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Some morphometric features of congeneric pipefish species (*Syngnathus abaster* Risso 1826, *Syngnathus acus* Linnaeus, 1758) distributed in Lake Bafa (Turkey)

by

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Abstract

The study was carried out between November 2014 and March 2016 to determine certain morphometric characteristics of two pipefish species occurring in Lake Bafa, *Syngnathus abaster* and *Syngnathus acus*. A total of 211 pipefish were captured during the sampling, including 77 individuals of *S. abaster* (♀: 25; ♂: 44; immature: 8) and 134 individuals of *S. acus* (♀: 31; ♂: 76; immature: 27). The male-female ratios were 1:1.76 and 1:2.45, respectively. A difference was found in sex ratios between the two species ($p < 0.05$). The mean length of the captured fish was 86.63 ± 16.77 mm for *S. abaster* and 82.63 ± 16.02 mm for *S. acus* and the relationship between the total length and weight, referred to as the length-weight relationship, was as follows: $W = 0.00000001L^{3.71}$ ($R^2 = 0.89$), and $W = 0.000000007L^{3.86}$ ($R^2 = 0.83$), respectively. Seven morphometric characteristics were analyzed. The analyses revealed that *S. acus* and *S. abaster* were significantly different from each other in terms of their body depth ($p = 0.006$; $p < 0.05$), mouth width ($p = 0.004$; $p < 0.05$) and height ($p = 0.008$; $p < 0.05$). High correlation values were obtained for TL/BD and TL/HD in *S. abaster* and *S. acus*, respectively ($r > 1$).

In conclusion, among the congeneric species occurring in Lake Bafa, *S. abaster* and *S. acus* are characterized by a shorter head length and total length compared to their sea counterparts.

Key words: morphometry, morphological difference, *Syngnathus abaster*, *Syngnathus acus*

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Introduction

Pipefish are a member of the Syngnathidae family and an important component of the fish fauna, due to their tolerance to high temperature and salinity (Kornienko 2001; Hablützel, Wilson 2011) in estuarine areas and shallow coastal waters (Howard, Koehn 1985). Pipefish belong to the same family as seahorses and are widely used in many parts of the world, mainly in aquariums, ornamental items, and as a raw material in the traditional Chinese medicine in the Far East (Payne et al. 1998). Therefore, the species is threatened by excessive hunting and deterioration of their habitats. *Syngnathus acus* and *Syngnathus abaster* are among typical small and cryptic fish of epibenthic habitats with abundant vegetation (Kuiter 2000).

Syngnathus acus can be found in sandy-muddy and densely vegetated habitats of continental and estuarine areas (Dawson 1986), while *S. abaster* (an euryhaline form) occurs in similar habitats of the open sea, brackish and fresh waters (Movčan 1988; Kuiter 2001; Cakić et al. 2002; Hablützel, Wilson 2011). These species are included in the Least Concern (LC) category of the Red Data Book (IUCN 2016) and they are important ecological examples, because of their sex-role reversal, parental care, single or multiple spawning seasons (Franzoi et al. 1993; Taylan et al. 2018), in addition to habitat sharing with other pipefish species (Campolmi et al. 1996; Curtis,Vincent 2005; Malavasi et. 2007).

Morphometric characteristics are important details revealing the structure and properties of fish stocks (Turan 2004). The degree of morphological diversity at the species or population level is evaluated by referring to morpho-ecological results of studies relating to the genetic structure (Chan 2001; Cakić et al. 2002). Length-weight and length-length relationships are frequently used in ichthyological studies to analyze fish stocks (Ricker 1975). These parameters enable local and regional comparisons of populations and species.

Over the last decade, studies focusing on morphometric characteristics of pipefish have gathered momentum (Cakić et al. 2002; Mwale 2005; Gurkan 2008; Gurkan, Taşkavak 2012; Yildiz et al. 2015; Khrystenko et al. 2015). However, no studies have been found in relation to different coastal areas of Turkey, except for those carried out in the Aegean and Black Sea regions. The objective of this study was to determine the morphometric characteristics of the *S. acus* and *S. abaster* populations in Lake Bafa.

Materials and methods

Lake Bafa is a natural barrier lake situated in the southeast region of the Büyük Menderes River delta, with an indented coastline. The sampling was carried out by seining in the coastal area of the Kapıkırı region (37°30′N, 27°31′E–37°29′N, 27°31′E) of the lake at depths not exceeding 1–1.5 m (Fig. 1).

