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Distribution and length-weight relationships of the Mediterranean banded killifish (*Aphanius fasciatus*) in Mediterranean brackish water systems of Turkey

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Aphanius fasciatus (Valenciennes, 1821), is a cyprinodontid euryhaline fish occur in many brackish water habitats along the Mediterranean coasts. The current study aims to update the range of *A. fasciatus* (Mediterranean Killifish, South European Toothcarp) along river estuaries and lagoon systems of Mediterranean coast of Turkey, and to determine its length–weight relationship. A total of 15 sites were surveyed from November 2014 to June 2017. Altogether, 69 specimens were sampled and measured from different systems. At each locality, the general observations on the population, length-weight relationships, its situation and threats were presented.

[Keywords: Alien species, Gambusia, Lessepsian species, Mediterranean banded killifish]

Introduction

Due to its geographic structure and geologic features, Anatolia has various isolated aquatic environments, and thus harbours richest aquatic fauna in Eurasia. Iran and Anatolia are believed to be the center for diversification of genus *Aphanius*. Their natural distribution has also been affected by Mediterranean Sea level changes during glacial and interglacial periods[1]. In recent years, the distribution and systematics of *Aphanius* in Turkey have undergone numerous taxonomic changes and intensive investigations[2,3]. Except *A. fasciatus* and *A. mento,* all other species of genus *Aphanius* are endemic to Anatolia.

Aphanius fasciatus is a small fish with a relatively short life span. It shows an external sexual dimorfism. Additionally, this fish can tolerate a wide range of salinity and temperature[4,5]. Morphometric characteristics[6-10], parasite fauna[11], population structure and some growth properties[12-15], reproductive biology[16-18], genetic diversity[5,19,20], distribution and threats[21-23] to *A. fasciatus* have been investigated by several authors.

Status of fish assemblage composition and biological properties of species in Brackish water systems of Turkey are still poorly understood. The current study aims to update the range of Mediterranean banded killifish occurring in lagoon systems and river estuaries of Mediterranean coast in Turkey, and to determine the length–weight relationship of specimens.

Material and Methods

A total of 15 sites (Fig. 1 and Table 1), representing a variety of habitats (including mouths of river and creeks, canals of rivers and lagoonal areas), were repeatedly surveyed from November 2014 to June 2017.

Details (type, substrate structure, macrophyte vegetation density, flow regime, antropogenic activities) of habitats were recorded. Potential threats to *A. fasciatus* were grouped into 15 categories as follows; water quality problems, siltation, shoaling, drought, climatic problems, habitat degradation by agriculture, habitat degradation by urbanization, boat traffic problems, dams and weirs, migration barriers, water removal, overfishing, aquaculture facilities, coast engineering facilities, and exotic species. Those data were assessed through long term observation in indicated locations. The ichthyofauna of the systems was sampled using a shore seine net (10 m long and 2 m high; 1.2 x 2 mm mesh size). Fish species were identified according to identification keys previously described in the literature[24-26]. Exotic or introduced taxa were identified by Innal and Erk'akan[27].

At each location, the general observations on the population and its situation were also made. A total of 69 specimens of *A. fasciatus* were sampled and

