



## Diversity and Distribution of the Ichthyofauna in the Göksu River Estuary, Turkey

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**Abstract:** The Göksu River estuary at the Mediterranean coast is among the major estuarine systems in Turkey. The aims of the present study were to analyse the distribution and qualitative and quantitative composition of the ichthyofauna in the Göksu River estuarine zone. Fish were sampled by different nets at four sites from November 2014 till June 2017. A total of 47 fish species were identified in the coastal marine zone and 32 species belonging to 16 families in the river estuary. *Chelon auratus*, *Chelon saliens* and *Mugil cephalus* were the dominant species and comprised over 75% of the total catch number. Marine fish dominated by species richness and abundance. Five alien species (*Carassius gibelio*, *Gambusia holbrooki*, *Chelon carinatus*, *Oreochromis niloticus* and *Sillago suezensis*) were caught in the estuary. Of them, *Gambusia holbrooki* had the highest abundance (77.6%). The indexes of species richness, diversity and evenness exhibited a strong spatial and temporal variation throughout the study period.

**Key words:** Marine and freshwater fish, species composition, abundance, threatened species, alien species, Mediterranean estuary.

### Introduction

Estuaries occur at the confluence of land and sea and form a natural link between the terrestrial and aquatic freshwater habitats and the marine environment (SHEAVES et al. 2012). They represent a special class of aquatic ecosystems clearly different from the open sea and the freshwater bodies (ALLEE et al. 2000). The estuaries act as dynamic environment for feeding, breeding and nursery ground for most of the aquatic communities (BEHERA et al. 2013). Estuaries represent important ecosystems in coastal zones that are affected by various biotic and abiotic factors and have both ecological and economic importance (BALASUBRAMANIAN 2011, WHITFIELD

& ELLIOT 2011). At the same time, the estuaries are among the most modified and threatened environments (BLABER et al. 2000). They have been exposed to various human activities that have caused the depletion of numerous important species, destroyed or changed important estuarine habitats, degraded water quality and introduced several non-indigenous species (MOTA et al. 2014).

The Göksu River estuary at the Mediterranean coast is among the major estuarine systems in Turkey. Due to its location, namely being on a bird migration route, the Göksu River and its delta have been declared a Wetland of International Importance according to the RAMSAR CONVENTION (1971). It has also been declared a Special Environmental

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Protection Zone in order to protect the area against the pollution and exploitation, and to ensure the development of the natural resources and cultural assets (DEMIREL et al. 2011). Earlier studies conducted on the fish fauna of the Göksu River provide valuable information about the species distribution (KÜÇÜK et al. 2007, RAD et al. 2013). KÜÇÜK et al. (2007) presented ten species and three subspecies belonging to seven families. KÜÇÜK et al. (2017) described a new cyprinid fish species *Chondrostoma toros* Küçük, Turan, Güçlü, Mutlu & Çiftci, 2017, from the river. ENGIN & INNAL (2017) identified a new gobiid fish species *Pomatoschistus anatoliae* in the estuarine zone of the river.

Monitoring the fish diversity of the Göksu River estuary is very important due to its ecological services provided to the coastal and freshwater ecosystems. Although there are many studies on the Göksu River, there are no surveys on the fish species diversity of the estuarine zone of this system. The aims of the present study were to analyse the distribution and qualitative and quantitative composition of the ichthyofauna in the Göksu River estuarine zone.

## Materials and Methods

The Göksu River is located in the middle of the Taurus Mountains which is the longest tectonic unit extending from the southwest to the southeast of Anatolia. It springs from the Konya-Karaman District and flows to the Mediterranean Sea in the Silifke-Mersin District.

Four sampling sites were selected in the coastal marine zone (Site 1) and different parts of the river estuary (Sites 2, 3 and 4) (Fig. 1). The fish species

were caught in different seasons between November 2014 and June 2017 (on 11 sampling dates). The sampling at the four sampling sites was carried out by gill nets with a total length of 310 m and various mesh sizes of 10, 17, 23 and 30 mm (Site 1, 2, 3 and 4), as well as by fish traps and fyke nets (Site 2, 3 and 4).

The environmental parameters were measured at each survey site at the start of each sampling. The temperature (°C), salinity (ppt), pH and dissolved oxygen (mg/l) concentration were determined by using portable meters WTW 340i. The Secchi depths (m) were estimated by a Secchi disk. The chlorophyll *a* concentration (µg/l) was measured according to 90% acetone extract methods described by APHA (2005). Captured fish were anaesthetised and then fixed in 4% formalin in the field.