Figure 1

Study area (□: Kapıkırı region in Lake Bafa)

Pipefish samples were seasonally collected from the study area between November 2014 and March 2016 by seining in the coastal area at depths up to 1.5 m. Regulations of the ethical committee were followed during the capturing and processing of the fish species. The captured fish samples were transported to the laboratory in sealed vessels containing 70% ethanol. In the laboratory, total lengths of fish specimens (TL, mm) were measured using a measuring board, weights (W, g) were determined using a scale with 0.01 g sensitivity, and morphometric measurements were performed using a digital caliper with 0.001 mm sensitivity. Sexes of the pipefish specimens were macroscopically determined and the sex ratio of the captured species was calculated for the sampling area.

The total length-weight relationship of the samples was determined according to the procedure proposed by Ricker (1975). The length-weight relationship for the total body weight was calculated using the equation $W = aL^b$, where W is the weight (g), L is the length (TL, mm), *a* is the intercept, and *b* is the slope. The determination coefficient (R^2) was used to calculate the degree of association between the variables. The parameters a and b were determined by linear regression on the (Log10) equation:

$$log(W) = log(a) + b\ log(L)$$

The significance of the regression was assessed by ANOVA, and the *b* value for each species was tested by t-test. Growth types were assigned to the values of b that are different from 3 (positive allometric if $b > 3$; negative allometric if $b < 3$; isometric if $b = 3$).

A total of 69 adult *S. abaster* and 107 adult *S. acus* samples were included in the analysis of morphometric characteristics. Immature individuals were ignored. The principles introduced by Cakić et al. (2002) were followed during the morphometric measurements. Moreover, the regression relationship (R^2) of the transformation equations for morphometric characteristics and length was determined (Sokal, Rohlf 1981). The t-test was used to determine the morphometric relationships between the species. The statistical differences between the sexes were analyzed using the Chi-square test (χ^2).

Results

A total of 77 *S. abaster* (♀: 25; ♂: 44; immature: 8) and 134 *S. acus* (♀: 31; ♂: 76; immature: 27) samples were analyzed in the present study. The male-female ratios were 1:1.76 and 1:2.45, respectively. A difference was found between *S. abaster* ($\chi^2 = 65.757$; $p < 0.05$) and *S. acus* ($\chi^2 = 116.213$; $p < 0.05$). The total length values ranged from 55 mm to 130 mm (mean ± SD: 86.63 ± 16.77 mm) for *S. abaster* and from 54 mm to 125 mm (mean: 82.63 ± 16.02 mm) for *S. acus*. The total length-weight relationship in *S. abaster* and *S. acus* samples were calculated as follows: $W = 0.00000001\ TL^{3.71}$ ($R^2 = 0.89$) (Fig. 2) and $W = 0.000000007\ TL^{3.86}$ ($R^2 = 0.85$) (Fig. 3), respectively.

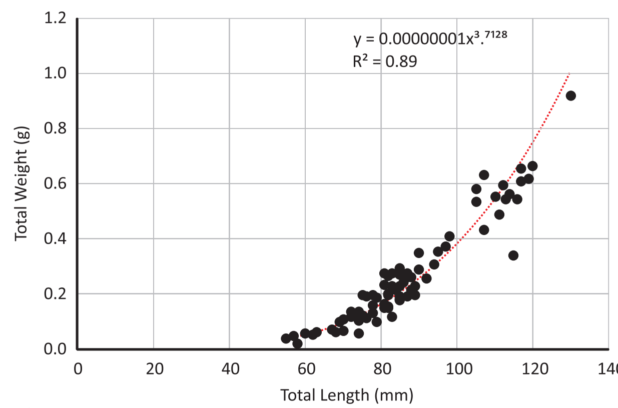

Figure 2

Length-weight relationship in *S. abaster*

The relationships (linear regressions) were significant for both species ($p < 0.05$), with R^2 values greater than 0.95. The regression analysis showed that both *S. abaster* (mean: 3.408 ± 0.026; 95% CI) and *S. acus* (mean: 3.406 ± 0.028; 95% CI) had positive allometric growth.

In total, 69 adult *S abaster* and 107 adult *S. acus* samples were included in the analysis of morphometric characteristics. The results of comparative measurements of other body parts corresponding to the total length are shown in Table 1. According to the t-test results, the body depth – BD ($t_{0.05(206)}$) = 2.729

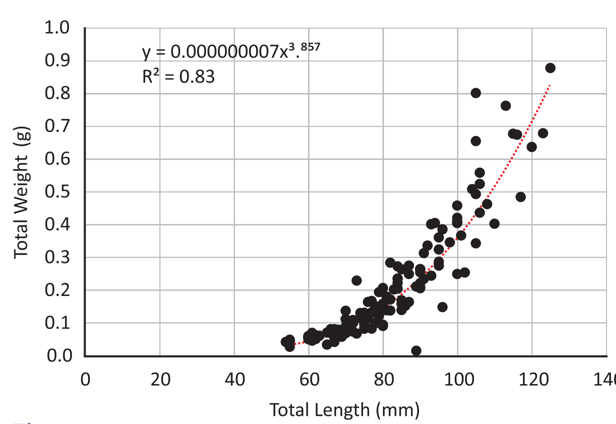

Figure 3

Length-weight relationship in *S.acus*

Table 1

Morphometric features of *S. abaster* and *S. acus* occurring in Lake Bafa (M – mean; SD – standard deviation)

