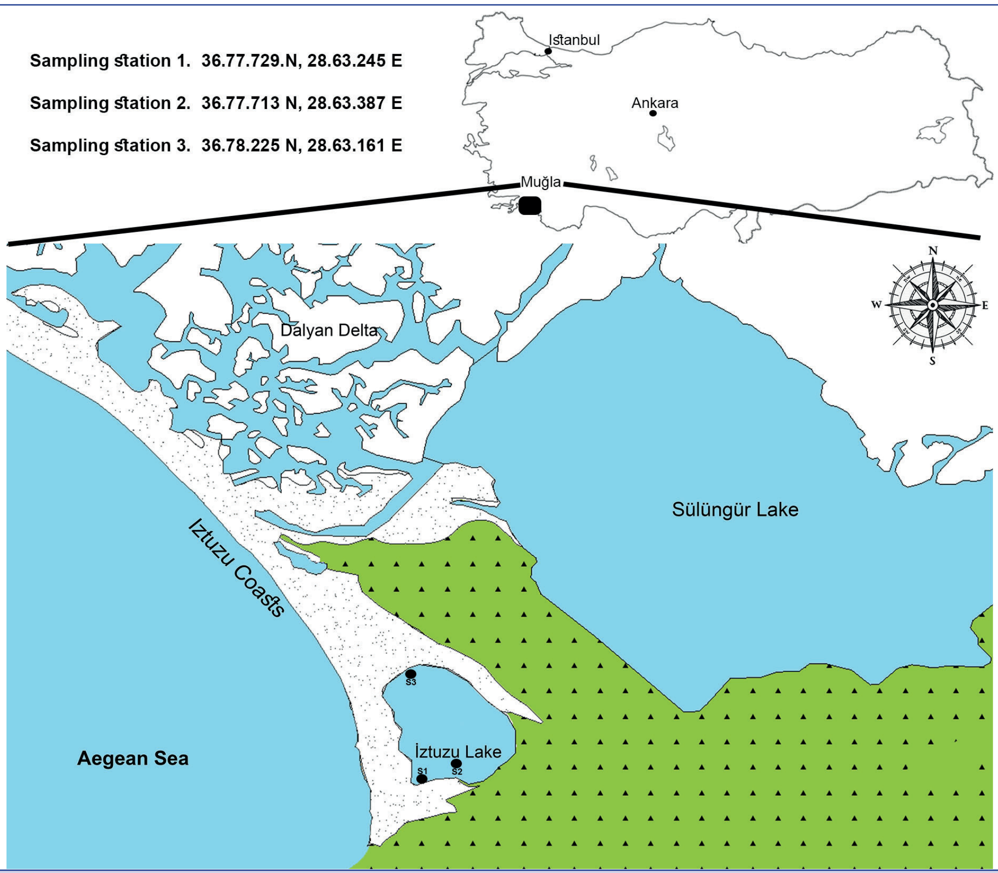

Figure 1. Sampling area of Iztuzu Lake, Dalyan, Muğla.

Table 1. Distribution of the benthic diatom composition of Iztuzu lake in 2011 and 2015. Habitat information; M: marine, B: brackish, F: freshwater (Guiry & Guiry, 2019; Kociolek et al., 2019). *asterisk indicates the taxa first time observed in Turkey.

Taxa	2011		2015	Habitat
	Epl	Epps	Epl	(M/B/F)
Amphora cymbamphora Cholnoky	+	+	+	M-B
Amphora hamata Heiden*	+			M
Amphora proteus Gregory			+	M
Amphora* cf. *pseudoproteus Wachnicka & Gaiser			+	M
Anomoeoneis sphaerophora Pfitzer			+	M/F
***Ardissonea* sp.**		+	+	-
Brachysira aponina Kützing*			+	B-F
Brachysira estonarium Witkowski, Lange-Bertalot & Metzeltin			+	M-B
***Campylodiscus* sp.**			+	-
Chammaepinnularia alexandrowiczii Witkowski, Lange-Bertalot & Metzeltin*	+	+	+	M
Cocconeis placentula Ehrenberg	+	+	+	M, F
Cocconeis scutellum Ehrenberg			+	M, B, F
Delphineis australis Watanabe, Tanaka, Reid, Kumada & Nagudo			+	M
Diploneis bombus (Ehrenberg) Ehrenberg		+	+	M-B
***Entomoneis* sp.**			+	-
***Epithemia* sp.**			+	-
Fallacia schaeferae (Hustedt) Mann	+			M
Grammatophora angulosa Ehrenberg			+	M
Gyrosigma eximium (Thwaites) Boyer		+		M
Halamphora acutiuscula (Kützing) Levkov	+	+	+	B-M
Halamphora subholsatica (Krammer) Levkov			+	B-M
Halamphora tenerrima (Aleem & Hustedt) Levkov			+	M-B
***Lyrella* sp.**			+	-
Mastogloia acutiuscula Grunow*			+	M
Mastogloia angulata Lewis		+		M
Mastogloia belaensis Voigt*		+		M
Mastogloia braunii Grunow		+		M, B
Mastogloia crucicula (Grunow) Cleve			+	M
Mastogloia crucicula* var. *alternans Zanon*			+	M
Mastogloia lanceolata Thwaites ex Smith		+	+	B
***Mastogloia* spp.**	+	+	+	-
Navicula cryptotenella Lange-Bertalot	+	+	+	F
Navicula* cf. *lagunae Seddon & Witkowski	+	+		M
Navicula* cf. *perminuta Grunow			+	M, B
Navicula ramoissisima (Agardh) Cleve			+	M
Navicula reichardtiana Lange-Bertalot	+			F
Navicula subagnita Proshkina-Lavrenko			+	M
Navicymbula pusilla (Grunow) Krammer		+	+	F
Navicymbula pusilla* var. *lata Krammer	+	+		B
Nitzschia elegantula Grunow	+	+	+	F
Nitzschia fontifuga Cholnoky			+	M
***Nitzschia* sp.**			+	-
Nitzschia improvisa Simonsen*			+	M
Nitzschia inconspicua Grunow			+	F
Nitzschia* cf. *pellucida Grunow		+		M
Nitzschia valdestriata Aleem & Hustedt			+	M, B, F
Pleurosigma elongatum Smith			+	M, B
Pleurosigma strigosum Smith			+	M, B
Pseudostaurosira elliptica (Schumann) Edlund, Morales & Spaulding		+		F
Rhoicosphenia* cf. *marina (Kützing) Schmidt			+	M
Rhopalodia acuminata Krammer*		+	+	B
Seminavis strigosa (Hustedt) Danielidis & Economou-Amilli			+	M
Tabularia fasciculata (Agardh) Williams & Round			+	M-F
Tabularia parva (Agardh) Williams & Round			+	M
Tabularia tabulata (Agardh) Snoeijs			+	M-F
Tryblionella apiculata Gregory			+	M, B
Tryblionella granulata (Grunow) Mann			+	M
Tryblionella pararostrata (Lange-Bertalot) Clavero & Hernández-Mariné*		+	+	B

(2014). Diatom distribution in Turkey was compared with Maraşlıoğlu & Gönülol (2019). Slides and processed materials are deposited at the Department of Freshwater Resource and Management, Aquatic Sciences Faculty, Istanbul University.

RESULTS AND DISCUSSION

Benthic diatom biodiversity and the changes in the flora throughout the years were investigated in Iztuzu coastal Lake of Dalyan. Forty-six diatom taxa identified to species level. Amongst the genera, *Mastogloia* was represented with the highest numbers of taxa (8), followed by *Nitzschia* (7), *Navicula* (6) and *Amphora* (4). Although being the most abundant taxa in the composition *Cocconeis* was represented by two species. In total the most abundant species were *Cocconeis placentula* (22.38 %), *Mastogloia* sp.1 (15.31 %) *Diploneis bombus* (14.58 %) and *Chamaepinnularia alexandrowiczii* (13.86 %) respectively. These former dominant taxa composed 66.13 % of the diatom composition in the lake. The most abundant species in the epipsammon were *C. placentula*, *C. alexandrowiczii*, *Nitzschia elegantula* and *D. bombus*. Furthermore, in epilithic samples, *D. bombus*, *C. placentula* and *Nitzschia* sp. occurred abundantly (Table 1).