The morphological and morphometrical features of the fish specimens were used for fish species identification, following the method described by AKŞIRAY (1987) and GELDIAY & BALIK (1988). The classification of systematic position of the fish species was carried out based on FRICKE et al. (2020). The fish species were categorised according to the salinity preference and migratory behaviour into marine, migratory, estuarine and freshwater species (ARAÚJO et al. 1999). The alien or native taxa were identified by references to INNAL & ERK'AKAN (2006) and TARKAN et al. (2015). The information on the conservation status of the fish species was retrieved from the IUCN (2019).

The environmental variables were analysed using ANOVA to measure the significant difference among the sampling sites.

The fish community was characterised using either the species richness (S) – the total number of



Fig. 1. Map of Turkey showing the sampling sites in the Göksu River estuarine zone.

species obtained at each sampling, or the Shannon-Wiener diversity index ( $H'$ ). The distribution of individuals was measured by the uniformity or 'evenness' index ( $J$ ) (MAGURRAN 1988). Data on fish captured by 310 mm gill nets were used for the ecological index calculations. A two-way ANOVA was used to test for significant differences between the environmental variables, the species richness and the abundance among the sampling sites and study periods. Prior to the analysis of variance, all variables were tested for normality (Kolmogorov-Smirnov test) and homogeneity of variances (Cochran tests).

## Results

### Environmental parameters

The water temperature of the Göksu River estuary ranged from 7.7°C to 28.3°C and there was no significant difference between the sites ( $p > 0.05$ ). The highest temperature was recorded in August 2016 and the lowest in January 2017 (Table 1). The mean Secchi depth did not show a strong seasonal pattern. Its values varied from a minimum of 0.2 m to a maximum of 0.6 m and were significantly different between the sites ( $p < 0.05$ ). The values of salinity ranged from 0.1 to 36.2 ppt (Table 1). The salinity showed a spatial gradient along the length of the estuary, decreasing progressively from the downstream to the upstream sites. This decrease was statistically significant ( $p < 0.05$ ). The mean monthly pH values did not show a strong seasonal pattern. The values of pH were not significantly different between the sites. The dissolved oxygen concentration varied from a minimum of 0.9 mg/l to a maximum of 11.9 mg/l (Table 1) and was not significantly different between the sites ( $p > 0.05$ ).

### Fish species composition

In total, 72 fish species were identified in the coastal marine zone (Site 1) and river estuary zone (Sites 2, 3 and 4) of the Göksu River. Seven of the species were detected in both the marine zone and the river estuary zone (Table 2). These species are as follows: *Chelon labrosus*, *Diplodus annularis*, *Lithognathus mormyrus*, *Mugil cephalus*, *Sardinella maderensis*, *Sillago suezensis*, and *Trachinotus ovatus*.

A total of 5,005 fish specimens, representing 32 species and 16 families, were collected in the Göksu River estuary (Sites 2, 3 and 4) during our study (Tables 2 and 3). The species composition differed between the different sampling periods.

The order Perciformes had the highest species richness (37.5% of all species). It was followed by

Mugiliformes (18.8%) and Cypriniformes (12.5%). The family with the highest number of species was Mugilidae (six species). It was followed by Cyprinidae (four species), Sparidae, Soleidae and Carangidae (three species), and Moronidae and Clupeidae (two species). Several other families (Anguillidae, Cichlidae, Clariidae, Cyprinodontidae, Engraulidae, Gobiidae, Poeciliidae, Sciaenidae and Sillaginidae) were represented by single species.

The species of the family Mugilidae were among the most abundant, accounting for 78.42% of the total catch number. The golden grey mullet *Chelon auratus* was the dominant species (41.88%), followed by the leaping mullet *Chelon saliens* (22.42%) and *Mugil cephalus* (7.97%) (Table 3). *Chelon saliens* and *C. auratus* were present throughout the whole sampling period (Table 3).

The fish were categorised as marine, migratory, estuarine and freshwater species. The marine species of the Göksu River estuary, with 21 species (65.63%), represented the highest abundance (82.92%). The freshwater species, with seven species (21.88%), represented 11.13% of abundance. Two migrant species represented 1.48 % of the total abundance, while two estuarine dependent species represented 4.48% of the total abundance (Table 3).

The conservation status of the estuarine fish in the Göksu River revealed one critically endangered (CR) species, one vulnerable (VU) species, 20 species under the least concern (LC) category, two species under the data deficient (DD) category and eight species were not evaluated (NE) (IUCN 2019) (Table 3).

