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Fish Diversity Patterns in the Manavgat River Estuary (Antalya, Türkiye)

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Abstract: This study was conducted between November 2014 and June 2017 to assess the diversity of fishes in the Manavgat River Estuary. A total of 7804 individuals from 33 species were captured. The native and non-indigenous fish belonged to 18 families. *Chelon auratus*, *Chelon saliens*, *Alburnus baliki*, and *Mugil cephalus* were the dominant species and comprised over 75% of the total number. The fish fauna included 23 marine, eight freshwater, one migrant, and one brackish species. A total of ten non-indigenous and two endangered fish species were also recorded in this study. The indexes of species richness, Shannon-wiener diversity, and evenness showed a consistent seasonal pattern.

Key words: Fish assemblages, functional guilds, alien fish, endemic fish, endangered fish, Water quality

Introduction

Throughout the world, several studies have underlined the biological and environmental relevance of estuarine environments. Estuarine systems are important parts of coastal ecosystems because they provide a diverse range of habitats, food supplies, and nursery places for a wide range of species (Costa & Bruxelas 1989, Elliott & Hemingway 2002, McLusky & Elliott 2004, Rountree & Able 2007, Vinagre et al. 2008, Whitfield 2020). Estuarine environments are essential for a range of unique and native species in the Levantine Sea, including numerous commercially valuable species. The Levantine Sea has encountered ecological and economic problems with the invasion of many non-native species in recent years (Goren & Galil 2005, Giangrande et al. 2020, Çınar et al. 2021). During the last century, estuarine systems in this region have been subjected to human effects (Martinez-Megias & Rico 2022). Even though fish species are commercially and scientifically significant, the diverse fish communities of Levantine Sea estuaries have received little attention. Many estuaries are still completely unsurveyed, and information on spatial and temporal patterns of fish species diversity and composition is scarce.

Manavgat River is a water resource of strategic importance in the Eastern Mediterranean Basin due to its special location and high flow capacity. The Manavgat River has been impacted by a variety of factors, including a considerable increase in tourism activities and population expansion in the region (D. Innal, Pers. observation). The conservation and management of the Manavgat River estuary habitats are critical for the survival of numerous marine and estuarine-dependent species that live in this river. Several study activities in the Manavgat River were carried out and published, including research on water quality and zooplankton composition (Erdoğan & Ertan 2014), microplastic pollution (Güven 2022), drought analysis (Kale 2021), fish biology (Innal & Gülle 2019), fish composition (Küçük et al. 2020), and heavy metal content in aquatic biota

Fig. 1. Map of Türkiye showing sampling locality (Manavgat Estuary).

(Özan 2021). However, no studies have been conducted on the fish diversity of this system's estuary zone. The present study aims to identify diversity patterns in the Manavgat River estuary. Improving the management of the critical ecosystem and its fisheries resources is necessary.

Materials and Methods

The Manavgat River (Figure 1) is located in the western part of the Taurus Mountains, the longest tectonic unit extending between southwest and southeast Anatolia. The flow regime of the Manavgat River is quite regular. It can be classified as permanently open. The total length of the main channel is approximately 90 km. Three dams were built on it (Oymapınar Dam, Manavgat Dam and Naras Dam) (Küçük et al. 2020). The main estuary channel (Manavgat-Antalya) was divided into two areas (upper and lower estuary) according to physicochemical gradients. The upstream area is characterised by agricultural farming, while tourism activities dominate the lower estuary area. Three sampling stations [Station 1, Lower Estuary, River mouth; Station 2, Trout Aquaculture station; Station 3, Hotels region] were selected in different parts of the Estuary

Fish species were caught seasonally between October 2014 and June 2017 (11 sampling dates) with gill nets of various mesh sizes (310 m total length; 10, 17, 23, 30 mm bar lengths), fish traps, and fyke nets. The same fishing effort was applied at each sampling time and site.

Captured fishes were anesthetised, then fixed in 4% formalin in the field. According to Aksiray (1987) and Geldiay & Balik (1988), fish specimens were identified at a species level. Fish species in the Manavgat Estuary have been categorised regarding salinity preference and migratory behaviour into marine, migratory, estuarine, and freshwater (Araujo et al. 1999). Exotic or native taxa were identified concerning Innal & Erk'akan (2006). Information on the conservation status of all taxa in this paper was retrieved from the International Union for Conservation of Nature (IUCN) accessed from 01 to 03 October 2023.