Morphometric features	*Syngnathus abaster*		*Syngnathus acus*		
	Range (mm)	M ± SD	Range (mm)	M ± SD	*p*
Total Length	55–130	86.7 ± 7.80	54–125	92.7 ± 18.09	$p > 0.05$
Head Length	6.4–16.3	10.19 ± 3.30	6.5–13.5	2.76 ± 2.25	$p > 0.05$
Head Depth	1.4–5.4	2.70 ± 10.09	1.2–4.5	2.44 ± 14.60	$p > 0.05$
Body Depth	1.0–6.6	2.48 ± 1.31	0.7–5.1	2.04 ± 10.78	$p < 0.05$
Body Width	1.6–4.5	2.86 ± 11.58	1.1–5.1	2.73 ± 12.51	$p > 0.05$
Mouth Width	0.43–2.5	1.12 ± 18.28	0.3–2.4	0.94 ± 0.36	$p < 0.05$
Mouth Height	1.1–2.6	2.20 ± 2.36	0.8–3.3	1.42 ± 21.9	$p < 0.05$

$p < 0.05$ – significant differences

($p = 0.006$), the mouth width – MW ($t_{0.05(210)}$) = 2.953 ($p = 0.004$) and the mouth height – MH ($t_{0.05(210)}$) = 2.652 ($p = 0.008$) were different among the morphometric characteristics of all samples from two species, which leads to the conclusion that the body depth of *S. abaster* was greater than that of *S. acus* and the mouth structure of *S. abaster* was bigger than that of *S. acus*.

The regression analysis for *S. abaster* (Table 2) yielded the highest correlation ($R^2 = 0.81$) between the total length (TL) and the body depth (BD), while the lowest correlation ($R^2 = 0.22$) between the head length (HL) and the mouth height (MH). Therefore, the body depth explained closely the total length, but the increase in the head length (HL) could not be explained by its relationship with the mouth height (MH).

In the case of *S. acus*, the highest correlation (R^2) was determined between the total length (TL) and the head depth (HD), while the lowest one between the head length (HL) and the mouth width (MW). The correlation value suggests that the total length was explained by the head depth, as opposed to the relationship between the head length (HL) and the mouth width (MW), which fails to explain the evident increase in the head length.

Tables 3 and 4 show the comparison of the morphometric characteristics between the sexes. According to the t-test results, the difference between the body width of the sexes was statistically significant for both *S. abaster* ($t_{(0.05)(63)} = 2.752$; $p = 0.008$) and *S. acus* ($t_{(0.05)(91)} = 2.168$; $p = 0.032$).

Discussion

In this study, selected morphometric characteristics of *S.abaster* and *S. acus* species in Lake Bafa were investigated in relation to the species and the sex of the specimens examined. The male to female ratios for *S.abaster* and *S. acus* were determined as 1:1.76 and 1:2.45, respectively. The sex ratios were found to be higher than those reported in other studies (Vincent et al. 1995; Silva 2008; Gurkan et al. 2009). This may be

Table 2

Length-length relationship values for specimens of *S. abaster* and *S. acus* (CI – Confidence Intervals; F – observed)

	Variables	R^2	Formulas	CI (95%)	F	*p*
Syngnathus acus	Ln TL/HL	0.500	Y = –4.535 + 2.790x	–6.328; –2.741	38.015	$p < 0.05$
	Ln TL/BD	0.568	Y = 1.706 + 0.236x	1.228; 2.184	52.179	$p < 0.05$
	Ln TL/BW	0.55	Y = 1.499 + 0.221x	1.052; –1.945	46.140	$p < 0.05$
	Ln TL/HD	0.597	Y = –2.529 + 1.510x	–3.327; 1.103	56.275	$p < 0.05$
	Ln HL/MW	0.169	Y = 0.132 + 0.47x	0.36; –0.228	7.721	$p < 0.05$
	Ln HL/MH	0.522	Y = –0.37 + 0.41x	0.188; 0.354	43.509	$p < 0.05$
Syngnathus abaster	Ln TL/HL	0.778	Y = –1.109 + 0.189x	0.901; 1.289	131.028	$p < 0.05$
	Ln TL/BD	0.809	Y = –4.210 + 0.376x	1.970; 2.743	152.915	$p < 0.05$
	Ln TL/BW	0.367	Y = –1.040 + 0.325x	–1.698; –0.382	20.888	$p < 0.05$
	Ln TL/HD	0.745	Y = –1.718 + 0.215x	–2.155; 0.897	105.071	$p < 0.05$
	Ln HL/MW	0.642	Y = 0.986 + 0.564x	0.961; 0.422	64.571	$p < 0.05$
	Ln HL/MH	0.219	Y = 1.006 + 0.020x	0.965; 1.046	10.095	$p < 0.05$