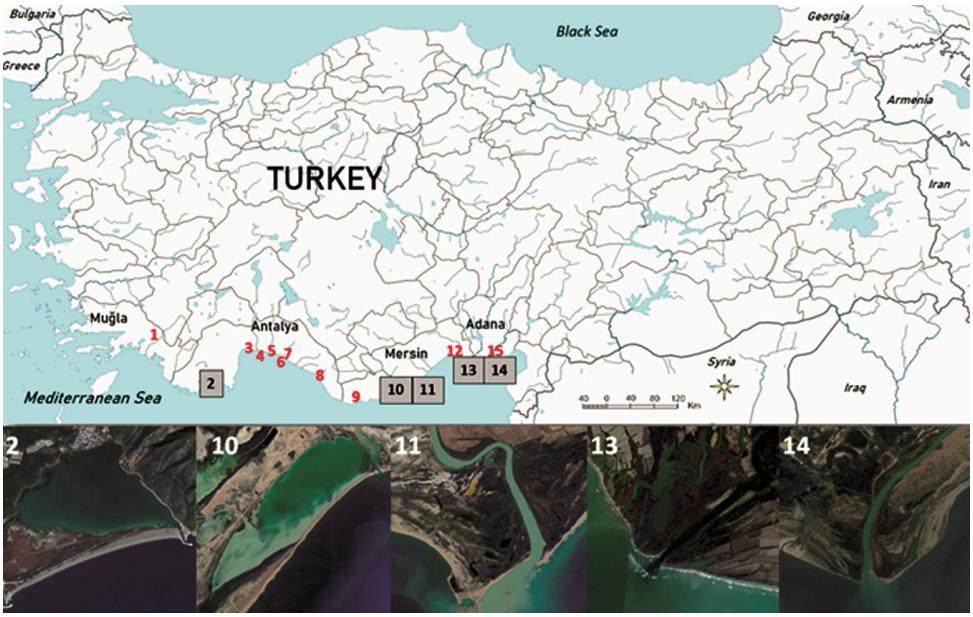

Fig. 1 — Map of Turkey showing localities and photographs of sample found localities from Google Earth
Localities: 1 - Köyceğiz Lagoon Lake; 2 - Beymelek Lagoon Lake; 3 - Kopak Creek Estuary; 4 - Beşgöz Creek Estuary; 5 - Köprüçay River Estuary; 6 - Manavgat River Estuary; 7 - Karpuzçay Creek Estuary; 8 - Hacımusa Creek Estuary; 9 - Sultansuyu Creek Estuary; 10 - Paradeniz Lagoon Lake; 11 - Göksu River Estuary; 12 - Berdan River Estuary; 13 - Seyhan River Estuary; 14 - Ceyhan River Estuary; 15 - Yelkoma Lagoon Lake. Note: The localities only *A. fasciatus* found were put in square in map, namely 2, 10, 11, 13, 14.

Table 1 — Description of sampling sites

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

measured from different systems. Specimens were measured to the nearest 0.1 cm total length (L) and weighed to the nearest 0.01 g total weight (W). Length-weight relationship was calculated using the equation $W = aL^{b}$[refs. 28,29], where, 'a' is a coefficient related to body form and 'b' is an exponent indicating isometric growth when equal to 3. The positive or negative allometric growth occurred when the b-value deviated significantly from 3. The significance of the b-value for all populations was tested by *t*-test.

Results

No specimens were recorded in the ten out of 15 localities during the surveys. The Mediterranean banded killifish was found only at five investigated localities *viz*. Beymelek Lagoon Lake, Paradeniz Lagoon Lake, Göksu River Estuary, Seyhan River Estuary and at Ceyhan River Estuary. Altogether, 69 specimens were sampled from 5 different brackishwater system of Turkey. Total length varied between 2.1 cm and 4.6 cm (Table 2).

The b values of the length-weight equations from three localities recorded ranged between 3.24 and 3.38. All length–weight relationships were significant ($p < 0.001$), with all r^2 values > 0.93.

Various threat factors (Table 3) were observed at all five different localities which are habitats of *A. fasciatus*. Three non-indigenous freshwater species

Table 2 — Locality, sample size, size range (cm, TL; gr, TW), length–weight parameters a, b and the determination coefficient (r^2)

Locality	N	TL (cm)	W(g)	a	b	r^2	
		Mean ± SD (min-max)	Mean ± SD (min-max)		Mean (95 % confidence interval)		Growth type
Göksu River	34	3.0 ± 0.35 (2.3-3.6)	0.32 ± 0.13 (0.138-0.681)	0.0087	3.2798 (3.2429-3.3106)	0.93	Positive allometric
Beymelek Lagoon	14	2.7 ± 0.68 (2.1-4.6)	0.26 ± 0.37 (0.089-1.506)	0.0068	3.3802 (3.3044-3.4596)	0.97	Positive allometric
Paradeniz Lagoon	14	3.1 ± 0.38 (2.4-3.8)	0.35 ± 0.16 (0.157-0.68)	0.0086	3.2418 (3.1827-3.2919)	0.93	Positive allometric
Seyhan River	5	2.9 ± 0.38 (2.5-3.5)	0.30 ± 0.15 (0.177-0.547)				
Ceyhan River	2	3.2 ± 0.35 (2.9-3.4)	0.41 ± 0.16 (0.3-0.529)				

Table 3 — Potential environmental problems in the sampling locations

Parameters	Locality				
	Beymelek	Paradeniz	Göksu	Seyhan	Ceyhan
Water quality problems	√	√	√	√	√
Siltation	√	√			
Shoaling	√	√			
Climatic problems	√	√	√	√	√
Drying up	√	√			
Habitat degradation by agriculture	√	√	√	√	√
Habitat degradation by urbanization			√	√	√
Boat traffic problems			√	√	√
Dams and weirs			√	√	√
Migration barriers	√	√	√	√	√
Water removal	√	√	√	√	√
Over fishing	√	√	√	√	√
Aquaculture facilities			√	√	√
Coast engineering facilities	√				
Alien species	√	√	√	√	√
Alien species					
Carassius gibelio			√	√	
Equulites klunzingeri		√		√	
Gambusia holbrooki	√	√	√	√	√
Liza carinata		√	√	√	√
Oreochromis niloticus		√	√	√	√
Siganus rivulatus	√				
Sillago suezensis			√		√

namely, Prussian carp, *Carassius gibelio* (Bloch, 1782); Eastern mosquitofish, *Gambusia holbrooki* Girard, 1859 and the Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758) were observed in the sampling sites. In addition to these freshwater species, several lessepsian species namely, *Equulites klunzingeri* (Steindachner, 1898); Keeled mullet, *Liza carinata* (Valenciennes, 1836); Marbled spinefoot, *Siganus rivulatus* Forsskål & Niebuhr, 1775 and *Sillago suezensis* Golani, Fricke & Tikochinski, 2013 were observed in the sampling areas.