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

Hydrological parameters were measured at each survey site at the start of each sampling. Temperature (C °), salinity, pH, and oxygen concentration of bottom water were determined using WTW 340*i*. Secchi depths were estimated with the Secchi disk.

Hydrological parameters were analysed using one-way analysis of variance (ANOVA) to determine differences among the stations and months. Assumptions of normality and equal variance were

tested. In cases where assumptions of normality or equal variance could not be met, the Kruskal-Wallis nonparametric test was used.

Results

Environmental Parameters

Water quality parameters are given in Table 1. Although water temperature tended to decrease from station 1 (mouth) to station 3, this decrease was not statistically significant ($p>0.05$). Mean monthly Secchi depth did not show a strong seasonal pattern. Mean monthly Secchi depth varied from a minimum of 0.8 m to a maximum of 2.1 m and was not significantly different between sites ($p>0.05$). Salinity values ranged from 0.1 to 35.2. The mean bottom highest and lowest mean salinity values were measured for December 2016 (30.4) and April 2017(0.1), respectively. Salinity showed a spatial gradient along the length of the estuary, decreasing progressively from the mouths to the upstream sites with a statistically significant difference between the locations ($p<0.05$). Mean monthly pH values did not show a strong seasonal pattern, and readings were not significantly different between sites ($p>0.05$). Dissolved Oxygen concentrations did not differ significantly between stations ($p>0.05$).

Fish community patterns

Thirty-three fish species, representing 18 families, were recorded in the Manavgat Estuary. A total of 7804 individuals were caught throughout the study (Table 2). Mugilidae was the family most represented in terms of number of species (seven species).

Mugilidae was followed in species number by Sparidae (four species) and Leuciscidae (three species), while two species represent Mullidae, Moronidae, Gobiidae and Blenniidae. The remaining families (Anguillidae, Engraulidae, Clariidae, Cyprinidae, Gobionidae, Poeciliidae, Salmonidae, Scaridae, Siganidae, Sillaginidae, Sphyraenidae) were all represented by one species. Members of the Mugulidae family were among the most abundant species, accounting for 51.9% of the total catch. The species composition differed between the sampling periods.

The most abundant species were *Chelon auratus* (32.4%). *Chelon saliens* (21.5%), *Alburnus baliki* (10.9%), and *Mugil cephalus* (10.5%), which comprised 75.2% of the total sample. Fishes have been categorised as marine, estuarine, freshwater, and migratory species. The marine species of the Manavgat Estuary, with twenty-three species (69.7%), represented the highest abundance (77.3%). The freshwater species, with eight species (24.2%), represented 15.1% of the abundance. The migrant species (*Anguilla anguilla*) and Estuarine species (*Pomatoschistus anatoliae*) were represented by only one species.

Ten introduced species comprised 30.3% of the catches in terms of number of species and 4.9% abundance. Among these, four species (*Carassius gibelio, Gambusia holbrooki, Oncorhynchus mykiss, Pseudorasbora parva)* originated from freshwater and six species (*Planiliza carinata, Siganus rivulatus, Sillago suezensis, Sphyraena chrysotaenia, Upeneus moluccensis, Upeneus pori*) were classified as Lessepsian migrants (Table 3).

Table 1. Environmental parameters of the Manavgat River estuary in the study period.