The fish diversity varied with spatial gradients in the Göksu River. The upstream area, with 14 species, had lower species richness than the middle and downstream areas (17 and 28 species, respectively). In total 11 species were found at the three stations: *Chelon auratus*, *Chelon saliens*, *Mugil cephalus*, *Luciobarbus pectoralis*, *Pomatoschistus anatoliae*, *Gambusia holbrooki*, *Solea solea*, *Alosa fallax*, *Acanthobrama orontis*, *Dicentrarchus labrax* and *Anguilla anguilla*.

### Alien fish assemblage

Over the study period, a total of 214 individuals belonging to five alien species (*Carassius gibelio*, *Oreochromis niloticus*, *Gambusia holbrooki*, *Chelon carinatus* and *Sillago suezensis*) were caught and identified in the Göksu River (Table 3). The alien fish belonged to five genera, five families and four orders. The alien species comprised 4.28% of the catches in terms of number of specimens. Three of these species (*C. gibelio*, *G. holbrooki* and *O. niloticus*)

**Table 1.** Environmental parameters of the coastal marine zone (Site 1) and the Göksu River estuary (Sites 2, 3 and 4) in the study period.

Date	Temperature (°C)				Ph				Dissolved oxygen (mg/l)			
	Site 1	Site 2	Site 3	Site 4	Site 1	Site 2	Site 3	Site 4	Site 1	Site 2	Site 3	Site 4
November 2014	18.9	15.5	15.3	15.1	7.3	7	6.5	6.4	4.1	3.9	0.9	7.6
February 2015	17.1	9.9	7.9	7.7	7.6	7.3	7.4	8.2	6.3	11.1	10.2	10.5
May 2015	25.1	20.3	21.1	20.5	7.5	7.4	7.3	7.4	6.1	7.2	7.2	8.3
August 2015	29.6	21.1	22.4	21.1	7.5	7.4	7.4	7.3	5	4.8	6.7	6.6
November 2015	21	21.3	20.9	20.2	7.3	7.3	7.3	7.2	5.1	2.4	2.4	2.6
February 2016	17.4	15.5	15.1	12.1	7.8	7.6	7.7	7.5	3.3	3.4	3.5	4
April 2016	20.3	18	17.9	18	7.7	7.8	7.6	7.5	6.4	5.9	8	8.1
August 2016	30.6	24.4	28.3	22.1	8.4	8.2	8.3	8.2	4.3	4.4	3.3	5.8
January 2017	15.1	8.4	8.3	8.2	7.8	7.6	7.5	7.7	5.3	11.4	11.4	11.9
April 2017	18	14.8	15	15.1	7.4	7.3	7.2	7.3	4.6	5.4	7.2	9.6
June 2017	25.2	24.1	25.3	24.5	7.5	7.5	7.4	7.3	3.1	4.1	1.9	2.5
Minimum	15.1	8.4	7.9	7.7	7.3	7	6.5	6.4	3.1	2.4	0.9	2.5
Maximum	30.6	24.4	28.3	24.5	8.4	8.2	8.3	8.2	6.4	11.4	11.4	11.9
Mean	21.7	17.6	18	16.8	7.62	7.49	7.42	7.45	4.87	5.82	5.7	7.05
Date	Salinity (ppt)				Secchi depth (m)				Chlorophyll a (µg/l)			
	Site 1	Site 2	Site 3	Site 4	Site 1	Site 2	Site 3	Site 4	Site 1	Site 2	Site 3	Site 4
November 2014	30	26.1	18.2	0.5	2.5	0.6	0.6	0.6	0.2	2.7	2.7	2.6
February 2015	29.8	0.5	0.3	0.3	2.5	0.5	0.6	0.6	1.2	0.5	0.3	0.5
May 2015	29.8	25.1	24.8	3.7	2	0.5	0.5	0.6	0.6	5.7	6.1	4.6
August 2015	29.3	28	3	2.9	3	0.4	0.4	0.4	0.5	0.8	1.0	1.2
November 2015	29.5	28.5	28.5	28.1	2	0.5	0.5	0.5	0.3	0.3	0.3	0.6
February 2016	29.5	24.2	5.8	1.2	2.5	0.4	0.4	0.3	0.8	1.5	0.8	1.3
April 2016	29.9	0.2	0.2	0.1	0.5	0.4	0.4	0.4	1.2	0.6	0.8	1.2
August 2016	27.2	27.8	6.2	0.1	2	0.5	0.6	0.6	1.2	1.2	1.2	1.0
January 2017	37	0.2	0.2	0.2	1.5	0.5	0.5	0.5	0.4	0.4	0.5	0.4
April 2017	35.2	0.2	0.2	0.2	0.8	0.2	0.2	0.2	0.6	0.4	0.2	0.2
June 2017	35.1	36.2	31.2	30.2	1.1	0.4	0.4	0.4	0.2	0.3	0.3	0.2
Minimum	27.2	0.2	0.2	0.1	0.5	0.2	0.2	0.2	0.2	0.3	0.2	0.2
Maximum	37	36.2	31.2	30.2	3	0.6	0.6	0.6	1.2	5.7	6.1	4.6
Mean	31.1	17.9	10.8	6.14	1.85	0.45	0.46	0.46	0.6	1.3	1.3	1.2

