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Monitoring of the trophic ecology of pipefish species (*Syngnathus abaster, Syngnathus acus*) in an alluvial lake habitat (Lake Bafa, Turkey)

by

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Abstract

The present study investigated the trophic ecology of two species living in an alluvial lake ecosystem in terms of season, length groups, sex, and mouth morphology. The fish were caught in a coastal lake area between December 2014 and March 2016 using a seine. In general, *C. aquaedulcis* was the most important prey for *S. abaster*, accounting for 10.99% of all prey, while amphipods accounted for 54.04% of the *S. acus* diet. Amphipods were the most frequently consumed prey in autumn, while *C. aquaedulcis* was the most important prey in spring. This result indicates that the species preferred similar prey groups and generated food competition depending on the season. The short-length group contained samples of *S. abaster* with empty guts, whereas *S. acus* in the same group consumed *C. aquaedulcis*. Length group II and III of individuals indicated that both species consumed amphipods and juvenile *Syngnathus* sp. Thus, the two species had statistically different preferences in terms of prey length. The mouth width of *S. abaster* was larger than that of *S. acus*. In conclusion, zooplankton constituted the main prey for both species in the lake and the morphological differences between the mouth apparatus of the species were due to the differences in feeding habits.

Key words: pipefish, *Syngnathus abaster*, *Syngnathus acus*, feeding habits, prey partition, trophic relations

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1. Introduction

Pipefish are representatives of ichthyofauna from vegetated habitats in coastal and estuarine areas (Howard & Koehn 1985; Kuiter 2000). These are ideal habitats for feeding, reproduction, protection against predators and wintering (Teixeira & Musick 1995). Decaying algae and dead seagrass are known to serve as a shelter and refuge, and even as means of transportation to shallower or deeper waters (Teixeira & Musick 1995). *Syngnathus abaster* (Risso 1827) is a euryhaline pipefish species adapted to freshwater bodies with sandy, muddy and detritus-containing habitats, such as lagoons and lakes (Cakić et al. 2002; Didenko et al. 2018). *Syngnathus acus* (Linnaeus 1758) occurs mostly in densely vegetated regions of sandy and muddy estuarine waters (Dawson 1986).

Lake Bafa is an alluvial lake located at the southeastern end of the Aegean region and connected to the Greater Meander delta (Turgutcan 1957). The lake is fed by the Meander River and therefore harbors a wide variety of fish species, thus representing a large ground for research on ichthyofauna. Changes in the populations of diadromous and potamodromous fish species are closely associated with the connection between lakes and rivers (Sarı et al. 1999). Research on fish species in Lake Bafa dates back 30 years and so far 20 species have been identified in the lake (Kasparek 1988; Balık & Ustaoglu 1989; Kuru et al. 2001). In addition to economic species, species from the Syngnathus genus occur in the lake (Sarı et al. 1999; Kuru et al. 2001; Gurkan & Innal 2018). In Europe, research on feeding strategies, especially of *S. abaster*, is common in certain freshwater habitats and estuarine systems, but there are no studies on *S. acus*. Pipefish are passive predators (Howard & Koehn 1985). They select their prey depending on the habitat in which they live and generally feed on small crustaceans (Ryer & Orth 1987; Teixeira & Musick 1995). Moreover, the mouth structure and size of prey also affect their choice of prey groups in microhabitats in which they hunt (De Lussanet & Muller 2007). Prey groups of *S. abaster* include phytal organisms, copepods and small crustaceans (Franzoi et al. 1993; Oliviera et al. 2007; Didenko et al. 2018), while prey groups of *S. acus* include planktic crustaceans and zooplankton (Moreira et al. 1992; Taskavak et al. 2010).

The study carried out by Franzoi et al. (1993) involved feeding habits of two Syngnathus species in an estuarine system of the Mediterranean Sea (Po River delta). Research by Vizzini & Mazzola (2004) on the trophic structure of pipefish species from the western Mediterranean coast is important, because the authors addressed the issue in detail. The most recent study, according to our review of the relevant literature, determined the feeding model of *S. abaster* in a freshwater habitat in Ukraine (Didenko et al. 2018). The first detailed study on feeding habits of *S. acus* on the European coasts (Aegean coast) was carried out by Taskavak et al. (2010). A subsequent study determined feeding habits of various species, including *S. acus* and *S. abaster*, from the Black Sea coast (Gürkan & Uncumusaoglu 2016). Both *S. abaster* and *S. acus* are listed in the Least Concern (LC) category of the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (Smith-Vaniz 2015; Pollom 2016). Thus, the lack of knowledge about the populations of the two species is somewhat remedied, but there is a need for research on how these two species, adapted to estuarine systems, feed and share food in alluvial lake habitats.