$p < 0.05$ – significant differences

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Table 3

Morphometric features of sexes, *Syngnathus abaster* (N – sample size; M – mean; SD – standard deviation)

Morphometric features	Males			Females			p
	N	Range	M ± SD (mm)	N	Range	M ± SD (mm)	
Total Length	25	74–117	93.94 ± 14.79	44	72–130	97.58 ± 18.45	$p > 0.05$
Head Length	25	8.76–15.08	11.38 ± 1.80	40	11.95–6.73	11.94 ± 2.87	$p > 0.05$
Head Depth	25	2.35–4.24	3.08 ± 0.55	40	2.11–5.38	3.28 ± 0.900	$p > 0.05$
Body Depth	24	1.26–4.62	2.74 ± 0.99	40	1.33–6.64	3.41 ± 1.75	$p > 0.05$
Body Width	24	1.56–4.47	2.67 ± 0.59	40	1.88–3.86	2.88 ± 0.56	$p < 0.05$
Mouth Width	25	0.90–1.66	1.30 ± 0.25	40	0.63–2.52	1.45 ± 0.54	$p > 0.05$
Mouth Height	23	1.35–2.74	1.87 ± 0.36	40	1.12–3.24	1.90 ± 0.65	$p > 0.05$

$p < 0.05$ – significant differences

Table 4

Morphometric features of sexes, *Syngnathus acus* (N – sample size; M – mean; SD – standard deviation)

Morphometric features	Males			Females			p
	N	Range	M ± SD (mm)	N	Range	M ± SD (mm)	
Total Length	31	82–117	98.16 ± 12.32	76	73–125	99.35 ± 14.87	$p > 0.05$
Head Length	31	9.88–13.91	11.88 ± 1.53	52	7.05–15.33	11.97 ± 2.43	$p > 0.05$
Head Depth	31	2.56–3.83	3.16 ± 0.43	52	2.25–4.50	3.24 ± 0.64	$p > 0.05$
Body Depth	31	1.27–4.10	2.77 ± 0.87	52	1.510–5.06	2.98 ± 1.11	$p > 0.05$
Body Width	31	1.58–3.58	2.71 ± 0.59	52	2.16–4.51	3.30 ± 0.76	$p < 0.05$
Mouth Width	31	0.72–2.36	1.28 ± 0.45	52	0.85–1.97	1.39 ± 0.34	$p > 0.05$
Mouth Height	31	1.19–2.32	1.68 ± 0.34	52	1.27–3.34	2.01 ± 0.53	$p > 0.05$

$p < 0.05$ – significant differences

due to the number of males and females carrying eggs, as well as the fact that females have a higher potential reproductive rate than males (Silva 2008).

Since the early 2000s, a growing number of studies have shown that the length and weight values of the pipefish species vary depending on the region of their distribution (Table 5). The results of this study were compared with the results obtained in the studies carried out in the last decade (Gurkan, Taskavak 2007; Gurkan, Çulha 2008; Veiga et al. 2009; Gurkan et al. 2010; Keskin, Gaygusuz 2010; Altin et al. 2015; Yildiz et al.2015; Khrystenko et al. 2015; Taylan et al. 2018). The minimum length values of *S. acus* occurring in Lake Bafa were higher than those reported in the studies by Gurkan & Taskavak (2007), Liousia et al. (2012), and Vieria et al. (2014) and lower than those reported by Altin et al. (2015) and Yildiz et al. (2015). Similar results were also observed for *S. abaster*. The minimum length values obtained in this study were higher than those obtained by Veiga et al. (2009), Gurkan et al. (2010), Keskin & Gaygusuz (2010), and Ben Amor et al. (2011), and lower than those obtained by Altin et al. (2015).

The species *S. acus* and *S. abaster* occurring in Lake Bafa showed positive allometric growth ($b > 3$). The total length-weight relationship revealed that the *S. abaster* samples from Lake Bafa showed a lower growth rate compared to the population in the Black Sea (Cakić et al. 2002) and a higher growth rate compared to the population in the Dnieper reservoir (Khrystenko et al. 2015). The length-weight relationship in the *S. acus* samples showed that the growth value of the samples was lower compared to that of the Aegean (Gurkan, Taskavak 2007) and Black Sea populations (Yildiz et al. 2015). The differences in the growth values are attributable to biotic and abiotic factors (Tesch 1971). The difference between the length-weight relationships is due to the regional and seasonal changes, the sampling type and time, physicochemical parameters, sex, habitat, reproduction time, and presence of nutrients in the environment (Tesch 1971).