**Table 2.** List of the fish species identified in the coastal marine zone (Site 1) and river estuarine zone (Sites 2, 3 and 4) of the Göksu River.

No	Species	Family	Order	Sampling zone	
				Marine zone	River estuary
1	<i>Chelon labrosus</i> (Risso, 1827)	Mugilidae	Mugiliformes	X	X
2	<i>Diplodus annularis</i> (Linnaeus, 1758)	Sparidae	Perciformes	X	X
3	<i>Lithognathus mormyrus</i> (Linnaeus, 1758)	Sparidae	Perciformes	X	X
4	<i>Mugil cephalus</i> Linnaeus, 1758	Mugilidae	Mugiliformes	X	X
5	<i>Sardinella maderensis</i> (Lowe, 1838)	Clupeidae	Clupeiformes	X	X
6	<i>Sillago suezensis</i> Golani, Fricke & Tikochinski, 2013	Sillaginidae	Perciformes	X	X
7	<i>Trachinotus ovatus</i> (Linnaeus, 1758)	Carangidae	Perciformes	X	X
8	<i>Alepes djedaba</i> (Forsskål, 1775)	Carangidae	Perciformes	X	
9	<i>Boops boops</i> (Linnaeus, 1758)	Sparidae	Perciformes	X	
10	<i>Caranx crysos</i> (Mitchill, 1815)	Carangidae	Perciformes	X	
11	<i>Chelidonichthys lucerna</i> (Linnaeus, 1758)	Triglidae	Scorpaeniformes	X	
12	<i>Dasyatis marmorata</i> (Steindachner, 1892)	Dasyatidae	Myliobatiformes	X	
13	<i>Diplodus vulgaris</i> (Geoffroy Saint-Hilaire, 1817)	Sparidae	Perciformes	X	
14	<i>Echelus myrus</i> (Linnaeus, 1758)	Ophichthidae	Anguilliformes	X	
15	<i>Epinephelus aeneus</i> (Geoffroy Saint-Hilaire, 1817)	Serranidae	Perciformes	X	
16	<i>Equulites klunzingeri</i> (Steindachner, 1898)	Leiognathidae	Perciformes	X	
17	<i>Etrumeus golanii</i> DiBattista, Randall & Bowen, 2012	Dussumeriidae	Clupeiformes	X	
18	<i>Gymnura altavela</i> (Linnaeus, 1758)	Gymnuridae	Myliobatiformes	X	
19	<i>Jaydia queketti</i> (Gilchrist, 1903)	Apogonidae	Perciformes	X	
20	<i>Labrus merula</i> Linnaeus, 1758	Labridae	Perciformes	X	
21	<i>Lagocephalus suezensis</i> Clark & Gohar, 1953	Tetraodontidae	Tetraodontiformes	X	
22	<i>Lichia amia</i> (Linnaeus, 1758)	Carangidae	Perciformes	X	
23	<i>Lophius piscatorius</i> Linnaeus, 1758	Lophiidae	Lophiiformes	X	
24	<i>Mullus barbatus</i> Linnaeus, 1758	Mullidae	Perciformes	X	
25	<i>Nemipterus randalli</i> Russell, 1986	Nemipteridae	Perciformes	X	
26	<i>Oblada melanura</i> (Linnaeus, 1758)	Sparidae	Perciformes	X	
27	<i>Oedalechilus labeo</i> (Cuvier, 1829)	Mugilidae	Mugiliformes	X	
28	<i>Ostorhinchus nigripes</i> (Playfair, 1867)	Apogonidae	Perciformes	X	
29	<i>Pagellus erythrinus</i> (Linnaeus, 1758)	Sparidae	Perciformes	X	
30	<i>Pelates quadrilineatus</i> (Bloch, 1790)	Terapontidae	Perciformes	X	
31	<i>Pempheris vanicolensis</i> Cuvier, 1831	Pempheridae	Perciformes	X	
32	<i>Pomadasys stridens</i> (Forsskål, 1775)	Haemulidae	Perciformes	X	
33	<i>Raja miraletus</i> Linnaeus, 1758	Rajidae	Rajiformes	X	
34	<i>Sardina pilchardus</i> (Walbaum, 1792)	Clupeidae	Clupeiformes	X	
35	<i>Sardinella aurita</i> Valenciennes, 1847	Clupeidae	Clupeiformes	X	
36	<i>Sargocentron rubrum</i> (Forsskål, 1775)	Holocentridae	Beryciformes	X	
37	<i>Sarpa salpa</i> (Linnaeus, 1758)	Sparidae	Perciformes	X	
38	<i>Saurida lessepsianus</i> Russell, Golani & Tikochinski, 2015	Synodontidae	Aulopiformes	X	
39	<i>Scomber scombrus</i> Linnaeus, 1758	Scombridae	Perciformes	X	
40	<i>Serranus cabrilla</i> (Linnaeus, 1758)	Serranidae	Perciformes	X	
41	<i>Siganus rivulatus</i> Forsskål & Niebuhr, 1775	Siganidae	Perciformes	X	
42	<i>Spicara maena</i> (Linnaeus, 1758)	Sparidae	Perciformes	X	
43	<i>Symphodus mediterraneus</i> (Linnaeus, 1758)	Labridae	Perciformes	X	