Between the sampling years, there was a significant difference occurred in the observed taxa numbers. In 2011, a total of 25 taxa were observed while 48 taxa were found in 2015. Some of the species occurred in both of the samples. These taxa were *Cocconeis placentula*, *Chamaepinnularia alexandrowiczii* and *Diploneis bombus*, and *Navicymbula pusilla*, *Navicula* sp., *Nitzschia elegantula* as well. However, some of the taxa decreased in numbers in

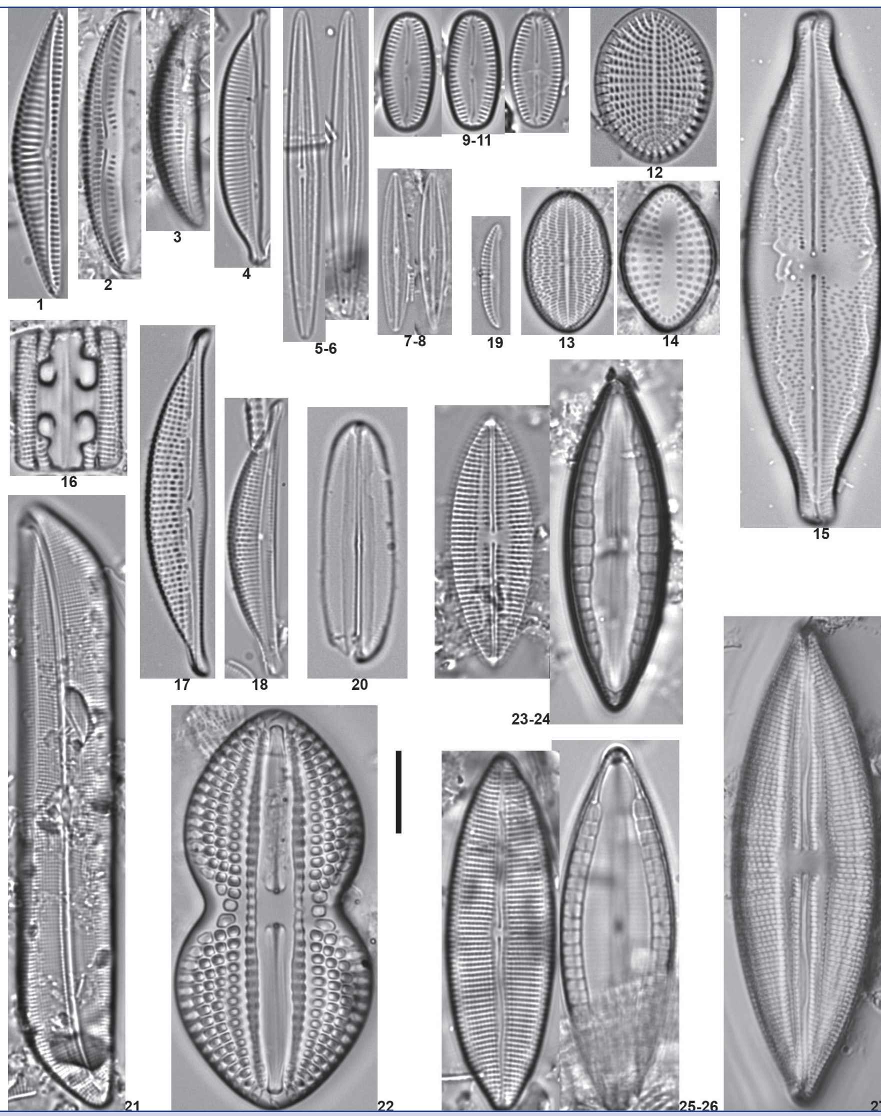

Figure 2. 1. *Amphora cymbamphora*, 2. *A. proteus*, 3. *A.* cf. *pseudoproteus*, 4. *A. hamata*, 5, 6. *Brachysira aponina*, 7, 8. *B. estonarium*, 9-11. *Chamaepinnularia alexandrowiczii*, 12. *Cocconeis scutellum*, 13. *C. placentula*, 14. *Delphineis australis*, 15. *Anomoeoneis sphaerophora*, 16. *Grammatophora angulosa*, 17. *Halamphora subholsatica*, 18. *H. acutiuscula*, 19. *H. tenerrima*, 20. *Fallacia schaeferae*, 21. *Gyrosigma eximium*, 22. *Diploneis bombus*, 23, 24. *Mastogloia braunii*, 25, 26. *M. acutiuscula*, 27. *M. belaensis*. Scale bar: 10 µm.

2015 samples; e.g., *C. placentula*, *C. alexandrowiczii*, *Mastogloia* sp.1, *N. pusilla*, *N. elegantula*. Eleven taxa which were recorded in the 2011 samples did not occur in the 2015 samples, e.g., *Amphora hamata*, *Fallacia schaeferae*, *Gyrosigma eximium*, *Mastogloia angulata*, *M. belaensis*, *M. braunii*, *Navicula* cf. *lagunae*, *N. reichardtiana*, *Navicymbula pusilla* var. *lata*, *Nitzschia* cf. *pellucida*, and *Pseudostaurosira elliptica* (Figure 2-4).

The results revealed that nine taxa contributed to the knowledge of benthic diatoms in Turkey and were recorded for the first time. These were; *Amphora hamata*, *Brachysira aponina*, *Chamaepinnularia alexandrowiczii*, *Mastogloia belaensis*, *M. acutiuscula*, *M. crucicula* var. *alternans*, *Nitzschia improvisa*, *Rhopalodia acuminata*, and *Tryblionella pararostrata*.

Coastal lakes, lagoons and transitional waters are very diverse habitats and are composed of challenging environmental conditions. Diatoms are good examples of adaptation to the variable conditions, and it is possible to observe high biodiversity; marine, brackish and freshwater diatoms could occur altogether. Here in this study, 49 taxa were observed in Iztuzu Lake, and 9 of them were recorded for the first time in Turkey. Since Iztuzu Lake is separated from the sea via dunes and inputs of seawater by tides and wave sprays which occur during winter and early spring,

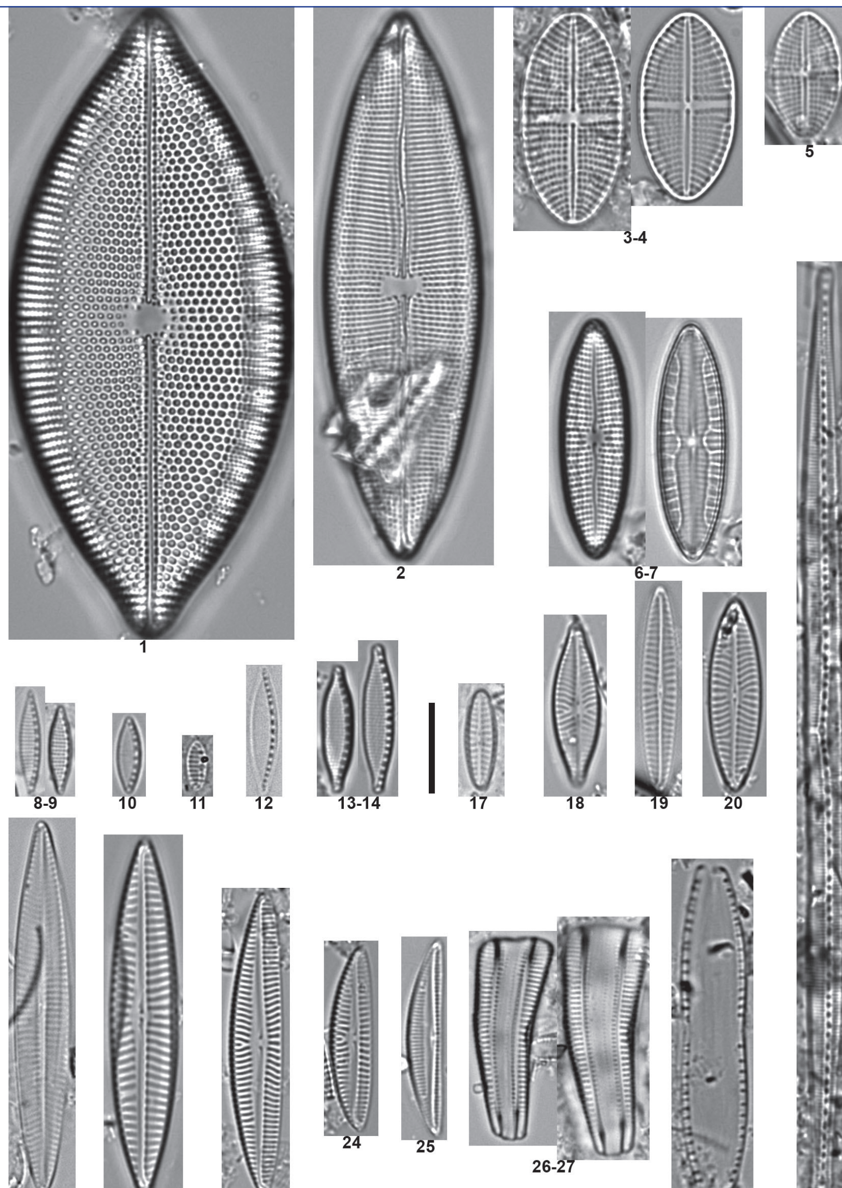

Figure 3. 1. *Mastogloia angulata*, 2. *M. lanceolata*, 3, 4. *M. crucicula*, 5. *M. crucicula* var. *alternans*, 6, 7. *M.* sp1., 8, 9. *Nitzschia* sp., 10. *N. inconspicua*, 11. *N. valdestriata*, 12. *N. fontifuga*, 13, 14. *N. elegantula*, 15. *N.* cf. *pellucida*, 16. *N. improvisa*, 17. *Navicula* cf. *perminuta*, 18. *N. reichardtiana*, 19. *N. ramoissisima*, 20. *N. cryptotenella*, 21. *N. subagnita*, 22. *N.* cf. *lagunae*, 23. *Navicymbula pusilla*, 24. *N. pusilla* var. *lata*, 25. *Seminavis strigosa*, 26-27. *Rhoicosphenia* cf. *marina*. Scale bar: 10 μm.

both freshwater and brackish species were observed as well as marine taxa. However, the marine and the brackish taxa were dominant in benthic diatom composition. The results were compared with the coastal diatom samples, and Sülüngür Lake (*unpublished data*) and similar freshwater and brackish-freshwater taxa were typical in Sülüngür Lake (e.g., *B. aponina*, *C. placentula*, *N. elegantula*, *R. acuminata*), and some taxa (*D. bombus*, *Grammatophora angulosa*, *N. pusilla* var. *lata*) were also observed in coastal samples (Kaleli et al., *pers. obs.*). It is remarkable that species recorded for the first time from the coastal samples (*Amphora cymbamphora*, *Brachysira estoniarum*, *F. schaeferae*, *Mastogloia crucicula*) were also observed in Iztuzu Lake, which is a possible transfer of taxa from the marine waters to the brackish lake.