This is an important study, because it is the first time the trophic ecology of two congeneric pipefish species occurring in alluvial Lake Bafa (Aegean region, Turkey) has been determined. The study investigates changes in prey group choices of both Syngnathus species with respect to two seasons (autumn and spring), length groups, sex and morphological differences in the mouth apparatus.

2. Materials and methods

2.1. Sample collection

Lake Bafa is a natural barrier lake located in the southeastern region of the Greater Meander River delta and has an indented shoreline. Pipefish samples were collected seasonally, from November 2014 to March 2016, by seining in the coastal area of the Kapıkırı region (between 37°30′N–27°31′E and 37°29′N–27°31′E), the maximum depth of which is 1–1.5 m (Fig. 1). The potential effect of the mesh opening was ignored. Ethics committee regulations were followed when fish species were caught. A total of 205 fish individuals were caught (*S. abaster* – 76 ind., *S. acus* – 129 ind.). The collected fish samples were brought to the laboratory in sealed vessels containing 70% ethanol. In the laboratory, the total length of each fish specimen (TL, mm) was measured using a measuring board, the total weight (W, g) was determined using an analytical balance with a sensitivity of 0.01 g and the mouth width (MW) was measured using a digital caliper with an accuracy of 0.001 mm. Fish samples were assessed according to three length groups (Length Group I: < 60 mm, Length Group II: 60–100 mm and Length Group III: >100 mm). The sex of the collected specimens was determined macroscopically

Figure 1
Fish samples

based on the pouch in males (Vincent et al. 1995). Females were dissected on their ventral side up to the anus and gonads were analyzed macroscopically.

The tubular gastrointestinal system of pipefish is not fully developed. For the purpose of examining digested food particles, the anterior of the gastrointestinal tube was defined as the gut. The guts were dissected and removed. The gut content analysis was performed on 149 samples with full guts. The dissected guts were kept in 4% formalin solution. Empty and full guts were examined under a binocular microscope. Prey items found in full guts were identified according to different groups. Food particles were counted and weighed with a sensitivity of 0.0001 g. Dominant prey groups were determined in the gut contents of both fish species.

2.2. Data analysis

Fish with empty and full guts were determined. The feeding activity was described using the fullness index FI (Hureau 1969). The fullness index was calculated using the following formula: $FI = 100*(Gut\ W)*(W)^{-1}$, where Gut W is the gut content weight and W is the fish weight.

Frequency of gut contents (F%), numerical occurrence (N%), weight percentage (W%), the index of relative importance (IRI) and the percent index of relative importance (IRI %) with respect to length groups and two seasons were separately calculated in accordance with Liao & Larscheid (2001). The t-test was used both to determine the differences in the gut contents with respect to length groups and seasons as well as the correlation and regression relationships between the total length and mouth width (Sokal, Rohlf 1969). One-way ANOVA was performed using the Statistica software.

3. Results

3.1. *Syngnathus abaster*

A total of 76 samples (44 females, 25 males, 7 immatures) were collected in the study period, i.e. in spring and autumn. The total length of the samples varied from 55 mm to 130 mm, with Length Group II containing the largest number of samples (75%). The gut fullness ratio in the samples was 68.42% and it was higher in female samples (75%) than in male samples.

Eight major prey groups were identified in *S. abaster* depending on its feeding activity. Amphipods were the most dominant prey group (F%, 68.09%) in the food composition and *C. aquaedulcis* was the most important prey group (IRI%; Table 1). The highest gut fullness index was determined in spring and was 6.70, whereas the lowest fullness index was 0.36 and was determined in autumn in Length Group II (Table 2; Fig. 2). Table 2 shows the food composition of *S. abaster* samples in terms of the length groups.

According to Table 2, guts in the samples of Length Group I were empty, while the samples in Length Group II contained eight prey groups. In these medium-size samples, amphipods and *C. aquaedulcis*

Table 1

Stomach contents in *Syngnathus abaster*

Prey items	F%	N%	W%	IRI%
Copepods				
Calanipeda aquaedulcis	51.06	64.71	1.26	10.99
Other cyclopoids	4.26	1.76	0.20	0.03
Ostracods	10.64	0.79	0.16	0.03
Amphipods	68.09	18.44	0.81	4.28
Amphipod pieces	10.64	0.00	0.00	0.00
Diptera				
Chironomidae larvae	4.26	0.48	93.67	1.31
Fish larvae (*Syngnathus* sp.)	2.13	0.32	0.74	0.01
Unknown eggs	2.13	13.51	3.16	0.12
Total prey number	629			
Number of full stomachs	52			

Note: F% – percentage frequency; N% – percentage of prey number; W% – percentage dry weight; IRI% – percentage relative importance index.