Table 2. Continued.

No	Species	Family	Order	Sampling zone	
				Marine zone	River estuary
44	<i>Synodus saurus</i> (Linnaeus, 1758)	Synodontidae	Aulopiformes	X	
45	<i>Torpedo nobiliana</i> (Bonaparte, 1835)	Torpedinidae	Torpediniformes	X	
46	<i>Trachurus trachurus</i> (Linnaeus, 1758)	Carangidae	Perciformes	X	
47	<i>Trichiurus lepturus</i> Linnaeus, 1758	Trichiuridae	Perciformes	X	
48	<i>Acanthobrama orontis</i> Berg, 1949	Cyprinidae	Cypriniformes		X
49	<i>Alectis alexandrina</i> (Geoffroy Saint-Hilaire, 1817)	Carangidae	Perciformes		X
50	<i>Alosa fallax</i> (Lacepède, 1803)	Clupeidae	Clupeiformes		X
51	<i>Anguilla anguilla</i> (Linnaeus, 1758)	Anguillidae	Anguilliformes		X
52	<i>Aphanius fasciatus</i> (Valenciennes, 1821)	Cyprinodontidae	Cyprinodontiformes		X
53	<i>Carassius gibelio</i> (Bloch, 1782)	Cyprinidae	Cypriniformes		X
54	<i>Chelon auratus</i> (Risso, 1810)	Mugilidae	Mugiliformes		X
55	<i>Chelon carinatus</i> (Valenciennes 1836)	Mugilidae	Mugiliformes		X
56	<i>Chelon ramada</i> (Risso, 1827)	Mugilidae	Mugiliformes		X
57	<i>Chelon saliens</i> (Risso, 1810)	Mugilidae	Mugiliformes		X
58	<i>Chondrostoma toros</i> Küçük, Turan, Güçlü, Mutlu & Çiftci, 2017	Cyprinidae	Cypriniformes		X
59	<i>Clarias gariepinus</i> (Burchell, 1822)	Clariidae	Siluriformes		X
60	<i>Dicentrarchus labrax</i> (Linnaeus, 1758)	Moronidae	Perciformes		X
61	<i>Dicentrarchus punctatus</i> (Bloch, 1792)	Moronidae	Perciformes		X
62	<i>Engraulis encrasicolus</i> (Linnaeus, 1758)	Engraulidae	Clupeiformes		X
63	<i>Gambusia holbrooki</i> Girard, 1859	Poeciliidae	Cyprinodontiformes		X
64	<i>Luciobarbus pectoralis</i> (Heckel, 1843)	Cyprinidae	Cypriniformes		X
65	<i>Oreochromis niloticus</i> (Linnaeus, 1758)	Cichlidae	Perciformes		X
66	<i>Pegusa lascaris</i> (Risso, 1810)	Soleidae	Pleuronectiformes		X
67	<i>Pomatoschistus anatoliae</i> Engin & Innal, 2017	Gobiidae	Perciformes		X
68	<i>Seriola dumerili</i> (Risso, 1810)	Carangidae	Perciformes		X
69	<i>Solea solea</i> (Linnaeus, 1758)	Soleidae	Pleuronectiformes		X
70	<i>Sparus aurata</i> Linnaeus, 1758	Sparidae	Perciformes		X
71	<i>Synapturichthys kleinii</i> (Risso, 1827)	Soleidae	Pleuronectiformes		X
72	<i>Umbrina cirrosa</i> (Linnaeus, 1758)	Sciaenidae	Perciformes		X

were freshwater, while two fish (*C. carinatus* and *S. suzeensis*) were Red Sea immigrants. *Gambusia holbrooki* had the highest population abundance (77.6%) among the alien species.