In Turkey, some lagoons and coastal lakes were investigated in terms of the composition of Bacillariophyta (Sıvacı et al., 2008; Soylu et al., 2011; Çolak-Sabancı, 2012; Aslan et al., 2018). Re-

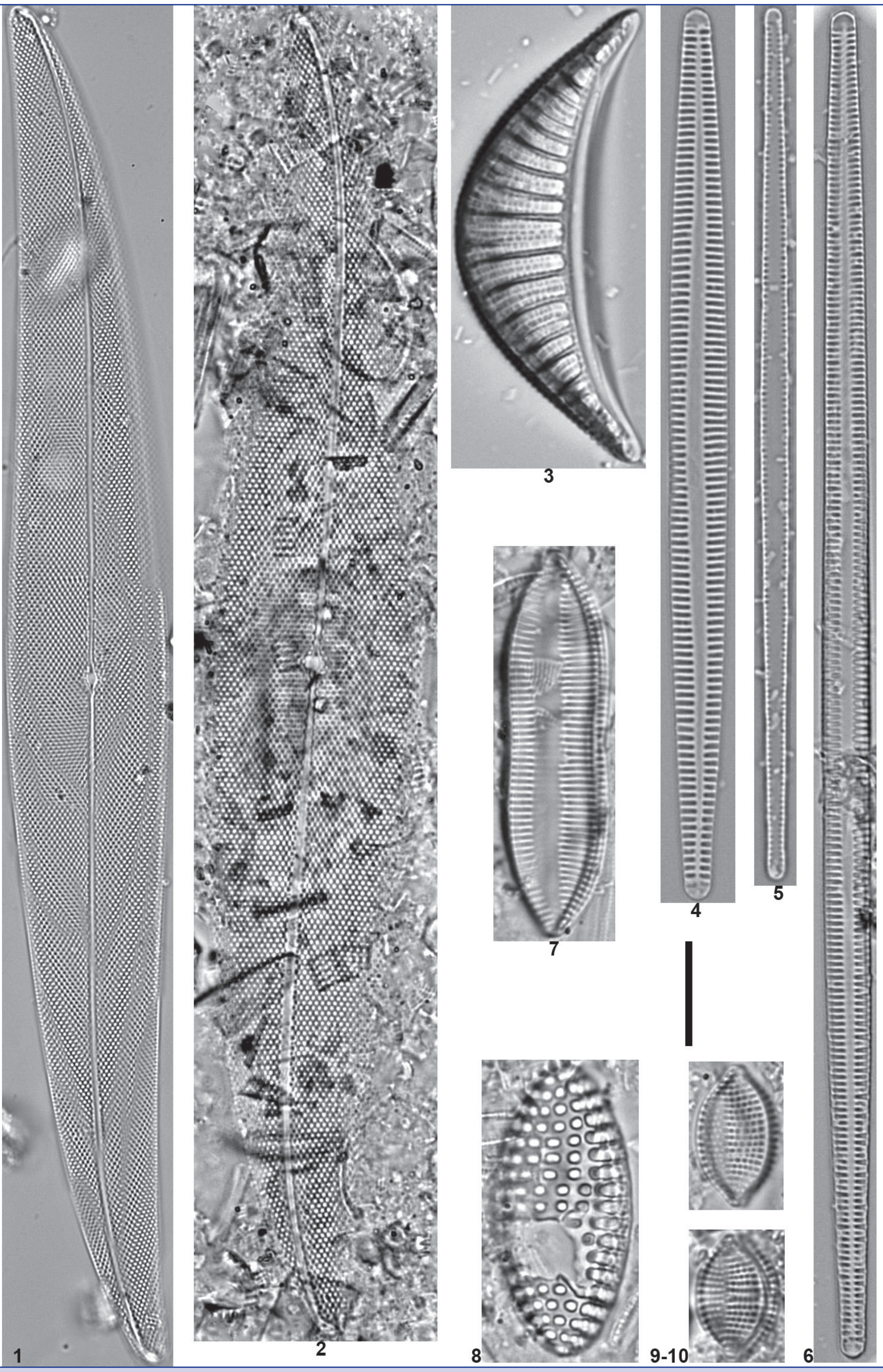

Figure 4. 1. *Pleurosigma elongatum*, 2. *P. strigosum*, 3. *Rhopalodia acuminata*, 4.*Tabularia fasciculata*, 5. *T. parva*, 6. *T. tabulata*, 7. *Tryblionella apiculata*, 8. *T. granulata*, 9-10. *T. pararostrata*. Scale bar: 10 μm.

search determined that diatom diversity of other lakes have less common taxa compared to each other, possibly similar to adjacent coastal or river habitats. Sıvacı et al. (2008) found 64 taxa and Soylu et al. (2011) recorded 30 taxa in the Black Sea coastal lakes. Authors observed predominantly freshwater taxa, including species of *Cymbella*, *Gomphonema*; however, high biodiversity of diatoms was recorded in the lagoons in different regions (Giffen, 1976; Park, Lobban & Lee, 2018). The diatom composition of Akyatan and Tuzla Lagoons (Çevik et al., 2008) resembles the results found in this study with 42 marine and brackish taxa observed. Çolak-Sabancı (2012) reported 67 diatom taxa (*Cocconeis*, *Mastogloia*, *Nitzschia*) with common brackish and marine species from Homa Lagoon, located in the Aegean coasts of Turkey. Furthermore, research conducted by Aslan et al. (2018) revealed that 34 benthic diatom taxa composed of freshwater-brackish species were found in a coastal salt lake in Gökçeada, Aegean Sea.

Diatom composition in coastal lakes may be affected by sprays of seawater. However, the previous research showed that freshwater input could be more important to shape diatom assemblages in coastal lakes (Soylu et al., 2011). As a result of the fluctuations, brackish taxa could adapt to these conditions. Geographical differences are also crucial for the distribution of species in coastal lakes. Liman and Sarıkum Lakes, located in Black Sea region, have been influenced mainly by rivers (e.g., Kızılırmak River), and floodwater, only a few marine taxa were observed in these lakes (Sıvacı et al., 2008; Soylu et al., 2011). Nevertheless, low salinity of the Black Sea is suitable for marine and marine-brackish species to establish a community (Baytut & Gönülol, 2016; Kaleli, Kulikovskiy & Solak, 2017). Diatom flora of the two Black Sea lagoons revealed that both lakes were influenced mostly by the freshwater inputs. On the other hand, in the coastal lakes and lagoons of the Aegean Sea and the Mediterranean Sea, more various diatom composition was recorded. Seventeen taxa were marine, and the remaining were brackish and freshwater species found in Akyatan and Tuzla Lagoons in the Mediterranean Sea (Çevik et al., 2008). In Homa Lagoon, 44 of the total 67 taxa were marine species (Çolak-Sabancı, 2012). These results are nearly the opposite of the marine species observed in the Black Sea lagoon, where only five taxa were marine in Sarıkum Lagoon (Sıvacı et al., 2008). Biodiversity of the diatoms and marine taxa abundance could be conducted with the effects (sea spray) of the saline waters of the Aegean and the Mediterranean Sea, as well as that; both lagoons were under pressure by agriculture which may have lead to high diversity in terms of organic matter release. Unlike, Akyatan, Tuzla and Homa Lagoons, Iztuzu Lake is covered by the hills and due to the area being protected, there are no settlements and agriculture in the surroundings. It could be a reason for the diatom composition, and the diversity of the taxa remained balanced and not influenced by anthropogenic effects over the years.

Diatom identification is somewhat difficult due to the close taxonomic characters amongst similar taxa or can be overlooked because of the small cell size. Scanning Electron microscopy (SEM) could distinguish the taxa where light microscopy (LM) can be insufficient. It was found out that some small celled taxa can be indiscernible in LM like the genus *Olifantiella* in the Black Sea coasts of Sinop. However, SEM images revealed that two taxa existed in the material; *O. pseudobiremis*, and *O.* cf. *mascarenica* (Kaleli et al., 2018). In the taxonomical perspective, several taxa found in this study needs further observation. Some species were rarely found in the material, and there would be more valves needed to see the morphological variation. For instance; *Amphora* cf. *proteus*, *Navicula* cf. *perminuta* and *Rhoicosphenia* cf. *marina* specimens were represented with few valves therefore identified as "cf." due to lack of distinguishing features of each taxon. *Navicula* cf. *lagunae* conforms well with descriptions by Seddon, Froyd & Witkowski (2011); with the presence of the Voigt discontinuity and asymmetrical central area. Similar taxa *Navicula flagellifera* Hustedt has 12-18 striae in 10 µm (Witkowski et al., 2000) comparing to *N. lagunae,* which has 10-11 striae (Seddon et al., 2011). The valves observed in Iztuzu Lake have 11 striae. Specimens found here presumably belong to *N. lagunae*. However, better LM or possible SEM images would contribute accurately to the identification of the taxa. One of the abundant taxa *Mastogloia* sp.1 have similar valve outline to *Mastogloia elliptica* (Agardh) Cleve. Nevertheless, specimens observed here lacks elliptical central area and have strongly undulated raphe in most valves. *Rhopalodia acuminata* specimens external valve endings were found distinctly produced. The taxa found here possibly a variety of *R. acuminata* due to the type species, have slightly produced endings (Witkowski et al., 2000; Pl. 214: 24). One of the other rarely found and recorded species is *Nitzschia improvisa*. Taxa resemble *Nitzschia prolongata* Hustedt (Kaleli et al., 2017); both taxa have a similar valve outline and characteristic and could be conspecific (Witkowski et al., 2000). In the material, *N. improvisa* has narrower valves than *N. prolongata* found in the Black Sea coasts; more valves could give comparable data to distinguish two taxa precisely.