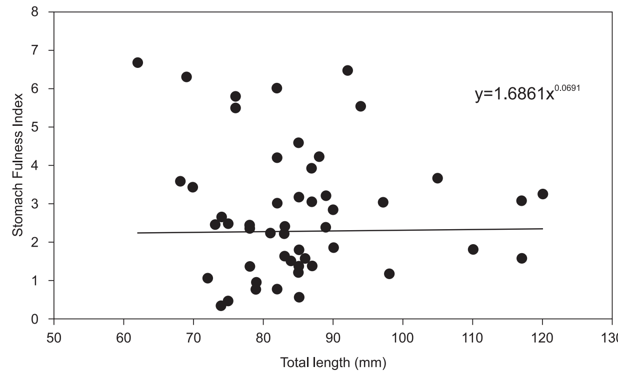

Figure 2

Relationship between the total length and the stomach fullness index in *S. abaster*

(56.10%, F%) were the most dominant prey groups, while amphipods were the most important prey group (IRI%, 82.12%). On the other hand, the same fish samples contained also cyclopoid copepod, ostracod, and amphipod particles, chironomid larvae, and unidentified eggs. Moreover, the same group preferred pipefish larvae as food. Length Group III preyed on four prey groups. Amphipods were both the most dominant and important prey group in these large fish samples, while *C. aquaedulcis* was the second most important prey group. *Syngnathus* larvae and unidentified eggs were preferred so frequently that the question of cannibalism was raised. The results of the t-test revealed no significant differences between the prey groups in the length groups ($p > 0.05$). The food composition in *S. abaster* and *S. acus* samples was also compared for the same length group. The comparison revealed significant differences between the food composition in the length groups of both species (Group I: t-value = 16.68, $p = 0.00001$; Group II: t-value = 27.315, $p = 0.0005$; Group III: t-value = 27.314, $p = 0.0001$, $p < 0.05$). Table 3 shows prey groups consumed by *S. abaster* specimens in autumn and spring.

Only six prey groups were favored by individuals caught in autumn. Amphipods were the most dominant and important prey group in autumn, followed by chironomid larvae, which are aquatic insects. Fish larvae were also preferred, albeit at a low level. Four prey groups were consumed in spring and *C. aquaedulcis* and amphipods were both the most dominant and important prey groups (Table 3). However, there were no statistically significant differences between the food groups in the *S. abaster* samples across seasons (t-value = 1.285, $p = 0.219$, $p > 0.05$).

Table 2

Food composition in *S. abaster* size groups

Prey items	Fish length groups					
	< 60 mm		60–100 mm		100 mm >	
	F%	IRI%	F%	IRI%	F%	IRI%
Copepods						
Calanipeda aquaedulcis	0.00	0.00	56.10	0.49	7.37	28.99
Other cyclopoids	0.00	0.00	4.88	0.88	0.00	0.00
Ostracods	0.00	0.00	14.63	1.66	0.00	0.00
Amphipods	0.00	0.00	56.10	82.12	75.00	57.56
Amphipod pieces	0.00	0.00	36.59	0.00	0.00	0.00
Diptera						
Chironomidae larvae	0.00	0.00	4.88	7.31	0.00	0.00
Fish larvae (*Syngnathus* sp.)	0.00	0.00	2.44	0.06	8.33	0.61
Unknown eggs	0.00	0.00	2.44	0.95	8.33	12.84

Table 3

Food composition in *S.abaster* stomachs in two seasons

Prey items	Autumn		Spring	
	F%	IRI%	F%	IRI%
Copepods				
Calanipeda aquaedulcis	0.00	0.00	96.00	97.55
Other cyclopoids	6.67	3.22	0.00	0.00
Ostracods	16.67	3.63	0.00	0.00
Amphipods	53.33	76.81	64.00	2.17
Amphipod pieces	43.33	0.00	0.00	0.00
Diptera				
Chironomidae larvae	6.67	16.14	0.00	0.00
Fish larvae (*Syngnathus* sp.)	3.33	0.18	4.00	0.002
Unknown eggs	0.00	0.00	8.00	0.28

3.2. *Syngnathus acus*

A total of 129 samples (69 females, 30 males, 30 immatures) were collected during the study period. The total length values of the samples ranged from 55 mm to 125 mm and Length Group II contained the largest number of samples (57.5%). The gut fullness ratio for the species was 75.1% and it was higher in female samples (70%) than in male samples (63.76%). Of the 16 prey groups identified based on the feeding activity of *S. acus*, 15 prey groups were most frequently identified. According to the food composition, amphipods were the most dominant and important prey group (66.15%, 54.04%; Table 4).