#### Spatial and temporal variation in the fish abundance and the species richness

The index values of Shannon-Weiner ( $H'$ ), dominancy and evenness are shown in Fig. 2. The number of species varied from eight (January 2017) to 20 (May 2015) in the Göksu River estuary. Based on the Shannon-Wiener's diversity index ( $H'$ ), the highest ecological diversity was recorded in November 2015 (2.219), while the lowest – in

August 2016 (1.355). The Evenness Index had its highest value in January 2017 (0.9035) and the lowest – in August 2016 (0.3876). The number of species and values of the Diversity Index exhibited a strong spatial and temporal variation throughout the study.

## Discussion

According to our results, 32 fish species inhabited permanently or temporarily the study area. In a previous study Küçük et al. (2007) reported ten species and three subspecies belonging to seven families in the Göksu River, but their study

**Table 3.** Fish species composition in the Göksu River estuary (study sites 2, 3 and 4). N – number of the specimens caught; % – percentage of the total number of specimens.

No	Species	Origin	Habitat	Life cycles	Conservation status	Occurrence (%)	N	%
1	<i>Chelon auratus</i>	Native	Marine	Juveniles and adults	LC	100	2096	41.88
2	<i>Chelon saliens</i>	Native	Marine	Juveniles and adults	LC	100	1122	22.42
3	<i>Mugil cephalus</i>	Native	Marine	Juveniles and adults	LC	90.9	399	7.97
4	<i>Luciobarbus pectoralis</i>	Native	Freshwater	Juveniles and adults	LC	90.9	304	6.07
5	<i>Chelon ramada</i>	Native	Marine	Juveniles	LC	54.5	266	5.31
6	<i>Pomatoschistus anatoliae</i>	Native	Estuarine	Juveniles and adults	NE	63.6	190	3.80
7	<i>Gambusia holbrooki</i>	Alien	Freshwater	Juveniles and adults	LC	54.5	166	3.32
8	<i>Solea solea</i>	Native	Marine	Adults	DD	54.5	100	2.00
9	<i>Alosa fallax</i>	Native	Migrant	Adults	LC	63.6	53	1.06
10	<i>Acanthobrama orontis</i>	Native	Freshwater	Adults	NE	72.7	46	0.92
11	<i>Aphanius fasciatus</i>	Native	Estuarine	Juveniles and adults	LC	27.3	34	0.68
12	<i>Chelon labrosus</i>	Native	Marine	Juveniles and adults	LC	72.7	33	0.66
13	<i>Dicentrarchus labrax</i>	Native	Marine	Juveniles and adults	LC	63.6	30	0.6
14	<i>Umbrina cirrosa</i>	Native	Marine	Adults	NE	45.5	22	0.44
15	<i>Anguilla anguilla</i>	Native	Migrant	Juveniles and adults	CR	36.4	21	0.42
16	<i>Engraulis encrasicolus</i>	Native	Marine	Adults	LC	27.3	18	0.36
17	<i>Oreochromis niloticus</i>	Alien	Freshwater	Adults	NE	27.3	15	0.3
18	<i>Chondrostoma toros</i>	Native	Freshwater	Adults	NE	18.2	13	0.26
19	<i>Carassius gibelio</i>	Alien	Freshwater	Adults	NE	36.4	12	0.24
20	<i>Sillago suezensis</i>	Alien	Marine	Adults	NE	18.2	12	0.24
21	<i>Chelon carinatus</i>	Alien	Marine	Adults	NE	27.3	9	0.18
22	<i>Dicentrarchus punctatus</i>	Native	Marine	Adults	LC	27.3	8	0.16
23	<i>Lithognathus mormyrus</i>	Native	Marine	Adults	LC	36.4	8	0.16
24	<i>Sparus aurata</i>	Native	Marine	Adults	LC	36.4	8	0.16
25	<i>Synapturichthys kleinii</i>	Native	Marine	Juveniles	DD	18.2	8	0.16
26	<i>Trachinotus ovatus</i>	Native	Marine	Adults	LC	9.1	3	0.06
27	<i>Diplodus annularis</i>	Native	Marine	Adults	LC	18.2	2	0.04
28	<i>Pegusa lascaris</i>	Native	Marine	Adults	LC	9.1	2	0.04
29	<i>Sardinella maderensis</i>	Native	Marine	Adults	VU	18.2	2	0.04
30	<i>Alectis alexandrina</i>	Native	Marine	Adults	LC	9.1	1	0.02
31	<i>Clarias gariepinus</i>	Native	Freshwater	Adults	LC	9.1	1	0.02
32	<i>Seriola dumerili</i>	Native	Marine	Adults	LC	9.1	1	0.02

covered the upper parts of the Göksu River. Some species recorded in our study were also reported by KÜÇÜK et al. (2007).