Date	Temperature (°C)			ph			Dissolved Oxygen (mg/l)			Salinity (ppt)			Secchi (m)		
	Site 1	Site 2	Site3	Site 1	Site 2	Site3	Site 1	Site 2	Site3	Site 1	Site 2	Site3	Site 1	Site 2	Site3
Nov.14	12.9	12.9	12.7	8.3	8.1	8.2	9.8	8.1	11.2	3.5	1.0	0.5	1.0	1.0	1.0
Feb.15	13.3	12.1	12.2	8.2	8.2	8.3	8.8	10.6	10.7	0.9	0.3	0.2	0.9	1.1	1.0
May.15	18.0	15.1	14.6	7.0	7.3	7.3	8.0	11.0	11.8	3.1	2.4	0.4	1.2	1.2	1.6
Aug.15	21.3	17.5	17.4	7.3	7.3	7.3	5.0	9.8	10.3	28.0	5.6	0.4	1.0	1.6	1.6
Nov.15	21.9	14.4	14.5	7.4	7.5	7.5	4.0	4.0	3.1	29.6	2.3	2.6	1.0	1.0	1.2
Feb.16	17.1	11.9	15.9	7.8	7.6	7.9	4.4	6.0	4.6	2.1	3.8	2.5	0.9	1.1	0.8
Apr.16	20.8	20.7	20.7	8.0	7.9	8.0	5.6	5.8	5.4	29.2	28.8	28.4	1.9	2.0	2.1
Jul.16	30.0	29.9	29.6	8.8	8.7	8.6	2.9	3.7	2.9	29.3	29.0	28.74	1.0	1.0	1.0
Dec.16	18.2	18.3	18.1	7.8	7.7	7.7	5.2	5.9	4.7	32.5	30.2	28.5	1.2	1.0	1.0
Apr.17	14.4	14.5	14.5	7.2	7.2	7.2	9.2	9.6	9.6	0.2	0.1	0.1	0.8	0.8	0.8
Jun.17	24.1	19.6	23.3	7.3	7.3	7.4	4.9	9.0	5.8	35.2	32.1	11.2	0.9	0.9	0.9
Min	**12.9**	**11.9**	**12.2**	**7.0**	**7.2**	**7.2**	**2.9**	**3.7**	**0.7**	**0.2**	**0.1**	**0.1**	**0.8**	**0.8**	**0.8**
Max	**30.0**	**29.9**	**29.6**	**8.8**	**8.7**	**8.6**	**9.8**	**11.0**	**11.8**	**35.2**	**32.1**	**28.5**	**1.9**	**2.0**	**2.1**
Mean	**19.3**	**17.0**	**17.6**	**7.7**	**7.7**	**7.8**	**6.2**	**7.6**	**7.3**	**17.6**	**12.3**	**7.5**	**1.1**	**1.2**	**1.2**