The highest value of the gut fullness index was 17.9 and was determined in Length Group II in spring, while the lowest value was 0.22 and was determined in Length Group III (Table 2, Fig. 3).

According to Table 5, samples in Length Group I contained only one type of prey group (*C. aquaedulcis*). Samples in Length Group II contained an increased number of prey groups, totaling 13 prey groups. The dominant prey groups in these medium-size fish samples were amphipods and *C. aquaedulcis*, with *C. aquaedulcis* being the most important prey group. However, chironomid larvae, unidentified eggs and algae pieces were not included in the food composition. Nine prey groups were identified in Length Group III. Amphipods and amphipod pieces were both the most dominant and most important prey groups in these large-size fish samples. There was an increase in the consumption of larvae (Chironomidae and *Syngnathus* sp.) in the group. The results of the t-test revealed no statistically significant differences between the prey groups in the length groups ($p > 0.05$).

Table 6 shows the prey groups identified in the *S. acus* samples collected in autumn and spring.

Table 4

Stomach contents in *Syngnathus acus*

Prey items	F%	N%	W%	IRI %
Algae				
Diatom (*Surirella* sp.)	1.54	0.15	0.00	0.004
Brown algae pieces	1.53	0.00	0.00	0.00
Copepods				
Calanipeda aquaedulcis	44.62	51.35	1.58	42.37
Other Calanoids	1.54	0.30	0.002	0.009
Oithona sp.	1.54	0.15	0.009	0.004
Other cyclopoids	10.77	3.61	0.64	0.82
Harpacticoids	1.54	0.15	0.0002	0.004
Ostracods	4.61	0.45	0.24	0.06
Mysids	1.54	0.15	0.09	0.007
Amphipods	66.15	42.62	2.90	54.04
Amphipod pieces	36.92	0.00	0.00	0.00
Gastropods	3.08	0.15	0.01	0.009
Diptera				
Chironomidae larvae	1.54	0.15	46.96	1.29
Other Diptera larvae	1.54	0.15	46.69	1.29
Fish larvae (*Syngnathus* sp.)	3.08	0.30	4.35	0.08
Fish scales	1.54	0.15	0.00	0.04
Total prey number	664			
Number of full stomachs	65			

Thirteen prey groups dominated in the samples in autumn. Amphipods and amphipod pieces were the most dominant and important prey group in autumn. In addition, Ostracods, Chironomidae larvae and fish larvae were preferred, albeit at a low level. The collected fish individuals consumed seven prey groups in spring, and *C. aquaedulcis* and amphipods were both the most dominant and most important prey groups. On the other hand, there were no statistically significant differences between the prey groups identified in the *S. acus* samples with respect to seasons (t-value = 1.406, $p = 0.169$, $p > 0.05$). Figure 4 shows the relationship between the total length

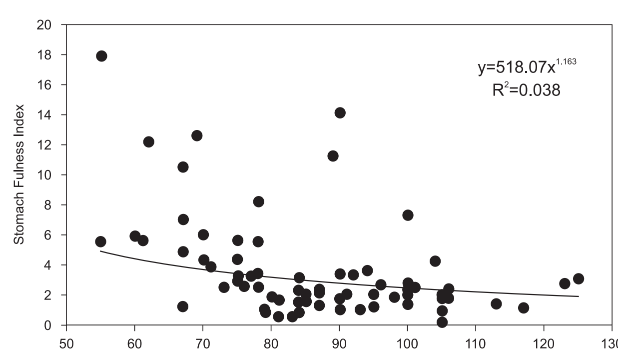

Figure 3

Relationship between the total length and the stomach fullness index in *S. acus*