Most of the species collected in the Göksu River estuary are commonly found in the estuaries of the Mediterranean region. Compared with other studies the number of the fish species is higher than in the Rihios River estuary, Greece (29 species) (KOUTRAKIS et al. 2000); the Kakanui River estuary, New Zealand (20 species) (JELLYMAN et al. 1997); the Solway River estuary, England (22

species) (ELLIOTT & DEWAILLY 1995), the Waitaki River estuary (16 species), the Clutha River estuary (14 species), the Waiou River estuary (14 species) and the Mohako River estuary (13 species), New Zealand (JELLYMAN et al. 1997); the Bahuda River estuary, India (25 species) (BEHERA et al. 2013); and the Minho River estuary, Iberian Peninsula (21 species) (MOTA et al. 2014). At the same time, the number of the fish species recorded in the Göksu River estuary is less than in the Köyceğiz estuary (42 species) (AKIN et al. 2005); the South African

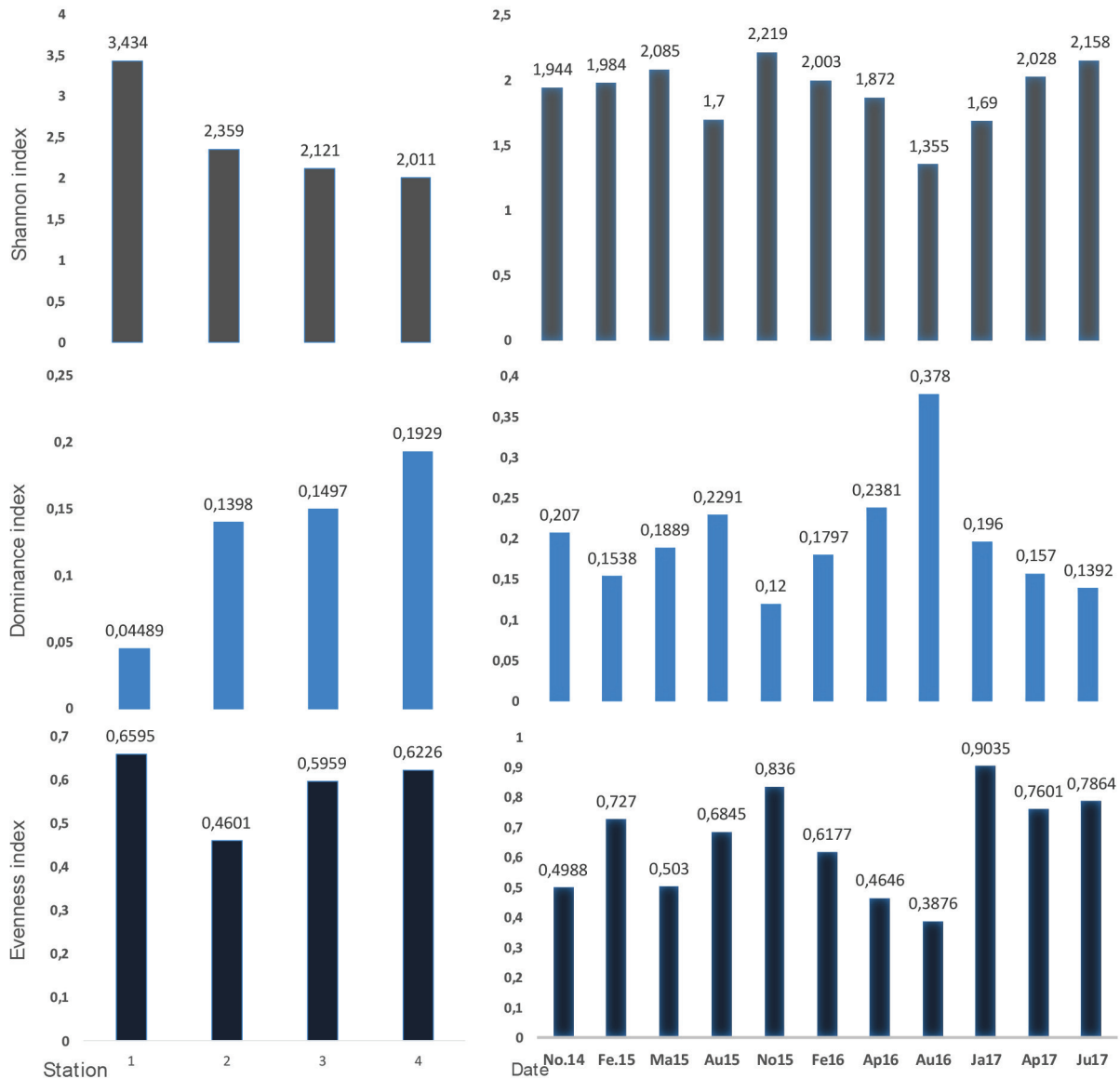


Fig. 2. Spatial and temporal variations of Shannon, Dominance and Evenness Indices.

estuaries (37 species) (DESMOND et al. 2002); the Pueblo Viejo estuary, Mexico (66 species) (CASTILLO-RIVERA et al. 2002); and the Richmond River estuary (64 species) and the Clarence River estuary (66 species), Australia (WEST & WALFORD 2000). However, it is difficult to compare the number of species between the various estuaries because of the different sampling areas and methods used.

The present study implies that Mugilidae is the dominant fish family in the Göksu River estuary with exactly 78.42% of catch. *Chelon auratus* and *Chelon saliens* were the most common species captured during the study. The Mugilidae species present a wide tolerance range towards the variable environmental conditions (THOMSON 1966, WHITFIELD 1998, NITA & NENCIU 2020).

The domination of the Mugilidae in the Göksu River estuary is similar with many other estuaries worldwide as previously reported (KOUTRAKIS et al. 2000, GARCIA et al. 2001, TZENG et al. 2002, AKIN et al. 2005, INNAL 2016).

Estuaries are areas of high productivity and may serve as feeding grounds for marine fish stocks (McDOWALL 1976). Of the 32 species recorded in the Göksu River estuary, 21 were marine and in terms of habitat guilds the diversity was mainly formed by the marine species. This dominance coincides with some other estuarine systems of Turkey (AKIN et al. 2005, INNAL 2016). At the same time, juveniles of 12 species (*Chelon auratus*, *Chelon saliens*, *Mugil cephalus*, *Luciobarbus pectoralis*, *Pomatoschistus anatoliae*, *Gambusia holbrooki*, *Aphanius fasciatus*, *Chelon labrosus*,