CONCLUSION

The Marine diatom database in Turkey almost only consists of planktonic forms; studies on benthic flora are rather scarce. This study brings results of the benthic diatom diversity in a coastal lake in Dalyan, and since there are few studies on marine coasts and coastal lakes, documentation of the taxa is essential to contribute to the knowledge of diatom flora of Turkey. The results of this study documented nine species recorded for the first time in Turkish diatom flora. One of the challenges of studying benthic diatoms of coastal areas, estuaries or lagoons is high biodiversity which can be mostly composed of marine and brackish tolerant species as well as some freshwater taxa. Therefore, coastal lakes and lagoons are essential habitats to determine the tolerance of diatom taxa. The results can be useful to compare the diatom species in different locations of Turkey in coastal and estuary habitats and can give ideas on the ecology of lakes and coasts in terms of the distribution of marine, marine-brackish, brackish and brackish-freshwater taxa for monitoring programmes based on benthic diatoms.

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REFERENCES

Aslan, H., Gönülal, O., Can-Yılmaz, E., Elipek, B., Baytut, Ö., Tosunoğlu, M., Karabacak, E. & Kurt, Y. (2018). Species diversity in lentic, lotic, marine and terrestrial biotopes of Gökçeada salt lake. *Fresenius Environmental Bulletin*, *27*, 2853–2866.

Aysel, V. (2005). Check-list of the freshwater algae of Turkey, *Journal of the Black Sea/Mediterranean Environ*ment, *11*, 1–124.

Başkale, E. & Kaska, Y. (2005). Sea turtle nest conservation techniques on Southwestern beaches in Turkey. *Israel Journal Zoology*, *51*, 13–26. [CrossRef]

Baytut, Ö. & Gönülol, A. (2016). Phytoplankton distribution and variation along a freshwater-marine transition zone (Kızılırmak River) in the Black Sea. *Oceanological and Hydrobiological Studies*, *45*(4), 453–465. [CrossRef]

Çevik, F., Polat, S. & Dural, M. (2008). Seasonal variations of phytoplankton in the Akyatan and Tuzla Lagoons (Adana, Turkey). *Journal of Fisheries Sciences*, *2*, 19–29. [CrossRef]

Çolak-Sabancı, F. (2012). Taxonomic survey of benthic diatoms on natural substrata from coastal lagoon (Aegean Sea, Turkey). *Turkish Journal of Fisheries and Aquatic Sciences*, *12*, 841–849.

Denys, L. (1997). Morphology and taxonomy of epizoic diatoms (*Epiphalaina* and *Tursiocola*) on a sperm whale (*Physeter macrocephalus*) stranded on the coast of Belgium. *Diatom Research*, *12*, 1–18. [CrossRef]

Desianti, N., Belton, T. J., Thomas, R., Enache, M., Potapova, M. G., Velinsky, D. J. & Mead, J. (2017). Sediment diatoms as environmental indicators in New Jersey Coastal Lagoons. *Journal of Coastal Research*, *78*, 127–140. [CrossRef]

Egemen, Ö., Önen, M., Büyükışık, B., Hoşsucu, B., Sunlu, U., Gökpınar, Ş. & Cirik, S. (1999). Ecosystem of Güllük Lagoon (Aegean Sea, Turkey). *Turkish Journal of Agriculture and Forestry*, *23*, 927-947.

Gasparon, M. & Burgess, J. S. (2000). Human impacts in Antarctica: trace-element geochemistry of freshwater lakes in the Larsemann Hills, East Antarctica. *Environmental Geology*, *39*, 963–976. [CrossRef]

Giffen, M. H. (1967). III. Diatoms of the Marine Littoral Region at Kidd's Beach Near East London, Cape Province, South Africa. *Nova Hedwigia*, *13*, 245–292.

Giffen, M. H. (1976). A further account of the marine littoral diatoms of the Saldanha Bay Lagoon, Cape Province, South Africa. *Botanica Marina*, *19*, 379–394. [CrossRef]

Gönülol, A., Ersanlı, E. & Baytut, Ö. (2009). Taxonomical and numerical comparison of epipelic algae from Balik and Uzun Lagoon, Turkey. *Journal of Environmental Biololgy*, *30*, 777–784.

Guiry, M. D. & Guiry, G. M. (2019). *AlgaeBase. World-wide electronic publication, National University of Ireland, Galway*. http://www.algaebase.org (Accessed 8 April 2019).

Hansson, L.-A. & Håkansson, H. (1992). Diatom community response along a productivity gradient of shallow Antarctic lakes. *Polar Biology*, *12*, 463–468.

Hendey, N. I. (1964). *An Introductory Account of the Smaller Algae of British Coastal Waters. Part V: Bacillariophyceae (Diatoms). Fishery Investigations, Series IV.* Her Majesty's Stationery Office, London, 317 pp.

Hoffman, G., Werum, M. & Lange–Bertalot, H. (2011). *Diatomeen im Süsswasser–Benthos von Mitteleuropa*. A.R.G. Gantner, Ruggell, Liechtenstein.

Kaleli, M. A., Kulikovskiy, M. S. & Solak, C. N. (2017). Some new records for marine diatom flora of Turkey from Akliman, Sinop (Black Sea). *Turkish Journal of Fisheries and Aquatic Sciences*, *17*, 1387–1395. [CrossRef]

Kaleli, A., Krzywda, M., Witkowski, A., Riaux-Gobin, C., Solak, C. N., Zgłobicka, I., Plocinski, T., Grzonka, J., Kurzydłowski, K. J., Car, A., Desrosiers, C., Kaska, Y. & McCartney, K. (2018). A new sediment dwelling and epizoic species of *Olifantiella* (Bacillariophyceae), with an account on the genus ultrastructure based on Focused Ion Beam nanocuts. *Fottea*, *18*, 212–226. [CrossRef]

Kaska, Y., Başkale, E., Katılmış, Y., Sözbilen, D. & Azmaz, M. (2016). *Monitoring and Conservation Studies of Sea Turtles (Caretta caretta) During the 2016 Nesting Season on Muğla Sea Turtle Nesting Beaches*. MacArt, Turkey.

Kociolek, J. P., Balasubramanian, K., Blanco, S., Coste, M., Ector, L., Liu, Y., Kulikovskiy, M., Lundholm, N., Ludwig, T., Potapova, M., Rimet, F., Sabbe, K., Sala, S., Sar, E., Taylor, J., Van de Vijver, B., Wetzel, C. E., Williams, D. M., Witkowski, A. & Witkowski, J. (2019). *DiatomBase*. http://www.diatombase.org on 2017-08-31 (Accessed 25 March 2019).

Loir, M. & Novarino, G. (2014). Marine *Mastogloia* Thwaites ex W. Smith and *Stigmaphora* Wallich species from the French Lesser Antilles. In A. Witkowski (Ed.), *Diatom monographs* 6 (pp. 1–133). Königstein: Koeltz Scientific Books.

Louvrou, I. (2007). *Periphyton and its colonization in marine hydrothermal regions of island Milos (Greece)*. PhD Thesis, University of Athens, Greece, 447 pp.

Maraşlıoğlu, F. & Gönülol, A. (2019). *Turkish algae electronic publication*. http://turkiyealgleri.hitit.edu.tr (Accessed 10 April 2019)

Margaritoulis, D., Argano, R., Baran, I., Bentivegna, F., Bradai, M. N., et al. (2003). Loggerhead turtles in the Mediterranean: present knowledge and conservation perspectives. – In: Bolten, A. B. & Witherington, B. E. (eds), *Loggerhead Sea Turtles* (pp. 175–198). Washington, DC: Smithsonian Books.

Park, J. S., Lobban, C. S. & Lee, K. W. (2018). Diatoms associated with seaweeds from Moen Island in Chuuk Lagoon, Micronesia. *Phytotaxa*, *351*, 101–140. [CrossRef]

Peragallo, H. & Peragallo, M. (1897-1908). *Diatomees marines de France et des district maritimes voisins*. M.J. Tempere, Grez sur-Loing, 491 pp. [CrossRef]

Polge, N., Sukatar, A., Soylu, E. N. & Gönülol, A. (2010). Epipelic algal flora in the Küçükçekmece Lagoon. *Turkish Journal of Fisheries and Aquatic Sciences*, *10*(1), 39–45. [CrossRef]

Riaux-Gobin, C. & Compère, P. (2009). *Olifantiella mascarenica* gen. & sp. nov., a new genus of pennate diatom from Réunion Island, exhibiting a remarkable internal process. *Phycological Research*, *57*, 178–185. [CrossRef]

Seddon, A. W., Froyd, C. A. & Witkowski, A. (2011). Diatoms (Bacillariophyta) of isolated islands: New taxa in the genus *Navicula* sensu stricto from the Galapagos Islands. *Journal of Phycology*, *47*, 861–879. [CrossRef]

Sıvacı, E. R., Yardım, O., Gönülol, A., Bat, L. & Gümüş, F. (2008). Benthic algae of Sarıkum (Sinop-Turkey) Lagoon. *Journal of Fisheries Sciences*, *2*(4), 592–600. [CrossRef]

Simonsen, R. (1987). *Atlas and catalogue of the diatom types of Friedrich Hustedt*. Berlin: J. Cramer.

Snoeijs, P. (1993). *Intercalibration and distribution of diatom species in the Baltic Sea,* Vol. 1, *The Baltic Marine Biologist Publication*, 16a, Uppsala, Opulus Press, 129.