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Table 5

Food composition in *S. acus* size groups

Prey Items	Length groups					
	< 60 mm		60–100 mm		100 mm >	
	F%	IRI%	F%	IRI%	F%	IRI%
Algae						
Diatom (*Surirella* sp.)	0.00	0.00	2.13	0.004	4.00	0.00
Brown algae pieces	0.00	0.00	0.00	0.00	4.00	0.00
Copepods						
Calanipeda aquaedulcis	100.00	100.00	51.06	76.57	16.00	3.23
Other Calanoids	0.00	0.00	2.13	0.01	0.00	0.00
Oithona sp.	0.00	0.00	2.13	0.004	0.00	0.00
Other Cyclopoids	0.00	0.00	14.89	0.72	4.00	0.02
Harpacticoids	0.00	0.00	2.13	0.004	0.00	0.00
Ostracods	0.00	0.00	4.26	0.02	4.00	0.02
Mysids	0.00	0.00	0.00	0.00	4.00	0.02
Amphipods	0.00	0.00	59.57	22.47	60.00	96.65
Amphipod pieces	0.00	0.00	31.91	0.00	40.00	0.00
Gastropods	0.00	0.00	2.13	0.04	0.00	0.00
Diptera						
Chironomidae larvae	0.00	0.00	0.00	0.00	4.00	0.03
Other Diptera larvae	0.00	0.00	2.13	0.18	0.00	0.00
Fish larvae (*Syngnathus* sp.)	0.00	0.00	2.13	0.01	4.00	0.02
Fish scales	0.00	0.00	2.13	0.004	0.00	0.00

and the mouth width. The food composition of the *S. abaster* and *S. acus* samples was also compared for the same season. The comparison revealed no statistically significant differences between the food composition of the two species in either autumn (t-value = 1.341, $p = 0.194$, $p > 0.05$) or spring (t-value = 0.355, $p = 0.727$, $p > 0.05$).

Table 6

Prey groups consumed by *S. acus* during two seasons

Prey items	Autumn		Spring	
	F%	IRI%	F%	IRI%
Algae				
Diatom (*Surirella* sp.)	3.13	0.22	0.00	0.00
Brown algae pieces	0.00	0.00	1.35	0.00
Copepods				
Calanipeda aquaedulcis	3.13	0.22	37.84	93.19
Other calanoids	3.13	0.44	0.00	0.00
Oithona sp.	3.13	0.23	0.00	0.00
Other cyclopoids	3.13	0.23	8.11	0.0002
Harpacticoids	0.00	0.00	1.35	0.0002
Ostracods	9.38	1.98	0.00	0.00
Mysids	3.13	0.22	0.00	0.00
Amphipods	50.00	85.18	36.49	6.75
Amphipod pieces	43.75	0.00	13.52	0.00
Gastropods	3.13	0.23	0.00	0.00
Diptera				
Chironomidae larvae	3.13	9.18	0.00	0.00
Other Diptera larvae	0.00	0.00	1.35	0.06
Fish larvae (*Syngnathus* sp.)	6.25	1.42	0.00	0.00
Fish scales	3.13	0.22	0.00	0.00

The mouth width (MW) of *S. abaster* was greater than that of *S. acus* (Fig. 4). There was a significant difference between the two species in terms of mouth width (t-value = 2.457, $p = 0.015$, $p < 0.05$). According to the regression relationship between the total length and the mouth width, the latter in the *S. abaster* samples gradually increased until the total length value reached 95 mm (MW = 0.044, TL – 2.4463, $r^2 = 0.48$). On the other hand, feeding continued in sampled *S. acus*, although there was no significant change in the width of mouths as their total length increased (MW = 0.0193, TL – 0.7534, $r^2 = 0.449$). Figure 5 shows the relationship between the total length and the weight of digested food.

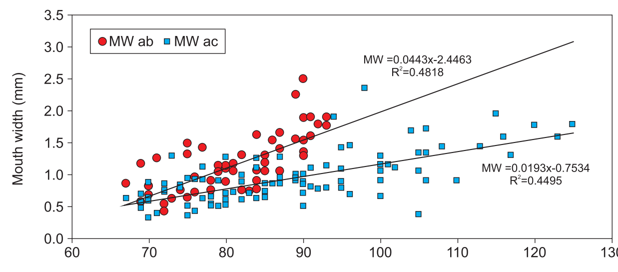

Figure 4

Relationships between the total length and the mouth width in pipefish species

Figure 5 shows the regression relationship between the total length (TL) and the food weight for both species. The figure reveals that feeding in the captured individuals of *S. acus*, which showed a wide distribution considering their increasing total length values, was more intense than in the *S. abaster* individuals. However, the results of the t-test revealed that the difference between the species in terms of food was not significant [t-value = –0.058, p = 0.95, p >*0.05*; y(abaster) = 0.00009, r^2 = 0.124; y(acus) = 0.0003TL – 0.0157, r^2 = 0.456].