*Dicentrarchus labrax*, *Anguilla anguilla*, *Chelon ramada* and *Synapturichthys kleinii*) were found in the Göksu River estuary during our study. 7 of the mentioned species are of marine origin. This result suggests that the Göksu estuary has been employed by the marine species for nursery area. Estuaries provide suitable habitat for juvenile fish with more abundant food and lower predation risk than in other habitats (VASCONCELOS et al. 2008). The use of estuaries as a nursery area by the marine fish has been reported by MARTINHO et al. (2007) for the Mondego estuary, Portugal and by POTTER et al. (1990) for the Western Australia and Southern Africa estuaries.

Five fish species from five families were identified as alien to the Göksu River estuary. These alien fish occupy a variety of trophic positions. Two of the species recorded are lessepsian fish (*Chelon carinatus* and *Sillago suezensis*). The construction of the Suez Canal has served as a major pathway for *C. carinatus* and *S. suezensis* introductions from the Indian Ocean into the Mediterranean ecosystems (MAVRUK & AVSAR 2008, BILGE et al. 2019) and the Göksu River (present study). The other three species has been introduced in the Göksu estuary anthropogenically for different reasons (increasing the reservoir fishing, cultivating some species, solving grass problem and facilitating mosquito control) (D. INNAL, pers. obs.). The presence of the highly invasive Prussian carp *C. gibelio* and the Eastern mosquito fish *G. holbrooki* is a potential threat to the native species of the Göksu River. They have wide tolerance range towards the variable environmental conditions (INNAL et al. 2019).

The structure of the fish assemblage in the Göksu River estuary differed significantly in different sampling periods. This study also shows the considerable changes in the diversity during the study period. The wide range (1.36–2.22) of the Shannon-Wiener diversity index reflects the large number of species that use the estuary on a seasonal basis. Marked seasonal changes in the fish assemblage structures have been detected in earlier studies of the estuarine ecosystems, where the presence, abundance and migration of fish are associated with both abiotic and biotic factors in specific ways (HAGAN & ABLE 2003, AKIN et al. 2005, JAUREGUIZAR et al. 2006, SOSA-LÓPEZ et al. 2007).

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