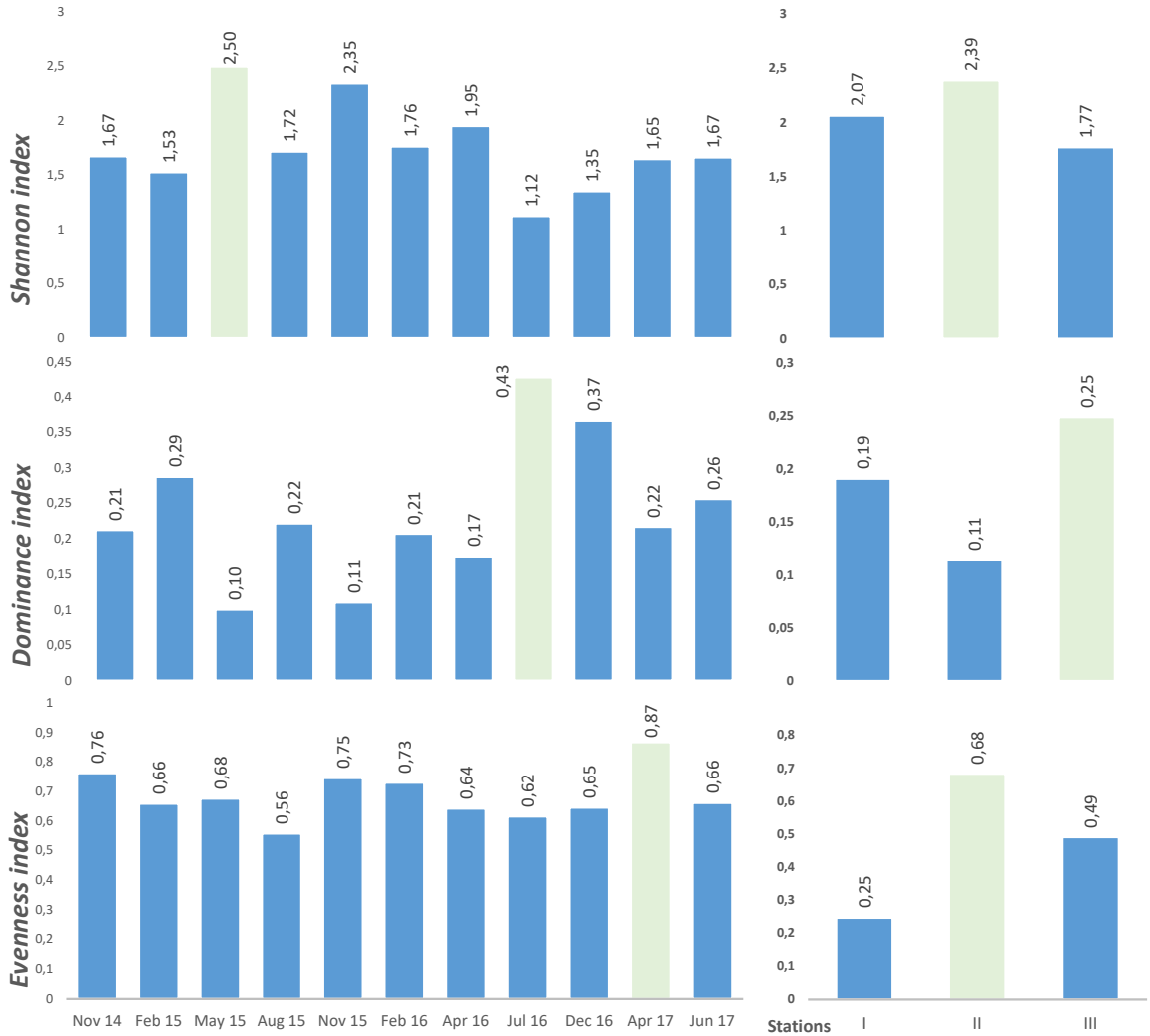

Fig. 2. Spatial and temporal variations of Shannon, Dominance and Evenness Indices.

The index values of Shannon-Weiner (H'), dominancy and evenness are shown in Figure 2. The number of Species varied from 9 (April 2017) to 23 (May 2015) in the Manavgat Estuary. Based on the Shannon-Wiener's diversity index (H'), the highest ecological diversity was recorded in May 2015 (2.5) and the lowest in July 2016 (1.12). The evenness index had its highest value in April 2017 (0.87) and the lowest in August 2015 (0.56). The dominancy index was analysed; the highest value was recorded in July 2016 (0.43), and the lowest in May 2015 (0.1). The number of species and values of the diversity index exhibited a strong spatial and temporal variation throughout the study. Fish abundance was highest in June 2017. The highest and lowest mean abundance values were obtained at Sites 1 and 3.

The conservation status of the estuarine fish in the Manavgat River revealed one critically endangered (CR) species, one endangered (EN) species, 23 species under the least concern (LC) category, and eight species not evaluated (NE) (IUCN 2023). Two threatened fish species were recorded in this study area. *Alburnus baliki* is classified in the endangered (EN) category, and *Anguilla anguilla* is classified as critically endangered (CR).

Discussion

According to this study, 33 species permanently or temporarily occupy the study area. The Manavgat River Estuary on the Mediterranean coast is among the major estuarine systems in Türkiye. Monitoring the fish diversity of this estuary is very important due to its ecological services provided to the coastal and freshwater ecosystems. Because there is limited information about the brackish waters flowing into the Levantine Sea, it was not possible to compare species numbers. Still, comparisons have been made with other reported brackish water regions world-

Table 2. List of fish species identified in the estuarine zone of the Manavgat River.

Table captions; origin 1, 2 (1-native; 2-alien); habitat 1, 2, 3, 4 (1-freshwater; 2-marine; 3-migrant; 4-estuarine); life cycles 1, 2, 3 (1-juvenile + adult individuals; 2- only adult individuals; 3-only juvenile individuals).