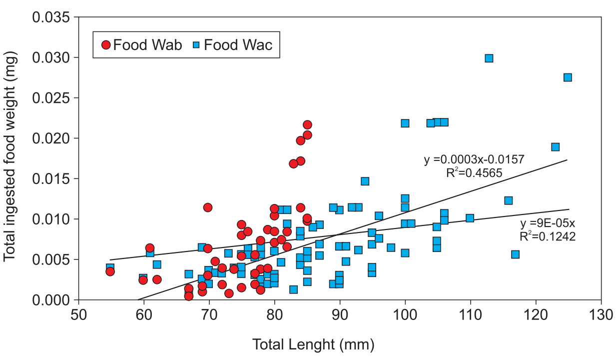

Figure 5

Relationship between the total length and the total weight of ingested food in pipefish species

4. Discussion

Pipefish species are bony fish with high trophic specialization, distinguished from other demersal fish species by distinct mouth morphology and feeding habits (Kendrick & Hyndes 2005). The main food items of pipefish are usually groups of small crustaceans (Howard & Koehn 1985; Tipton & Bell 1988; Franzoi et al. 1993; Lyons & Dunne 2004; Taskavak et al. 2010). The mouth apparatus of pipefish has a structural effect on prey capture (De Lussanet & Muller 2007). In this study, the length distribution of *S. abaster* individuals was greater than that of their relatives living in a coastal lagoon (Spain) and similar to the length distribution of *S. abaster* samples collected in an estuary in Greece. Similarities and differences between the length and weight values depend on season, habitat, hunting strategy and time, changes in environmental factors (water temperature, waves, etc.), gonad development, gut fullness, and sex (Tesh 1971; Bagenal & Tesch 1978).

The food of *S. abaster* consists of zooplankton that include copepods (Didenko et al. 2018), benthic organisms such as amphipods (Vizzini & Mazzola 2004), phytal harpacticoids (Franzoi et al. 1993), Cirripedia and Harpacticoida (Gürkan & Uncumusaoğlu 2016). The food of *S. acus* consists of Harpacticoida and amphipods (Taskavak et al. 2010), planktic crustaceans, zooplankton (Moreira et al. 1992) and *Euterpina acutifrons* (Gürkan, Uncumusaoğlu 2016). Benthic organisms from six classes (Bivalvia, Crustacea, Gastropoda, Polychaeta, Insecta, and Isopoda) occur in Lake Bafa (Tuna 2015). However, there were no significant differences between the two species in terms of food composition (t-value = –0.058, f-ratio = 1.045, p > 0.05). It has been reported that some congeneric species can feed in different microhabitats without competing (Franzoi et al. 1993; Vizzini & Mazzola 2004). This is consistent with the results of this study, which revealed that the species feed on different habitats in the lake without causing any difference in prey composition (t-value = 2.457, p = 0.015, p < 0.05). Campolmi et al. (1996) emphasized the mouth effect on food sharing in the environment. The difference is essentially attributable to the differences in the mouth aperture of the two species that are both passive predators, as well as the differences in the predatory strategy, which involves filtering from the medium or foraging (Howard & Koehn 1985; Franzoi et al. 1993). The mouth apparatus of *S. abaster* is morphologically short and cylindrical, while the mouth apparatus of *S. acus* is relatively longer. Franzoi et al. (1993) and Vizzini & Mazzola (2004) pointed out that morphological adaptations in congeneric species can be important factors in determining differences in ecological niches. This indicates that *S. abaster* with its short snout filters food from rich habitats, while another *Syngnathus* species with longer mouths capture their prey that floats above the water column by aiming (Franzoi et al. 1993). Thus, given the prey types identified in the samples, it is clear that *S. abaster* and *S. acus* maintain a similar niche in the lake habitat.