Snoeijs, P. & Balashova N. (1998). *Intercalibration and distribution of diatom species in the Baltic Sea*, Vol. 5, *The Baltic Marine Biologist Publication,* 16e, Uppsala, Opulus Press, 144.

Soylu, E. N., Maraşlıoğlu, F. & Gönülol A. (2011). Epiphytic diatom flora of Liman Lake (Bafra-Samsun). *Ekoloji*, *20*, 57–62.

Swift, E. (1967). Cleaning diatom frustules with ultraviolet radiation and peroxide. *Phycologia*, *6*, 161–163. [CrossRef]

Şanal, M. & Demir, N. (2018). Use of the epiphytic diatoms to estimate the ecological status of lake Mogan. *Applied Ecology and Environmental Research*, *16*, 3529–3543. [CrossRef]

Wachnicka, A. H. & Gaiser, E. E. (2007). Characterization of *Amphora* and *Seminavis* from south Florida, U.S.A. *Diatom Research*, *22*, 387–455. [CrossRef]

Witkowski, A., Lange-Bertalot, H. & Metzeltin, D. (2000). Diatom Flora of Marine Coasts I. In H. Lange-Bertalot (Ed), *Iconographia Diatomologica 7* (pp. 1–925). Konigstein: Koeltz Scientific Books.

Yerli, S. (1999). Türkiye Lagünlerine Genel Bir Bakış. In A. Demirsoy (Ed.), *Genel ve Türkiye Zoocoğrafyası* (pp. 465–474). Ankara, Türkiye: Metaksan press.

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Research Article

Nutritional Composition and Fatty Acid Profile of Commercially Important Mullet Species in the Köyceğiz Lagoon

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ABSTRACT

The present study is aimed to detect the nutritional composition and fatty acids profile of two different Mullet species caught from the/a fish barrier in Köyceğiz Lagoon (Muğla, Turkey) over a period of 12 months. A nutritional composition (protein, lipid, moisture and ash) and fatty acids profile were carried out for each commercially important mullet species; *Mugil cephalus* and *Chelon saliens* using standard measurement methods and gas chromatography (GC), respectively. The nutritional composition of the species showed differences depending on the harvesting and spawning seasons. Two mullet species had the highest fat content ($P<0.05$) in spawning time, while moisture content was low ($P<0.05$) during the same period. Predominant fatty acids for two different mullet species were myristic acid, palmitic acid and stearic acid as saturated (SFA); palmitoleic acid, oleic acid and cis-11-eicosenoic acid as monounsaturated fatty acids (MUFAs); linoleic, cis-8, 11, 14- eicosatrienoic, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) as polyunsaturated fatty acids (PUFAs). The nutritional and fatty acid composition content of species varied due to the harvesting season, reproduction period and age of the fish. The results exhibited that mullet species during the reproductive period have higher lipid content and fatty acid composition, especially in terms of EPA and DHA.

Keywords: Mullet species, nutritional composition, fatty acids profile, EPA, DHA

INTRODUCTION

Fish and seafood are most important source of animal protein and are consumed all around the world due to its high protein, amino acid and unsaturated fatty acid content. It is an essential nutritional source for human diet (Suvitha et al., 2014). Fish oil contains 15-20% saturated and 80-85% unsaturated fatty acids. The two major classes of polyunsaturated fatty acids (PUFAs) are the n-3 and n-6 fatty acids. Fish oils are known to be the main source of polyunsaturated fatty acids especially EPA and DHA (Schmidt et al., 2005). These fatty acids play an important role in human health, especially for nutrition, disease prevention and health promotion (Simopoulos, 2004) and are of great importance to humans for prevention of cardiovascular disease, inflammatory response and autoimmune disorders (Leaf et al., 2003). Long chain n-3 PUFA cannot be synthesized by humans and must be obtained through diet (Alasalvar et al., 2002).

Lipids are important components in fish and seafood product for human diets, both as energy and fatty acids (FA) sources (Sargent et al., 2002). It is known that the amounts of fat and fatty acids of the same species or different species are influenced by various factors such as environmental conditions (water temperature, salinity), sex, age, size, season, feeding habits, abundance of food, life stage, migration, spawning period and etc. (Mısır et al., 2013). The biochemical compositions of fish are closely associated with these factors (Chaouch et al., 2003). Köyceğiz Lagoon, located in the Mediterranean, is an important touristic area with its geomorphology and ecological variation. Lake Köyceğiz was declared as Köyceğiz-Dalyan Specially Protected Environmental Area (SPEA) in 1988 (Tosunoglu & Saygi, 2018). In Köyceğiz Lagoon, a total of 50 fish species were identified in different studies (Buhan, 1998). In the lagoon, Akın et al. (2005) reported that eighteen species were determined in trammel net samplings. Much research reported that five mullet species *Mugil cephalus*, *Liza aurata*, *Liza saliens, Liza ramada* and *Chelon labrosus* were detected in Köyceğiz Lagoon barrier traps (Yerli, 1992; Buhan, 1998; Akın et al., 2005). It is commonly preferred and consumed by all economic group of people and it is also considered as low cost seafood (Kumaran et al., 2012). Besides been marketed as a fresh product, their eggs are processed and economically important products for people living around the lagoons.

The aim of this work was to investigate the proximate differences of the fish from two different genus that enter the same lagoon to spawn. In this context, the current study aims to evaluate the nutritional composition and the fatty acids profiles of two mullet species harvested from Köyceğiz Lagoon (Muğla, Turkey) throughout the 12 month period of and compare the differences among the fish harvested in the same habitat to spawn.

MATERIALS AND METHODS

Fish samples

Each commercially important mullet species; *M. cephalus* and *C. saliens* harvested from Köyceğiz Lagoon in Muğla city were used as study materials. Samples were obtained from DALKO Fisheries Cooperative who harvested the fish from fishing traps in the lagoon for 12 months, between July of 2015 and June of 2016. For each trial group, 10 individuals of different mullet species were chosen. A total of 100 fish of both species were used during the study. Flesh fish samples were packed into an insulated polystyrene box with ice and immediately transported to the Seafood Processing Laboratory in the Fisheries Faculty at Muğla Sıtkı Koçman University, within 2 hours of harvesting. After the biometric measurements of the fish brought to the laboratory, the fish were gutted and filleted before the assays. The fish meat was homogenized and analyzed. These processes were repeated for each fish sample from each species. Study was carried out for 12 months depending on the harvesting yield from lagoons.

Nutritional composition analysis

The mullet samples were analyzed in triplicate for nutritional composition (5 samples from 2 fish species): the total lipid content (% wet weight) of 5 g homogenized raw edible parts of fish meat samples were determined by the chloroform/methanol extraction gravimetric method described by Bligh and Dyer (1959). The moisture contents (% wet weight) of 3-5 g homogenized raw edible parts of fish meat samples were determined for all samples by drying for 3 hours at 105 °C as described in the official method of the AOAC, 934.01 (2006). The ash content (% wet weight) of the moisture free samples were determined using the official AOAC method 920.153 by ashing for 4-6 hours at 550˚C (AOAC, 2002). The total crude protein (% wet weight) of 1 g homogenized raw edible parts of fish meat samples was analyzed by means of the Kjeldahl method 984.13 (AOAC, 2006a).

Fatty acids methyl esters (FAME) analyses

The methyl esters of lipid extracted was prepared by trans methylation using 2 M KOH in methanol and isooctane according to the method described by Ichihara et al. (1996) with minor modification; 25 mg of extracted oil were dissolved in 2 ml isooctane, followed by 4 ml of 2 M KOH in methanol. Then, the tube was vortexed for 2 min at room temperature. After centrifugation at 4000 rpm for 10 min, the isooctane layer was taken for Gas chromatography analyses.

Gas chromatography (GC) conditions

The fatty acid methyl esters were analyzed using Gas chromatograph of Agilent Technologies model 7820 equipped with a flame ionization detector (FID) and fitted with a HP-88 capillary column (60 m x 0.25 mm x 0.25 µm thickness). Helium was used as the carrier gas at a constant pressure of 16 psi. Injection port was maintained at 220°C, and the sample was injected in split mode with a split ratio of 50:1. Detector temperature was 280°C. Column temperature was started at 175°C, and then programmed at 3°C/min to 220°C, ramped at 1°C/min to 220°C, and held for 10 min. The total running time was 26 minutes. Helium was used as the makeup gas at a constant flow of 40 mL/min, and hydrogen and dry air were used as detector gases (ISO 1990). Identification of fatty acids was carried out by comparing sample FAME peak relative retention times with those obtained for Supelco standards (Supelco 37 Compounds FAME mix 10 mg/ml in CH_2Cl_2 – 47885 U, Supelco 1819-1 Ampule FAME mix C4-C24). Results of each fatty acids were expressed as FID response area relative percentages of the total fatty acids determined (ISO, 1990).

Statistical analyses

All experiments were carried out in triplicate and the results are reported as the mean and standard deviation of these measurements. Statistics on a completely randomized design were performed with the analysis of variance (ANOVA) procedure in SPSS (Version 21, SPSS Inc., Chicago, IL, USA) software. Tukey's multiple range test ($P<0.05$) was used to detect differences among mean values of all test intervals.

RESULTS AND DISCUSSION

Biometric parameter properties of mullet samples

Biometrical parameters of two mullet species were shown in Table 1. A statistically significant relationship was found between lengths and weights of the fish of the same species depending on the month ($P<0.05$). It was determined that the mean length and weight of *M. cephalus* were higher than the *C. saliens*.