No	Species	Family	Origin	Habitat	Life cycles	Threat status	Occurrence (%)	Total	%	Rank
1	*Chelon auratus*	Mugilidae	1	2	1	(LC)	100	2526	32.368	1
2	*Chelon saliens*	Mugilidae	1	2	1	(LC)	90,9	1676	21.476	2
3	*Alburnus baliki*	Leuciscidae	1	1	1	(EN)	90,9	852	10.917	3
4	*Mugil cephalus*	Mugilidae	1	2	1	(LC)	100	818	10.482	4
5	*Chelon ramada*	Mugilidae	1	2	1	(LC)	81,8	347	4.446	5
6	*Anguilla anguilla*	Anguillidae	1	3	1	(CR)	100	299	3.831	6
7	*Pomatoschistus anatoliae*	Gobiidae	1	4	1	(NE)	81,8	295	3.780	7
8	*Dicentrarchus labrax*	Moronidae	1	2	1	(LC)	63,6	277	3.549	8
9	*Oncorhynchus mykiss*	Salmonidae	2	1	2	(NE)	72,7	143	1.832	9
10	*Pseudorasbora parva*	Gobionidae	2	1	1	(LC)	63,6	85	1.089	10
11	*Lithognathus mormyrus*	Sparidae	1	2	1	(LC)	72,7	84	1.076	11
12	*Chelon labrasus*	Mugilidae	1	2	2	(LC)	81,8	78	0.999	12
13	*Gambusia holbrooki*	Poeciliidae	2	1	1	(LC)	45,5	61	0.782	13
14	*Dicentrarchus punctatus*	Moronidae	1	2	2	(LC)	27,3	37	0.474	14
15	*Sillago suezensis*	Sillaginidae	2	2	2	(NE)	18,2	30	0.384	15
16	*Spicara smaris*	Sparidae	1	2	2	(LC)	9,1	24	0.308	16
17	*Engraulis encrasicolus*	Engraulidae	1	2	3	(LC)	18,2	20	0.256	
18	*Parablennius s anguinolentus*	Blenniidae	1	2	3	(LC)	36,4	20	0.256	
19	*Diplodus annularis*	Sparidae	1	2	2	(LC)	18,2	15	0.192	
20	*Carassius gibelio*	Cyprinidae	2	1	1	(NE)	9,1	14	0.179	
21	*Upeneus moluccensis*	Mullidae	2	2	2	(LC)	18,2	14	0.179	
22	*Upeneus pori*	Mullidae	2	2	2	(NE)	27,3	13	0.167	
23	*Squalius anatolicus*	Leuciscidae	1	1	3	(LC)	18,2	10	0.128	
24	*Oedalechilus labeo*	Mugilidae	1	2	2	(NE)	18,2	10	0.128	
25	*Salaria fluviatilis*	Blenniidae	1	2	1	(LC)	18,2	10	0.128	
26	*Vimba vimba*	Leuciscidae	1	1	2	(LC)	9,1	10	0.128	
27	*Boops boops*	Sparidae	1	2	2	(LC)	36,4	9	0.115	
28	*Planiliza carinata*	Mugilidae	2	2	2	(NE)	18,2	8	0.103	
29	*Siganus rivulatus*	Siganidae	2	2	2	(LC)	18,2	7	0.090	
30	*Sphyraena chrysotaenia*	Sphyraenidae	2	2	2	(NE)	18,2	7	0.090	
31	*Clarias gariepinus*	Clariidae	1	1	2	(LC)	9,1	2	0.026	
32	*Sparisoma cretense*	Scaridae	1	2	2	(LC)	9,1	2	0.026	
33	*Gobius niger*	Gobiidae	1	2	2	(LC)	9,1	1	0.013	

Table 3. Origin and introduction ways of species of non-native fishes in Manavgat Estuary.

No	Species	Name	Region of origin	Habitat of origin	Purpose of introduction
1	*Carassius gibelio* (Bloch, 1782)	Prussian carp	Asia	Freshwater	Accidental transfer
2	*Pseudorasbora parva* (Temminck & Schlegel, 1846)	Stone moroko	Far East	Freshwater	Accidental transfer
3	*Gambusia holbrooki* Girard, 1859	Eastern mosquitofish	North America	Freshwater	Biological Control
4	*Oncorhynchus mykiss* (Walbaum, 1792)	Rainbow trout	North America	Freshwater	Aquaculture (Farm escape)
5	*Planiliza carinatus* (Valenciennes 1836)	Keeled mullet	Indo-Pacific	Marine	Lessepsian migration
6	*Upeneus moluccensis* (Bleeker, 1855)	Goldband goatfish	Indo-Pacific	Marine	Lessepsian migration
7	*Upeneus pori* Ben-Tuvia & Golani, 1989	Por's goatfish	Indo-Pacific	Marine	Lessepsian migration
8	*Siganus rivulatus* Forsskål & Niebuhr, 1775	Marbled spinefoot	Indo-Pacific	Marine	Lessepsian migration
9	*Sillago suezensis* Golani, Fricke & Tikochinski, 2013		Indo-Pacific	Marine	Lessepsian migration
10	*Sphyraena chrysotaenia Klunzinger, 1884*	Yellow stripe barracuda	Indo-Pacific	Marine	Lessepsian migration