In this study, the captured individuals of *S. abaster* fed on 17 prey groups and amphipods were the dominant prey group in their food composition, while *C. aquaedulcis* was the most important prey group. Among 36 prey groups of the same species in the Stugna River, copepods were the most important prey (Didenko et al. 2018). Copepods were also the most important prey group on the western Mediterranean (Stagnon di Marsela) coast (Vizzini, Mazzola 2004). Copepods and *Cirripede nauplii* were the most dominant and important prey group on the coast of the Black Sea (Gürkan & Uncumusaoğlu 2016). Copepod species are irreplaceable for *S. abaster* both in coastal areas and other estuary regions. A total of 17 prey groups were identified depending on the feeding activity of *S. acus*, with 15 prey groups being the most frequently found. Amphipods were both the most dominant and important prey group in the food composition. There are two studies investigating the food composition of *S. acus* in Turkey. According to the study by Taskavak et al. (2010), the Aegean populations of *S. acus* preferred harpacticoid copepods and amphipods, while according to the study by Gürkan & Uncumusaoğlu (2016), the populations of the species from the Black Sea fed mainly on *Euterpina acutifrons*. Seasonal and vertical distribution of prey groups in their microhabitats and habitat structure (sandy, vegetated, etc.) are important factors in the feeding of Syngnathidae species (Howard & Koehn 1985). Seasonal changes affecting water temperature impacted the feeding activity of both species during the study period. In this study, the mean water temperature in autumn and spring was 19.2°C and 17.8°C, respectively. In Lake Bafa, the feeding activity of *S. abaster* decreased in autumn and increased in spring. The *S. acus* samples contained considerably high levels of food in spring. The low water temperature in the lake during spring was due to the annual precipitation, and the increase in the number of planktic organisms in the lake during this season led to increased feeding activity. Didenko et al. (2018) emphasized that the feeding activity of fish species frequently changed depending on water temperature. The gut fullness ratios of *S. abaster* and *S. acus* differed by sex. The gut fullness ratio in female samples was higher than that in male samples. In addition to differences in the food composition depending on species, the feeding ecology of the sexes also differs (Vizzini, Mazzola 2004). Stefee et al. (1989) reported that female samples from two different pipefish species indicated that females were more successful than males in terms of feeding. This is mostly attributable to the lower ability of male fish to capture prey due to providing brood care.

The number of studies investigating the food consumption and dominant prey groups in *S. abaster* and *S. acus* with respect to length groups has increased since the 2000s (Vizzini & Mazzola 2004; Taskavak et al. 2010; Gürkan & Uncumusaoğlu 2016; Didenko et al. 2018). In Lake Bafa, *S. abaster* and *S. acus* preferred different prey groups depending on their length groups. Moreover, considering the increasing length values, the *S. acus* individuals fed more intensively than the *S. abaster* individuals. While there were fish with empty guts among the *S. abaster* samples from the short length group, Length Group II contained amphipods and *C. aquaedulcis* among eight prey groups and Length Group III contained amphipods among four prey groups. It is clear that the sampled fish preferred larger prey as their length increased. *S. acus* from the short-length samples preyed on *C. aquaedulcis* and *S. acus* from Length Group II preyed on amphipods and *C. aquaedulcis*, while fish from the large-length samples preyed on amphipods. Pipefish have restricted mouth gape, which affects their choice of prey groups (Ryer & Orth 1987; Oliviera et al. 2007; De Lussanet & Muller 2007).

Considering the seasons, amphipods and chironomid larvae were the most dominant and important prey groups for sampled *S. abaster* both in spring and autumn. *S. acus* consumed amphipods and low levels of chironomid larvae. In addition to being important bioindicators of the nutritional efficiency of a lake (Tasdemir & Ustaoglu 2005), chironomid larvae are the ideal prey group for pipefish.

5. Conclusion

The results of the study showed that zooplankton was the main prey group in the alluvial lake environment, and the differences in feeding habits of the two species were attributable to the differences in their mouth apparatus. However, the effect of pipefish on the food ecology of the lake was not significant. On the other hand, maintaining the existing aquatic vegetation in the lake will help in the survival of the fish species and allow more detailed studies.

References

Bagenal, T.B. & Tesch, F.W. (1978). Age and Growth. In T. Bagenal (Ed.), *Methods for Assessment of Fish Production in Fresh Waters, 3rd Edition, IBP Handbook No. 3* (pp. 101–136). Blackwell Science Publications, Oxford.

Balık, S. & Ustaoglu, M.R. (1989). Bioecological and Economic Examination of Ulubat Fish (Acanthobrama mirabilis Ladiges, 1960) in Bafa Lake. *Turk. J. Zool*, 13(3): 141–174.

Cakić, P.M., Lenhardt, D., Mićković, N., Sekulić, L. & Budakov, J. (2002). Biometric Analysis of *Syngnathus abaster* populations. *J. Fish Biol*. 60: 1562–1569. DOI: 10.1016/j.jglr.2015.07.004.

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

Dawson, C.E. (1986). Syngnathidae. In P.J.P. Whitehead, M.-l. Bauchot, J.-C Hureau, J. Nielsen & E. Tortonese (Eds.), *Fishes of the north-eastern Atlantic and the Mediterranean. Vol. 2* (pp. 628–639). Unesco, Paris.

De Lussanet, M.H.E. & Muller, M. (2007). The smaller your mouth, the longer your snout: predicting the snout length of *Syngnathus acus*, *Centriscus scutatus* and other pipette feeders. *JR Soc Interface* 4(14): 561–573. DOI: 10.1098/rsif.2006.0201.