Nutritional composition analysis results

Monthly changes in nutritional composition of *M. cephalus*, and *C. saliens* was shown in Table 2. Protein content of *M. cephalus* was found between 18.18% and 22.53% throughout the study. The highest protein content was observed in August. Lipid contents were found to be high in May, June and July while they were low in August and September. The highest moisture and ash value were obtained in September (77.86% and 1.83%, respectively).

Table 1. The biometric parameters of two mullet species.

Months	*M. cephalus*		*C. saliens*	
	Mean Length (cm)	Mean Weight (g)	Mean Length (cm)	Mean Weight (g)
May	33.45±6.10^{b}	364.77±187.52^{b}	30.75±2.08^{a}	270.03±59.95^{a}
June	34.58±6.10^{a}	411.80±217.60^{a}	*	*
July	35.08±4.74^{a}	427.41±185.59^{a}	30.58±1.51^{a}	208.68±32.50^{b}
August	32.38±4.58^{c}	314.31±149.79^{c}	30.73±2.61^{a}	213.32±53.25^{b}
September	33.93±3.65^{b}	343.20±107.74^{b}	*	*

* The sample of that species was not caught from lagoon, Values are expressed as mean ±SD (N:10), mean values in the same column with different superscripts were significantly different (P≤0.05)

Table 2. Changes of nutritional composition of mullet species.

	M. cephalus			
	Protein (%)	Lipid (%)	Moisture (%)	Ash (%)
May	18.18±0.08^{D}	4.03±0.05^{A}	73.58±0.18^{C}	1.36±0.03^{C}
June	21.49±0.15^{B}	3.67±0.22^{AB}	74.67±0.26^{B}	1.42±0.02^{B}
July	20.72±0.53^{C}	3.41±0.29^{B}	74.67±0.65^{B}	1.33±0.10^{C}
August	22.53±1.40^{A}	1.37±0.28^{C}	77.46±0.21^{A}	1.34±0.51^{C}
September	21.34±0.34^{B}	0.94±0.03^{D}	77.86±0.40^{A}	1.83±0.48^{A}
	C. saliens			
May	17.39±0.02^{B}	4.19±0.03^{B}	75.27±0.46^{B}	1.42±0.12^{A}
July	18.07±1.31^{B}	5.48±0.06^{A}	73.10±0.25^{C}	1.25±0.12^{A}
August	20.16±0.13^{A}	3.47±0.64^{C}	76.61±0.64^{A}	1.32±0.04^{A}

Values are expressed as mean ±SD, mean values in the same column with different superscripts were significantly different (P≤0.05).

The highest protein and moisture content of *C. saliens* were detected in August (20.16 and 76.61%, respectively), while highest lipid content (5.48%) was in July (P<0.05). There were no significant differences for ash content depending on months (P>0.05). It has been observed that there is an inverse correlation between the ratio of lipid to the moisture content of all mullet species. The results of the nutritional composition analyses revealed that there were significant differences in protein, moisture and lipid contents for two mullet species except for the ash content which are thought to be related to the harvesting season (P<0.05). The nutritional composition of fish was highly dependent on a number of factors, namely catching months, environmental conditions, geographical regions, age, and fish diets. The high ash content obtained indicates that all these fish are rich in minerals (Tenyang et al., 2016). This inverse relationship between moisture and lipid content has been reported for sea bream (*Sparus aurata*) and sea bass (*Dicentrarchus labrax*) (Grigorakis, 2007). Özogul and Özogul (2007) investigated that lipid content of *M. cephalus* is 2.09%. In another study from Bangladesh, moisture, ash, protein and lipid contents of *M. cephalus* were reported as 70.83, 1.7, 21.38 and 6.12%, respectively (Azam et al., 2004). In the study which investigated the microbiological and nutritional character of processed *M. cephalus*, the moisture content of fresh samples was determined as 71.91%, protein content 18.48% and lipid content 8.44% (Mostafa & Salem 2015). Khitouni et al. (2014) determined the water content of *L. aurata* species obtained from Tunisian coast and found that they were in the range of 64.86-77.68% in male specimens and 63.77-77.89% in females. They also found the annual lipid; protein; ash content mean for male and female specimens as 4.58% and 5.09%; 19.93% and 20.20%; 1.56% and 1.59%, respectively.

The lower lipid content of mullet species from Köyceğiz Lagoon may be due to the gonadal maturation because it was caught off during its spawning migration, which occurs at different times for each mullet species. There is a widespread decrease in the amount of whole body fat in many fish species, especially in the spawning period (Khitouni et. al., 2014).

Fatty acid profile of mullet samples

Fatty acid profile of *M. cephalus* were shown in Table 3. Miristic, palmitic and stearic acid as saturated fatty acids (SFA); palmitoleic (C16:1), oleic and *cis*-11-eicosenoic acid as mono unsaturated fatty acids (MUFA); linoleic, *cis*-8-11-14-eicosatrienoic, EPA and DHA as poly unsaturated fatty acids (PUFA) were detected as major fatty acids. EPA content was higher in May and June when compared to other months. Similarly, DHA content was higher in September and August (P<0.05). The highest total SFA (34.61%) and PUFA (33.70%) were obtained in September, while the highest MUFA (21.84%) was obtained in June.

Table 3. Fatty acid profile (expressed as percentage of total fatty acids) in raw edible parts of *M. cephalus*.

Fatty acids	May	June	July	August	September
C11:0	0.20	0.09	0.27	0.09	0.17
C12:0	0.98	0.76	0.79	0.45	0.16
C13:0	0.26	0.13	0.29	0.13	0.00
C14:0	7.34±0.28[a]	6.47±0.33[b]	5.47±0.06[c]	5.03±0.39[d]	4.21±0.60[e]
C15:0	0.63	0.48	0.55	0.51	0.38
C16:0	20.19±0.70[b]	19.61±1.13[c]	19.11±0.76[d]	19.87±0.17[c]	21.19±0.01[a]
C17:0	0.38	0.29	0.42	0.23	0.28
C18:0	2.91±0[d]	3.40±0.08[c]	3.41±0.19[c]	5.14±0.48[b]	6.70±0.18[a]
C20:0	0.77	0.73	0.72	0.66	0.77
C22:0	0.23	0.27	0.25	0.23	0.28
C23:0	0.24	0.13	0.13	0.11	0.17
C24:0	0.12	0.11	0.11	0.32	0.30
ΣSFA	**34.24±1.26[a]**	**32.46±2.05[b]**	**31.52±3.25[c]**	**32.78±0.29[b]**	**34.61±2.78[a]**
C14:1	0.15	0.13	0.15	0.12	0.09
C15:1	0.07	0.05	0.05	0.05	0.09
C16:1	12.65±0.21[a]	12.86±0.29[a]	11.43±0.66[b]	9.18±056[c]	8.78±1.22[d]
C17:1	0.11	0.12	0.24	0.20	0.23
C18:n9t	0.31	0.27	0.23	0.16	0.14
C18:1n9c	6.27±0.04[d]	6.84±0.09[c]	9.07±0.62[a]	7.02±0.19b[c]	7.01±0.88[bc]
C20:1n9	1.96±0.01[a]	1.42±0.02[b]	1.29±0.05[b]	1.37±0.09[b]	0.76±0.01[c]
C22:1n9	0.12	0.14	0.09	0.23	0.28
ΣMUFA	**21.63±0.56[b]**	**21.84±1.20[b]**	**22.55±0.27[a]**	**18.33±3.12[c]**	**17.38±0.07[d]**
C18:2n6t	0.15	0.14	0.24	0.26	0.27
C18:2n6c	2.32±0.03[c]	2.00±0.05[d]	3.28±0.63[a]	2.65±0.13[b]	2.34±0.09[c]
C18:3n6	0.22	0.16	0.15	0.20	0.17
C18:3n3	0.56	0.53	0.69	0.57	0.55
C20:2	0.28	0.25	0.45	0.49	0.34
C20:3n6	2.51±0.05[c]	2.50±0.03[c]	3.67±0.14[b]	4.51±0.45[a]	4.84±0.22[a]
C20:3n3	0.12	0.14	0.18	0.15	0.19
C20:4n6	0.68	0.55	0.54	0.52	0.19
C22:2	0.65	0.76	0.70	0.75	0.70
C20:5n3	8.13±0.04[a]	7.73±0[b]	5.54±0.02[e]	6.68±0[c]	6.02±0.20[d]
C22:6n3	10.04±0.38[e]	13.72±0.13[c]	11.35±0.03[d]	16.67±0.21[b]	18.08±1.09[a]
ΣPUFA	**25.65±1.25[d]**	**28.50±0.96[b]**	**26.80±0.43[c]**	**33.46±1.62[a]**	**33.70±0.32[a]**
Σ n3	**18.85±0.12[d]**	**22.13±0.25[c]**	**17.77±0.11[e]**	**24.08±0.06[b]**	**24.84±1.04[a]**
Σ n6	**5.87±0.09[c]**	**5.36±0.67[c]**	**7.88±0.71[b]**	**8.14±0.45[a]**	**7.82±0.14[b]**
n6/n3	**0.31±0.01[b]**	**0.24±0.05[c]**	**0.44±0.01[a]**	**0.34±0.02[b]**	**0.32±0.00[b]**
Undefined	**18.47**	**17,08**	**19,04**	**15.33**	**14.31**

ΣSFA; Total saturated fatty acids. ΣMUFA; total monounsaturated fatty acids. ΣPUFA; total polyunsaturated fatty acids, Values are expressed as mean ±SD, mean values in row with different superscripts were significantly different (P≤0.05) between the months.