The difference in the body depth is the most distinct morphometric difference between *S. abaster* and *S. acus* samples ($p = 0.0056$; $p < 0.05$) – *S. abaster* has a greater body depth compared to *S. acus*. According to Dawson (1986), the body depth is an important morphological characteristic in the identification of the pipefish species. This is also evident in the macroscopic identification of two species sharing the same habitat.

In *S. abaster*, a high correlation was determined for the morphometric characteristics denoted as TL/BD and TL/HL ($R^2 > 0.78$ and $R^2 > 0.81$, respectively; $p < 0.05$). Furthermore, there are studies arguing that some differences in morphometric characters are related to the head region of the fish (Cakić et al. 2002; Khrystenko et al. 2015). The differences in the head

Table 5

Selected studies and their results on the two species from Turkey and other parts of the world

Species	Locality	N	Range		a	b	r	Reference
			TL (cm)	W (g)				
S. abaster	Strymon estuary	12	7.8–13.2		0.0003	3.156	0.962	Koutrakis & Tsikliras 2003
S. acus	Porto-Lagos lagoon	5	8.3–12.4		0.0001	3.729	0.958	
S. abaster	Spain	1260	1.3–10.9		0.00068	2.922	0.970	Verdiell-Cubedo et al. 2006
S. abaster	Iberian Peninsula	64	3.9–12.1	0–0.7	0.0004	3.1201	0.926	Morey et al. 2003
S. acus	Moray firth	4			0.00006	3.527		Coull et al. 1989
S. acus	Spain	225	11–29.3		0.00072	2.8831	0.958	Valle et al. 2003
S. acus	İzmir Bay	570	3.3–25.6	0.01–12.29	0.0001	3.43	0.91	Gurkan & Taşkavak 2007
S. acus	İzmir Bay	310			0.0001	3.43	0.89	Gurkan 2004
S. acus	İzmir Bay	202	6.1–20.7	0.07–4.49	0.0001	3.63	0.97	Özaydın & Taşkavak 2006
S. abaster	Arade estuary, southern Portugal	57	2.9–10.5		0.00015	3,53	0.963	Veiga et al. 2009
S. acus	Arade estuary, southern Portugal	66	7.1–34.6		0.00020	3.33	0.989	
S. abaster	Candarli Bay (north Aegean Sea)	9	2.78–10.60	0.08–0.78	0.0015	2.859	0.739	Gurkan et al. 2010
S. acus	Candarli Bay (north Aegean Sea)	77	5.40–21.20	0.06–4.98	0.0003	3.256	0.912	
S. abaster	Erdek Bay (Sea of Marmara, Turkey)	298	4.5–15.1		0.0002	3.181	0.901	Keskin & Gaygusuz 2010
S. acus	Erdek Bay (Sea of Marmara, Turkey)	15	10.3–37.8		0.0004	3.069	0.964	
S. abaster	River Strymon (Northern Greece)Estuary	137	3.6–13.5		0.0002	3.42	0.982	Petriki et al. 2011
S. abaster	Eastern Ionian Sea	419	2.2–22.1		0.00031	3.22	0.95	Liousia et al. 2012
S. acus	Eastern Ionian Sea	390	2.6–24.8		0.00032	3.30	0.97	
S. abaster	Gökçeada Island	10	11.3–17	0.49–1.72	0.000	3.359	0.907	Altın et al. 2015
S. acus	Gökçeada Island	12	11.4–25.5	0.04–6.75	0.000	3.592	0.956	
S. acus	Western Black Sea	280	15.6–39.2		0.0001	3.415	0.898	Yildiz et al. 2015
S. acus	South Africa	133	4.6–21.6		0.00038	3.074	0.961	Harrison 2001
S. acus	Croatia	22	7.6–13.9		0.0004	3.122	0.958	Dulčić & Glamuzina 2006
S. abaster	Kremenchug Reservoir,	60	0.69–1.32	0.18–1.20	0.0004	3.131	0.865	Khrystenko et al. 2015
S. abaster		60	0.69–1.31	0.15–1.53	0.0003	3.241	0.778	
S. abaster	Dneprodzerzhinsk Reservoir	60	0.86–1.41	0.23–1.41	0.0003	3.167	0.919	
S. acus	Turkey	17	21.3–28.4	4.51–11.92	0.0003	3.115	0.926	Bok et al. 2011
S. acus	Black Sea	4	25.7–33.9	2.19–13.97				Kasapoğlu & Düzgüneş 2014
S. abaster	Tunisian waters	104	7–19.8	0.19–3.32	3.4×10^{-6}	2.62	0.85	Ben Amor et al. 2011
S. acus	Tunisian waters	267	7.1–20.7	0.13–3.83	3.07×10^{-6}	2.64	0.86	
S. abaster	Iberian coast	579	3.7–11	0.02–1.0	0.00025	3.36	0.956	Vieria et al. 2014
S. acus	Iberian coast	529	3.6–41.4	0.02–54.57	0.00020	3.34	0.980	