Discussion

Aphanius species are significant ecological constituent within inland and brackish ecosystems. *A. fasciatus* is a cyprinodont species endemic to Mediterranean. It shows a distribution over the central and eastern coastal zones of the Mediterranean sea[30]. It has been recorded from Turkey in the past from a number of localities, including Seyhan river delta and a lagoon near Silifke[1]; lake Tuzla, Adana[31]; Izmir bay[32]; Küçükçekmece lagoon, Marmara region[33]; Gülbahçe bay, Izmir[10]; Seyhan dam lake[34]; Homa lagoon, and from Aegean sea[35]. The present investigation indicate that this species has been detected in five of 15 surveyed localities from Turkey.

A. fasciatus was present in very low abundance in five localities in this study. It is under considerable pressure from a range of anthropogenic activities. Agricultural activities and tourism are impoverishing the water quality. Water pollution and engineering facilities have also caused the loss of breeding sites of native fishes in the studied systems. Due to water pollution, dead fish were observed in Seyhan river estuary in several times (Personal observation of Deniz Innal during Tubitak Project between 2014 and 2017). Similarly, many studies[21,23,36,37] reported that Mediterranean populations of *A. fasciatus* were threatened by the various antropogenic activities.

Another issue is the introduction of non-indigenous species, which poses threats to the local ecosystems. This study showed that *Gambusia holbrooki* (Eastern mosquitofish) shares the same habitat with *A. fasciatus* in all sampling sites. The presence of *G. holbrooki* might cause competition for habitat use and food sources. *Gambusia holbrooki* was found in a variety of lotic and lentic habitats in the previous studies. It is one of the most invasive alien vertebrates. Several studies have shown that introduced mosquito fish have an adverse affect on native species[38-41]. Valdesalici *et al.*[23] reported that the populations of *A. fasciatus* were decreased due to habitat degradation and owing to the competition with the introduced poeciliid *G. holbrooki*. Caiola and de Sostoa[42] found that Eastern mosquitofish showed a negative impacts on the biology of two native toothcarp species. Further, Duchi[43] indicated that occurrence of *G. holbrooki* effected distribution of *A. fasciatus.*

Brackish water systems play a crucial role in the life span of *A. fasciatus*. Population decline of *A. fasciatus* have been documented in many areas of Mediterranean Coast[37,44]. Although the threat status of *A. fasciatus* was determined as least concern (LC)[45], this category does not seem to be appropriate for Mediterranean population in the current study. Besides, the abundance of *A. fasciatus* is found to be low in this study, there are many other threats threatening this species in the studied areas apart from the invasive species.

Altogether 69 specimens were sampled and measured from different aquatic systems. The analysis length weight relationships during the present study reported b value within the range of 3.24-3.38 and remained within the expected range of 2.5-3.5[29]. In addition to the present study, Table 4 gives a

Table 4 — Length weight relationships of *A. fasciatus* from literature

Country	N	Sex	Length	a	b	References
			Range-cm			
Croatia	10	All	2.8-5.3	0.0099	3.312	(46) Dulcic and Glamuzina, 2006
Egypt		Male		0.0156	2.74	(47) Penaz and Zaki, 1985
Egypt		Female		0.0068	3.619	(47) Penaz and Zaki, 1985
Greece	648	All	2.0-6.4	0.01	3.18	(12) Leonardos, 1996
Greece	911	All	2.0-7.0	0.0088	3.43	(12) Leonardos, 1996
Greece	451	All	2.0-7.2	0.0086	3.45	(12) Leonardos, 1996
Greece	16	All	2.9-5.2	0.0098	3.312	(48) Koutrakis and Tsikliras, 2003
Turkey	173	All	1.35-6.39	0.00000365	3.4	(10) Sarı *et al*., 2007
Turkey	143	All	2.7-7.1	0.006	3.532	(32) Özaydın and Taşkavak, 2006
Turkey	11	All	3.8-5.3	0.0182	2.94	(33) Tarkan *et al.*, 2006
Turkey	178	All	1.6-4.0	0.006	3.65	(35) Acarlı *et al.*, 2014

comparison of published growth parameters in different regions for the *A. fasciatus*. The b value of the LWR equations of *A. fasciatus* shows that the growth is positive allometric[28]. Similar results were found for the *A. fasciatus* from Croatia, Greece and Turkey[10,12,32,35,46-48]. Moreover some differences in length-weight relationships between sampling localities were reported for *A. fasciatus*. The observed difference could be due to the sample size, sampling procedure, sex ratio and length range or might be due to ecological and environmental factors.

There have been gaps in distribution data for *A. fasciatus* in Turkish coasts. This study documents an update on the distribution of *A. fasciatus* from the Mediterranean brackish water systems of Turkey, with an emphasis on some potential threats to the species. Effects of these threats need to be better explored and understood with further studies.

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