Özogul and Özogul (2007) found the total MUFA and PUFA ratios of the *M. cephalus* samples as 25.8 and 24.8%, respectively. The most abundant fatty acid was palmitic acid (C16: 0) as 21.5±0.33 (%). They also determined DHA as 7.69 and EPA as 10.5 % (42% of the total PUFA). Mostafa and Salem (2015) reported that palmitic acid, oleic acid and linoleic acid were identified as the major fatty acids for processed *M. cephalus*.

El-Sherif and El-Ghafour (2016) who investigated the nutrient composition and fatty acid content of four important fish species (*Tilapia zilii, Solea vulgaris, Metapenaeus stebbing* and *M. cephalus*) in Lake Quarin, determined the moisture, protein, lipid and ash content of *M. cephalus* as 74.85±0.45, 19.10±0.15, 4.48±0.09 and 1.33 ± 0.32% respectively. Dominant fatty acids were palmitic acid (C16:0) as SFA, oleic acid (C18:1 n-9cis) as MUFA and DHA (C22:6 n-3) as PUFA. Kumaran et al. (2012) found lipid, protein,

Table 4. Fatty acid profile (expressed as percentage of total fatty acids) in raw edible parts of *C. saliens.*

Fatty acids	May	July	August
C11:0	0.02	0.08	0.08
C12:0	0.12	0.33	0.31
C13:0	0.04	0.09	0.09
C14:0	4.42±0.02[c]	6.94±0.06[b]	7.40±0.08[a]
C15:0	0.44	0.41	0.46
C16:0	20.10±0.20[a]	17.49±0.41[b]	20.31±0.09[a]
C17:0	0.33	0.20	0.30
C18:0	3.12±0.04[a]	2.64±0.05[b]	3.12±0.03[a]
C20:0	0.64	1.15	1.21
C22:0	0.21	0.33	0.33
C23:0	0.17	0.16	0.16
C24:0	0.08	0.09	0.12
ΣSFA	**29.69±1.25[b]**	**29.92±3.21[b]**	**33.88±2.63[a]**
C14:1	0.14	0.10	0.10
C15:1	0.06	0.06	0.05
C16:1	16.39±0.35[a]	14.91±0.11[b]	16.06±0.07[a]
C17:1	0.10	0.21	0.04
C18:n9t	0.31	0.19	0.17
C18:1n9c	9.15±0.60[a]	8.41±0.31[b]	7.14±0.08[c]
C20:1n9	1.47±0.04[b]	1.69±0.03[a]	1.26±0.01[c]
C22:1n9	0.05	0.11	0.22
ΣMUFA	**27.62±0.97[a]**	**25.57±1.45[b]**	**24.82±1.99[b]**
C18:2n6t	0.16	0.12	0.28
C18:2n6c	2.04±0.01[c]	3.81±0.04[a]	3.11±0.01[b]
C18:3n6	0.09	0.16	0.17
C18:3n3	0.48	0.53	0.52
C20:2	0.36	0.24	0.19
C20:3n6	3.94±0.16[a]	3.02±0[b]	3.09±0.03[b]
C20:3n3	0.11	0.20	0.18
C20:4n6	0.41	0.88	0.78
C22:2	0.43	0.76	0.57
C20:5n3	8.33±0.04[a]	7.50±0[b]	7.01±0.16[c]
C22:6n3	9.38±0.18[b]	10.68±0.12[a]	9.49±0.10[b]
ΣPUFA	**25.73±1.01[b]**	**27.89±2.15[a]**	**25.38±0.82[b]**
Σn3	**18.29±0.15[b]**	**18.91±0.01[a]**	**17.21±0.02[c]**
Σn6	**6.64±0.50[c]**	**7.99±0.04[a]**	**7.42±0.17[b]**
n6/n3	**0.36±0.02[b]**	**0.42±0.00[a]**	**0.43±0.01[a]**
Undefined	**16.91**	**16.42**	**15.55**

ΣSFA; Total saturated fatty acids. ΣMUFA; total monounsaturated fatty acids. ΣPUFA; total polyunsaturated fatty acids, Values are expressed as mean ±SD, mean values in row with different superscripts were significantly different (P≤0.05) between the months.

ash content of *M. cephalus* in India Parangipattai coastal waters as 2.42, 17.56, 1.15%, respectively. The fatty acid composition was found as SFA 40.24%, MUFA 33.48%, PUFA 26.28%. Bayır et al. (2006) studied the fatty acid composition of 12 fish species harvested from Turkish seas. They reported that EPA and DHA value of *M. cephalus* as 8.7±0.84% and 22.7±1.61%, respectively. Şen (2006) seasonally investigated the total fatty acid composition of *M. cephalus* from Mersin. It was concluded that total PUFAs ratio were found higher than SFAs ratio for all seasons. However, the highest fatty acid was found to be palmitic as SFA and n-6 amount was determined to be higher than n-3.

Fatty acid composition results of *C. saliens* as shown in Table 4. Similar to *M. cephalus* and *L. aurata*, miristic, palmitic and stearic acid as saturated fatty acids (SFA); palmitoleic, oleic and *cis*-11-eicosenoic acid as mono unsaturated fatty acids (MUFA); linoleic, *cis*-8-11-14-eicosatrienoic, EPA and DHA as poly unsaturated fatty acids (PUFA) were detected as major fatty acids. EPA content was determined to be higher in May and DHA content was determined to be higher in July when they were compared with other months (P<0.05). The highest total SFAs were determined in August (33.88%) while the highest MUFAs (27.62%) and PUFAs (27.89%) were in May and July, respectively.

Kamdem et al. (2008) who investigated some safety indices (presence of pathogenic microbial species, heavy metal and biogenic amine concentrations) and nutritional content (percent composition and fatty acid profile) of *L. ramada, L. aurata* and *L. saliens* species reported that palmitic acid (C16:0) as SFAs was 13.27% for *L. saliens*, 13.56% for *L. aurata*; palmitoleic acid (C16:1 n-7) as MUFA was 19.48% for *L. saliens* and 25.38% for *L. aurata*. They also reported that n3/n6 ratio of *L. aurata* and *L. saliens* for PUFAs was 3 times lower in *L. saliens*. In a different study, the amount of total saturated, monounsaturated and polyunsaturated fatty acids for *L. saliens* from Mediterranean coastal lagoons were 43.5, 33.7, 22.8%, respectively while EPA and DHA values were 4.9 and 2.4%, respectively (Koussoroplis et al., 2011).

While the total SFA value of the *M. cephalus* was found to be higher than the *C. saliens* (P<0.05). These fatty acids are a potential source of metabolic energy in fish, especially in terms of growth and gonad development in female fish. The lowest amount of C16:0 in the flesh total lipids was detected for *L. aurata* during spawning time, which apparently corresponded to the changes in C16:0 in dietary plankton lipids (Huynh et al., 2007). The most abundant MUFA was C16:1, C18:1n9 and C20:1n9 for two mullet species. In contrast to the total SFA value, the total MUFA value of *M. cephalus* species was found to be lower than the *C. saliens* species. These MUFAs have been associated with zooplankton and variation in the levels could reflect varying amounts of zooplankton consumed in the diet (Budge et al., 2002; Huynh et al., 2007). As a result, our findings showed that two mullets is a better source of PUFA, especially linoleic acid, eicosatrienoic acid, EPA and DHA. It was also observed that the proportion of these fatty acids changed significantly between species. These results are in agreement with previous studies on fatty acid of other species (Özogul & Özogul, 2007; Tenyang et al., 2016).

The UK Department of Health recommends an ideal ratio of n6/n3 of 4.0 at maximum (COMA, 1994). Values higher than the maximum value are harmful to health and may promote cardiovascular diseases (Moreira et al., 2001). In this study, the highest n6/n3 ratio for *M. cephalus,* and *C. saliens* was determined in July (0.44 %), and August (0.43 %) (P<0.05), respectively. The ratio of n6/n3 was found at very low levels all mullet species. The data revealed that all mullet fish from Köyceğiz Lagoon were a good source of total ω-3 PUFA ranging from 14.74 % to 30.10 %. A good natural source of these fatty acids (especially EPA and DHA) is seafood (Calder & Yaqoob, 2009). The total n3 amount was found to be highest in August and September for *M. cephalus* and in July for *C. saliens*. As in this study, the high n-3 value in fish species is very important for human health. If taken in an adequate amount, it helps prevent health problems such as serious cardiovascular diseases (Mayneris-Perxachs et al., 2010).

CONCLUSIONS

In the current study, the nutritional composition and fatty acid profile of mullet species that were caught in Köyceğiz lagoon located on the northwestern Turkish coast of Mediterranean were investigated periodically. In conclusion, this study revealed the fatty acid compositions of all mullet species in spawning and non-spawning period of mullet, which have not previously been studied in Köyceğiz Lagoon. The results showed that the nutritional composition of mullet species varies depending on the catching season. This might be due to changes in environmental conditions i.e., spawning and migration periods as well as age and sex of fish. Protein, lipid and fatty acid contents of mullet species were found to be significantly higher during reproduction periods. Our study figured out that lipid contents and fatty acid profiles of mullets vary with the life cycle and condition at maturity. We have shown that spawning mullet species exhibit a marked increase in the relative concentration of MUFA. On the contrary, the PUFA concentrations were remarkably higher after the spawning period. This might be due to the lipid storage of the fish body due to the long migration period that fish need to spend to find a place to spawn. Fish body prepares itself to spawn, so the fish losses its lipid content for storing eggs. So, fatty acid profile of the fish fillets may vary depending on the pre and after spawning time. Low lipid contents cause an undesirable meat quality, so mullets are not advised to be consumed as a good n-3 source just after their spawning period. The study results revealed out that all mullet species have strong nutritional value and may be suggested for intake of PUFA (long-chain n-3) especially EPA (20:5n-3) and DHA (22:6n-3).