region are regarded as an adaptation to feeding in the habitat in which the species is found (Mitrofanov 1977). Syngnathid species feed on small planktonic and benthic prey items using their pipe-like mouth structure. This adaptation of the feeding apparatus in the mouth is specialized in catching the mobile prey (Franzoi et al. 1993; Kendrick, Hyndes 2005). The same specialization applies to the lotic systems (Khrystenko et al. 2015).

Among the morphometric characteristics of *S. acus*, TL/HD shows higher correlation ($R^2 > 0.59$; $p < 0.05$). In contrast with other species, morphometric characteristics of *S. acus* show higher correlation with the total length. For the *S. acus* populations in Europe and South Africa, Mwale (2005) and Yildiz et al. (2015) interpreted the same situation in a similar manner. According to Mwale (2005), differences in the body size of *S. acus* are an important source of morphological variation. It can therefore be argued that a difference in any of the morphological characteristics may lead researchers to the conclusion that species adapt to the habitat in which they live.

In both species, the differences between the sexes in terms of the body width are statistically significant ($p < 0.05$). Morphological differences between species are regarded as a phenotypic response to the habitat structure in which they live. According to Cakić et al. (2002), the morphological differences in *S. abaster* result from the aquatic system from which the species originates, whereas according to Khrystenko et al. (2015), *S. abaster* is more adapted to lotic ecosystems rather than lentic ones in terms of the manifested morphological differences. According to Silva (2008), females are bigger than males. This results mainly from the sexual dimorphism observed in *S. abaster*. The morphological difference between the sexes of *S. acus* in Lake Bafa can be examined from the same perspective. However, no morphometric differences between the sexes were reported in the study of the *S. acus* population from the Aegean Sea (Gurkan 2008). The morphometric differences between the sea populations and lake populations of *S. acus* were attributed to the aquatic ecosystem from which the species originates.

In conclusion, the two pipefish species occurring in Lake Bafa, *S. abaster* and *S. acus*, have a shorter head length and total length compared to their sea counterparts. To summarize, this study presents important morphological results, which can be used in the precise identification of the congeneric pipefish species occurring in the lacustrine environment. Therefore, the information presented in the study will contribute to other studies focusing on similar ecosystems.

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References

Altin A., Özen, Ö. & Ayyildiz, H. (2015). Temporal Variations of the Demersal Fish Community in the Shallow Waters of Çanakkale Strait, North Aegean Sea, during the Course of a Mucilage Event. *Turkish Journal of Fisheries And Aquatic Sciences* 15: 359–365.

Ben Amor, M.M., Ben Salem, M., Reynaud, C. & Capape, C. (2011). Length-weight relationships in syngnathid species from Tunisian waters (central Mediterranean). *Marine Biodiversity Records* 4(e44): 1–4.

Bok, T.D., Göktürk, D., Kahraman, A.E., Alıçlı, T.Z. & Acun, T. (2011). Length-Weight Relationships of 34 Fish Species from the Sea of Marmara, Turkey. *Journal of Animal of Veterinary Advances* 10(23): 3037–3042.

Cakič, P., Lenhardt, M., Mićković, D., Sekulić, N. & Budakov, L.J. (2002). Biometric analysis of *Syngnathus abaster* populations. *Journal of Fish Biology* 60: 1562–1569.

Campolmi, M., Franzoi, P. & Mazzola, A. (1996). Observations on pipefish (Syngnathidae) biology in the Stagnone lagoon (west Sicily). *Publicaciones Especiales Instituto Espanol Oceanografia* 21: 205–209.

Chan, M. D. (*2001*)*. Fish ecomorphology: Predicting habitat preference of steram fishes from their body shape*. Unpublished doctoral dissertation, Virginia Polytechnic Institute and State University.

Coull, K.A., Jermyn, A.S., Newton, A.W., Henderson, G.I. & Hall, W.B. (1989). Length/Weight Relationships for 88 Species of Fish Encountered in the North Atlantic. *Scottish Fisheries Research Report* 43: 80.

Curtis, J.M.R. & Vincent, A.C.J. (2005). Distribution of sympatric seahorse species along a gradient of habitat complexity in a seagrass-dominated community. *Marine Ecology Progress Series* 291: 81–91.

Dawson, C.E. (1986). Syngnathidae. In Fishes of the North-eastern Atlantic and the Mediterranean. In P.J.P. Whitehead, M.L. Bauchot, J.C. Hureau, J. Nielsen & E. Tortonese (Eds.), (628–639 pp.). Paris: Unesco.