wide. The number of fish species in the Manavgat Estuary is lower than that in other ecologically similar locations, such as the Richmond River Estuary (Australia, 64 species) and the Clarence River Estuary (Australia, 66 species) (West & Walford 2000), the Strymon River Estuary (Greece, 43 species). There are, however, other estuaries that have been discovered to have a lower species count, such as 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 (New Zealand, 16 species), the Clutha River Estuary (New Zealand, 14 species), the Waiau River Estuary (New Zealand, 14 species) and the Mohako River Estuary (New Zealand, 13 species) (Jellyman et al. 1997). In the studies carried out by the author of this paper using the same sampling methods in the Göksu (32 species) (Innal et al., 2020) and Seyhan (30 species) (Innal, 2020) estuarine systems in Türkiye on similar dates, the number of species was found to be quite close. Comparisons of species numbers between different estuaries are difficult because sampling sites and methods vary. Fish occurrence, distribution, and movement in estuarine systems are unquestionably impacted by a complex interplay between biotic and abiotic variables (Martino & Able 2003; Jaureguizar et al. 2006).

The functional group of the Manavgat estuary was mainly composed of marine species in terms of number of species. The dominance of marine species in this system coincides with some other estuarine systems of Türkiye (Akin et al. 2005; Innal 2016). The present study implies that Mugilidae is the dominant fish family in the Manavgat River estuary, with exactly 70% of the catch. *Chelon auratus* and *Chelon saliens* were the most common species captured during the study. The Mugilidae species present a wide tolerance range towards variable environmental conditions (Thomson 1966). Mullet abundance and distribution throughout the sampling period could be attributed to their successful adaptation to their environment, low predation, a wide range of salinity tolerance, and a change in feeding habits. The dominance of the Mugilidae in the Manavgat River estuary is similar to many other estuaries worldwide, as previously reported (Koutrakis et al. 2000; Garcia et al. 2001; Akin et al. 2005; Innal 2016).

At the same time, juveniles of 16 species (*Alburnus baliki, Anguilla anguilla, Carassius gibelio, Dicentrarchus labrax, Gambusia holbrooki, Lithognathus mormyrus, Chelon auratus, Chelon ramada, Chelon saliens, Mugil cephalus, Pomatoschistus anatoliae, Pseudorasbora parva, Salaria fluviatilis, Squailius anatolicus, Engraulis encrasicolus,*

Parablennius sanguinolentus) were found in the Manavgat River estuary during this study. Some of the mentioned species are of marine origin. Estuaries have been shown to provide suitable habitats for juvenile fish (Vasconcelos et al. 2008), as they enhance the growth and survival of juvenile fish because they provide high food availability, low predation risk, warm water temperatures and protection from adverse weather conditions. The use of estuaries as a nursery area by 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.

The fish assemblage structure in the Manavgat River estuary differed significantly in different sampling periods. This study also shows the considerable changes in diversity during the study period. The wide range 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).

Two threatened fish species were recorded in the study area. This brackishwater system is also very important for the Antalya bleak (*Alburnus baliki)*, an endemic fish species that forms a dense population in this area. The European eel (*Anguilla anguilla*) uses this system as in other Mediterranean brackish water systems. Certain conditions in this system negatively affect the survival of *A. baliki* and *A. anguilla*, such as the numerous tourist boats on the Manavgat River, which travel long distances along the river. On certain days, more than 10 boats operate in the estuarine zone. During this study, the coloured oil layer from some boats could be seen on the water during specific periods. The second problem regarding boats is the foam entertainment organised on large boats during summer. The detergents used in these entertainments mix into the river water. During hotel construction, deterioration occurs in the coastal structure of the river. The nursery areas of the populations in the lower zone of the river are also threatened by the modification of the seashore for the construction of tourist buildings and new recreation areas. Trout farming is practised in the river's brackish zones, and the trout sampled in this study are considered individuals escaping from this area. Besides four non-native fish species of freshwater origin, six non-native marine fish have also been identified in this study. Additionally, the water used for agricultural irrigation has been taken from the upper zones of the study area. As a result, fish larvae and young individuals were removed from the river and moved to the agricultural field.

In conclusion, the Manavgat estuary has excellent spatial diversity and is inhabited by more than 23 native fish species, some very rare and previously unstudied. This area has been determined to be an important habitat for marine species, especially juvenile individuals. The coast of the Manavgat Estuary is highly impacted by various threats, including aquaculture, tourist activities, overpopulation along the coasts, many forms of pollution, and introduced species. The protection and management of this estuarine habitat are essential for the survival of native fish species.

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