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REFERENCES

Alasalvar, C., Taylor, K. D. A., Zubcov, E., Shahidi, F. & Alexis, M. (2002). Differentiation of cultured and wild sea bass (*Dicentrarchus labrax*): total lipid content, fatty acid and trace mineral composition. *Food Chemistry, 79,* 145–150. [CrossRef]

Akın, S., Buhan, E., Winemiller, K. O. & Yılmaz, H. (2005). Fish assemblage structure of Köycegiz Lagoon Estuary, Turkey: Spatial and temporal distribution patterns in relation to environmental variation. *Estuarine, Coastal and Shelf Science, 64*(4), 671–684. [CrossRef]

AOAC (2002). Ash content. Official method 920.153. Official Methods of Analysis (17th ed.). Gaithersburg: Maryland (USA): Association of Official Analytical Chemists.

AOAC (2006). Moisture content. Official method 934.01. Official Methods of Analysis (17th ed.). Gaithersburg: Maryland (USA): Association of Official Analytical Chemists.

AOAC (2006a). Crude protein in meat. Official method 984.13. Official methods of analysis, ([Revised] (18th ed.). Washington: DC. (USA): Association of Official Analytical Chemists.

Azam, K., Ali, M. Y., Asaduzzaman, M., Basher, M. Z. & Hossain, M. M. (2004). Biochemical assessment of selected fresh fish. *Journal of Biological Sciences, 4*(1), 9–10. [CrossRef]

Bayır, A., Haliloğlu, H. İ., Sirkecioğlu, A. N. & Aras, N. M. (2006). Fatty acid composition in some selected marine fish species living in Turkish waters. *Journal of the Science of Food and Agriculture, 86*(1), 163–168. [CrossRef]

Bligh, E. G. & Dyer, W. J. (1959). A rapid method of total lipid extraction and purification. *Canadian Journal of Biochemistry and Physiology*, *37*(8), 911–917. [CrossRef]

Budge, S. M., Iverson, S. J., Bowen, W. D. & Ackman, R. G. (2002). Among- and within-species variability in fatty acid signatures of marine fish and invertebrates on the Scotian Shelf, Georges Bank, and southern Gulf of St. Lawrence. *Canadian Journal of Fisheries and Aquatic Sciences*, *59*(5), 886–898. [CrossRef]

Buhan, E. (1998). Development of Lagoon Management of Köyceğiz Lagoon System by Researching Present Situation and Grey Mullet Populations (in Turkish). Ministry of Agriculture and Rural Affairs, Bodrum Fishery Research Institute Press, Serial B, Publish No. 3, 347 pp.

Calder, P. C. & Yaqoob, P. (2009). Understanding omega-3 polyunsaturated fatty acids. *Postgraduate medicine, 121*(6), 148–157. [CrossRef]

Chaouch, A., Bouhlel, I., Chraief, I., Hammami, M., El Hani, A., Romdhane, M. S. & El Cafsi, M. (2003). Seasonal variation of polyunsaturated fatty acids (n-3) composition in *Diplodus annularis* from the gulf of Tunis: nutritional benefits. *Journal-Societe Chimique De Tunisie 5*(1), 55–64.

COMA (1994). Nutritional aspects of cardiovascular disease. Committee on Medical Aspects of Food Policy, Report No. 46, HMSO, London.

El-Sherif, S. A. E. H. & El-Ghafour, S. A. (2016). Investigation of the quality properties and nutritional values of four fish species from Lake Qaroun, Egypt. *International Journal of ChemTech Research, 9*(4), 16–26.

ISO (1990). Animal and vegetable fats and oils-Analysis by gas chromatography of methyl esters of fatty acids, EN ISO 5508.

Grigorakis, K. (2007). Compositional and organoleptic quality of farmed and wild gilthead sea bream (*Sparus aurata*) and sea bass (*Dicentrarchus labrax*) and factors affecting it: a review. *Aquaculture, 272*, 55–75. [CrossRef]

Huynh, M. D., Kitts, D. D., Hu, C. & Trites, A. W. (2007). Comparison of fatty acid profiles of spawning and non-spawning Pacific herring, *Clupea harengus pallasi*. *Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology, 146*(4), 504–511. [CrossRef]

Ichihara, K. I., Shibahara, A., Yamamoto, K. & Nakayama, T. (1996). An improved method for rapid analysis of the fatty acids of glycerolipids. *Lipids, 31*(5), 535–539. [CrossRef]

Kamdem, S. S., Vernocchi, P., Maffei, M., Belletti, N., Gardini, F., Guerzoni, M. E. & Lanciotti, R. (2008). Assessment of safety, nutritional, and spoilage characteristics of different lagoon grey mullets (*Liza ramada, Liza aurata,* and *Liza saliens*). *Journal of food protection*, *71*(12), 2572–2577. [CrossRef]

Khitouni, I. K., Mihoubi, N. B., Bouain, A. & Rebah, F. B. (2014). Seasonal variations in proximate and fatty acid composition of golden grey mullet *Liza aurata* (R, 1810) from the Tunisian coast. *International Journal of Agricultural Policy and Research*, *2*(7), 273–280.

Koussoroplis, A. M., Bec, A., Perga, M. E., Koutrakis, E., Bourdier, G. & Desvilettes, C. (2011). Fatty acid transfer in the food web of a coastal Mediterranean lagoon: Evidence for high arachidonic acid retention in fish. *Estuarine, Coastal and Shelf Science*, *91*(3), 450–461. [CrossRef]

Kumaran, R., Ravi, V., Gunalan, B., Murugan, S. & Sundramanickam, A. (2012). Estimation of proximate, amino acids, fatty acids and mineral composition of mullet (*Mugil cephalus*) of Parangipettai, Southeast Coast of India. *Advances in Applied Science Research*, *3*(4), 2015–2019.

Leaf, A., Kang, J. X., Xiao, Y. F. & Billman, G. E. (2003). Clinical prevention of sudden cardiac death by n-3 polyunsaturated fatty acids and mechanism of prevention of arrhythmias by n-3 fish oils. *Circulation*, *107*(21), 2646–2652. [CrossRef]

Mayneris-Perxachs, J., Bondia-Pons, I., Serra-Majem, L., Castello, A. I. & López-Sabater, M. C. (2010). Longchain n-3 fatty acids and classical cardiovascular disease risk factors among the Catalan population. *Food Chemistry, 119*, 54–61. [CrossRef]

Mısır, G. B., Kutlu, S. & Çibuk, S. (2013). Determination of total lipid and fatty acid composition of pearl mullet (*Chalcalburnus tarichi*, Pallas 1811). *Turkish Journal of Fisheries and Aquatic Sciences*, *13*(5), 777–783.

Moreira, A. B., Visentainer, J. V., de Souza, N. E. & Matsushita, M. (2001). Fatty acids profile and cholesterol contents of three Brazilian Brycon freshwater fishes. *Journal of Food Composition and Analysis*, *14*(6), 565–574. [CrossRef]

Mostafa, A. A. & Salem, R. H. (2015). Characterization of microbiological and nutritional variations in processed mullet (*Mugil cephalus*) Fish. *International Journal of Microbiological Research*, *6*(2), 108–122.

Özogul, Y. & Özogul, F. (2007). Fatty acid profiles of commercially important fish species from the Mediterranean, Aegean and Black Seas. *Food Chemistry*, *100*(4), 1634–1638. [CrossRef]

Sargent, J. R., Tocher, D. R. & Bell, J. G. (2002). The lipids. In E. Halver and R.W. Hard (Eds.), *Fish* nutrition (pp: 181–257). London, UK: Academic Press. [CrossRef]

Schmidt, E. B., Arnesen, H., de Caterina, R., Rasmussen, L. H. & Kristensen, S. D. (2005). Marine n-3 polyunsaturated fatty acids and coronary heart disease: Part I. Background, epidemiology, animal data, effects on risk factors and safety. *Thrombosis Research*, *115*(3), 163–170. [CrossRef]

Simopoulos, A. P. (2004). Omega-6/omega-3 essential fatty acid ratio and chronic diseases. *Food Reviews International, 20*(1), 77–90. [CrossRef]

Suvitha, S., Eswar, A., Anbarasu, R., Ramamoorthy, K. & Sankar, G. (2014). Proximate, amino acid and fatty acid profile of selected two Marine fish from Parangipettai Coast. *Asian Journal of Biomedical and Pharmaceutical Sciences, 4*(40), 38–42.

Şen, S. (2006). Seasonal variation of the total fatty acid composition of the mullet, *Mugil cephalus* L. 1758 (Osteichthyes: Mugilidae). Selçuk University, Institute of Science and Technology, Master thesis, Konya.

Tenyang, N., Ponka, R., Tiencheu, B., Womeni, H. M. & Tonfack, F. (2016). Proximate composition, fatty acid and mineral contents of four freshwater fish from Maga Lake (Far North Region of Cameroon). *American Journal of Food Science and Technology, 4*(3), 64–69.

Tosunoglu, Z. & Saygi, H. (2018). Analysis of long and short terms fishery landings of Köyceğiz Lagoon (Turkey). *Turkish Journal of Fisheries and Aquatic Sciences, 19*(3), 199–208. [CrossRef]

Yerli, S. (1992). Investigations on the stocks of *Liza ramada* (Risso, 1826) in Köyceğiz lagoon system (in Turkish). *Doğa Turkish Journal of Veterinary and Animal Sciences, 16*, 103–120.

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