Dulčić, J. & Glamuzina, B. (2006). Length-weight relationships for selected fish species from three eastern Adriatic estuarine systems (Croatia). *Journal of Applied Ichthyology* 22: 254–256.

Franzoi, P., Maccagnani, R., Rossi, R. & Ceccherelli, V.U. (1993). Life cycles and feeding habits of *Syngnathus taenionotus* and *S. abaster* (Pisces, Syngnathidae) in a brackish bay of the PO River Delta (Adriatic Sea). *Marine Ecology Progress Series* 97: 71–81.

Gurkan, Ş. (2004). *Investigations on the Ecomorphologic characteristics of the pipefish (Familia: Syngnathidae) Distributing in the Çamalti Lagoon (İzmir Bay).* Unpublished doctoral dissertation, Ege University, Department of Hydrobiolgy, İzmir.

Gurkan, Ş. & Taşkavak, E. (2007). Length-weigth relationships for syngnathid fishes of the Aegean Sea, Turkey. *Belgian Journal of Zoology* 137(2): 219–222.

Gurkan, Ş. (2008). The biometric analysis of pipefish species from Çamaltı Lagoon (İzmir Bay, Aegean Sea). *Ege Journal of Fisheries* and *Aquatic Sciences* 25: 53–56.

Gurkan, Ş. & Çulha, M. (2008). Regional and seasonal distributions of some Syngnathid species in the coastal waters of Sinop peninsula (Black Sea). *Journal of Fisheries Science* 2: 536–544.

Gurkan, S., Taskavak, E. & Hossucu, B. (2009). The reproductive biology of the Great Pipefish *Syngnathus acus* (Family: Syngnathidae) in the Aegean Sea. *North-Western Journal of Zoology* 5(1): 179–190.

Gurkan, Ş., Bayhan, B., Akçınar, S.C. Taşkavak, E. (2010). Length-Weight Relationship of Fish from Shallow Waters of Candarli Bay (North Aegean Sea, Turkey). *Pakistan Journal of Zoology* 42(4): 495–498.

Gurkan, Ş. & Taşkavak, E. (2012). Sexual dimorphism of the broad-nosed pipefish, *Syngnathus typhle,* from Aegean Sea (Turkey). *North-Western Journal of Zoo*logy 8: 41–45.

Hablützel, P.I & Wilson, A.B. (2011). Notes on the occurrence of Syngnathus rostellatus (Teleostei: Syngnathidae) in the Mediterranean. *Marine Biodiversity Records* 4(1–4).

Harrison, T.D. (2001). Length-weight relationships of fishes from South African estuaries. *Journal of Applied Ichthyology* 17: 46–48.

Howard, R.K. & Koehn, J.D. (1985). Population Dynamics and feeding Ecology of Pipefish (Syngnathidae) Associated with Eelgrass Beds of Beds of Western Port, Victoria Australian *Journal of Marine and Freshwater Research* 6: 361–70.

IUCN (2016). IUCN Red List Categories and Criteria Version 3.1. IUCN Species 265 Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK.

Kasapoğlu, N. & Düzgüneş, E. (2014). Length-weight relationships of marine species caught by five gears from the Black Sea. *Mediterranean Marine Science* 15(1): 95–100.

Keskin, Ç. & Gaygusuz, Ö. (2010). Length-weight relationships of fishes in shallow waters of Erdek bay (sea of Marmara, Turkey). *IUFS Journal of Biology* 69(2): 87–94.

Kendrick, A.J. & Hyndes, G.A. (2005). Variations in the dietary compositions of morphologically diverse syngnathid fishes. *Environmental Biology of Fishes* 72: 415–427.

Khrystenko, D., Kotovska, G. & Novitskij, R. (2015). Length-Weight Relationships and Morphological Variability of BlackStriped Pipefish *Syngnathus abaster* Risso, 1827 in the Dnieper River Basin. *Turkish Journal of Fisheries and Aquatic Sciences,* 15: 609–618.

Kornienko, E.S. (2001). Reproduction and Development in Some Genera of Pipefish and Seahorses of the Family Syngnathidae. *Russian Journal of Marine Biology* 27(Suppl. 1): S15–S26.

Koutrakis, E.T. & Tsikliras, A.C. (2003). Length-weight relationships of fishes from three northern Aegean estuarine systems (Greece). *Journal of Applied Ichthyology* 19: 258–260.

Kuiter, R.H. (2000). Seahorses, pipefish and their relatives. TMC Publishing, Chorleywoo.

Kuiter, R.H. (2001). *Revision of the Australian Seahorses of the Genus Hippocampus (Syngnathiformes: Syngnathidae) with Descriptions of Nine New Species. Records of the Austarlian Museum* 53: 293–340. ISSN 0067-1975.

Liousia, V., Batziakas, S., Panagiotou, N., Daouti I., Koutrakis, E. et al. (2012). Length-weight relations of 22 fish species from the littoral zone of the Eastern Ionian Sea, Greece. *Acta Ichthyologica et Piscatoria* 42(1): 69–72.

Malavasi, S., Franco, A., Riccato F. & Franzoi, P. (2007). Habitat selection and spatial segregation in three pipefish species. *Estuarine Coastal and Shelf Science* 75(1): 143–150.

Mitrofanov, V.P. (1977). *Jekologicheskie osnovy morfometricheskogo analiza ryb* [Ecological foundations of fish morphometric analysis]. Alma-Ata: KazGU. 33 pp. (In Russian).

Morey, G., Moranta, J., Massuti, E., Grau, A., Linde, M. et al. (2003). Weight-length relationships of littoral to lower slope fishes from the western Mediterranean. *Fisheries Research* 62: 89–96.

Movčan, Y.V. (1988). *Fauna of Ukraine (Fishes).* Kiev, Ukraine: Naukova Dumka. (In Russian).

Mwale, M. (2005). *The biology and systematics of South African pipefishes of the genus Syngnathus.* Unpublished doctoral dissertation, Rhodes University, Grahamstown, South Africa.

Özaydın, O. & Taşkavak, E. (2006). Length-weight relationships for 47 fish species from İzmir Bay (Aegean Sea, Turkey). *Acta Adriatica* 47(2): 211–216.

Payne, M.F., Rippingale, R.J. & Longmore, R.B. (1998). Growth and survival of juvenile pipefish (Stigmatopora argus) fed live copepods with high and low HUFA content. *Aquaculture* 167: 237–245.

Petriki, O., Gousia, E. & Bobori, D.C. (2011). Weight-length relationships of 36 fish species from the River Strymon system (northern Greece). *Journal of Applied Ichthyology* 27: 939–941.

Ricker, W.R. (1975). Computation and interpretation of biological statistics of fish populations. *Journal* of the *Fisheries Research Board* of *Canada* 191: 1–382.

Silva, C.S. (2008). Reproductive Ecology of the "Mildly" Sex-Role Reversed Pipefish, *Syngnathus abaster*.

(SFRH/BD/13171/2003) Departamento de Zoologia e Antropologia.

Sokal, R.R. & Rohlf, F.J. (1981). *Biometry*. W. H. Freeman. San Francisco, CA.

Taylan, B., Tatarhan, G.E., Aksoy, O. & Culha, M. (2018). Reproductive biology of the black-striped pipefish *Syngnathus abaster* Risso, 1827 (Pisces: Syngnathidae) in the Aegean Sea of Turkey. *Oceanological and Hydrobiological Studies* 47(1): 67–74. DOI: 10.1515/ohs-2018-0008.

Tesch, F.W. (1971). Age and growth. In W.E. Ricker (Ed.), *Methods for Assessment of Fish production in Fresh Waters* (pp. 99–130). Blackwell Scientific Publications, Oxford.

Turan, C. (2004). Stock identification of Mediterranean horse mackerel (*Trachurus mediterraneus*) using morphometric and meristic characters. *Journal of Marine Science* 61: 774–781.

Valle, C., Bayle, J.T., & Ramos, A.A. (2003). Weight-length relationships for selected fish species of the western Mediterranean Sea. *Journal of Applied Ichthyology* 19: 261–262.

Veiga P., Machado, D., Almeida, C., Bentes, L., Monteiro, P. et al. (2009). Weight-length relationships for 54 species of the Arade estuary, southern Portugal. *Journal of Applied Ichthyology* 25: 493–496.

Verdiell-Cubedo, D., Oliva-Paterna, F.J. & Torralva, M. (2006). Length-weight relationships for 22 fish species of the Mar Menor coastal lagoon (western Mediterranean Sea). *Journal of Applied Ichthyology* 22: 293–294.

Vieira, R.P., Monteiro, P., Ribeiro, J., Bentes, L., Oliveira, F. et al. (2014). Length-weight relationships of six syngnathid specieseria from Ria Formosa, SW Iberian coast. *Cahiers de Biologie Marine* 55(1): 9–12.

Vincent, A.C.J., Berglund, A. & Ahnesjo, I. (1995). Reproductive ecology of five pipefish species in one eelgrass meadow. *Environmental Biology of Fishes* 44: 347–361.

Yildiz, T., Uzer, U. & Karakulak, F.S. (2015). Preliminary report of a biometric analysis of greater pipefish *Syngnathus acus* Linnaeus, 1758 for the western Black Sea. *Turkish Journal of Zoology* 39: 1–8.