Didenko, A., Kruzhylina, S. & Gurbyk, A. (2018). Feeding patterns of the black-striped pipefish Syngnathus abaster in an invaded freshwater habitat. *Environ. Biol. Fishes* 101: 917–931. DOI: 10.1007/s10641-018-0747-x.

Franzoi, P.R., Maccagnani, R.R. & Ceccherelli, V.U. (1993). Life cycles and feeding habits of *Syngnathus taenionotus* and *Syngnathus abaster* (Pisces, Syngnathidae) in brackish bay of the Po River delta (Adriatic Sea). *Mar. Ecol. Prog. Ser.* 97: 71–81.

Gurkan, S. & Innal, D. (2018). Some morphometric features of congeneric pipefish species (*Syngnathus abaster* Risso 1826, *Syngnathus acus* Linnaeus, 1758) distributed in Lake Bafa (Turkey). *Oceanol Hydrobiol. Stud.* 47(3): 239–247. DOI: 10.1515/ohs-2018-0023.

Gürkan, S. & Uncumusaoglu, A.A. (2012). Food compositions of some Syngnathid species (*Syngnathus* sp., *Nerophis* sp., *Hippocampus* sp.) from coastal waters of Sinop peninsula (southern Black Sea). *BSJ Eng. Sci*. 2(7): 29–38.

Howard, R.K. & Koehn, D.J. (1985). Population dynamics and feeding ecology of pipefish (Syngnathidae) associated with eelgrass beds of Western Port, Victoria. *Mar.* Freshwater Res. 36: 361–370. DOI: 10.1071/MF9850361.

Kasparek, M. (1988). *Bafasee. Natur und Geschichte in der Türkischen Ägäis – Heidelberg* (p. 174).

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

Kuiter, R. (2000). *Seahorses, pipefish and their relatives: a comprehensive guide to Syngnathiformes (Marine Fish Families S.)* TMC Publishing.

Kuru, M., Balık, S., Ustaoğlu, M.R., Ünlü, E., Taşkavak, E. et al. (2001). *Evaluation Criteria of fish found by the Ramsar Convention on Wetlands in Turkey*. Project Report, (pp.55–58).

Liao, H., Pierce, C.L. & Larscheid, J.G. (2001). Empirical assessment of indices of prey importance in the diets of predacious fish. *T. Am. Fish. Soc*. 130: 583–591. DOI:10.1577/1548-8659(2001)130%3C0583:EAOIOP%3E2.0.CO;2.

Lyons, D.O. & Dunne, J.J. (2004). Inter- and intra-gender analyses of feeding ecology of the worm pipefish (*Nerophis lumbriciformis*). *J. Mar.* Bıol. *Assoc. UK* 84: 461–464. DOI: 10.1017/S0025315404009452h.

Moreira, F., Assis, C.A., Almeida, P.R., Costa, J.L. & Costa, M.J. (1992). Trophic relationships in the community of the Upper Tagus Estuary (Portugal: a preliminary approach. *Estuar Coast Shelf S.* 34: 617–623. DOI: 10.1016/S0272-7714(05)80066-6.

Oliviera, F., Erzini, K. & Goncalves, J.S. (2007). Feeding habits of the deep-snouted pipe-fish *Syngnathus typhle* in a temperate coastal lagoon. *Estuar. Coast. Shelf. S.* 72: 337–347 DOI: 10.1016/j.ecss.2006.11.003.

Pollom, R. (2016). *Syngnathus abaster*. *The IUCN Red List of Threatened Species*. e.T21257A19423178. DOI: 10.2305/Iucn.Uk.2016-3. RLTS.T21257A19423178.en.

Ryer, C.H. & Orth, R.J. (1987). Feeding Ecology of the Northern Pipefish, *Syngnathus fuscus*, in a Seagrass Community of the Lower Chesapeake Bay. *Estuaries* 10(4): 330–336. DOI: 10.2307/1351891.

Sarı, H.M., Balık, S., Bilecenoğlu, M. & Türe, G. (1999). Recent changes in the fish fauna of Lake Bafa, Aegean region of Turkey. *Zool. Mıddle East*. 18(1): 67–76. DOI: 10.1080/09397140.1999.10637783.

Smith-Vaniz, W.F. (2015). *Syngnathus acus*. The IUCN Red List Of Threatened Species. e.T198765A44933898. DOI: 10.2305/ıucn.uk.20154. RLTS.t198765a44933898.en. Feb.2020.

Sokal, R.R. & Rohlf, F.J. (1969). *Biometry*. W.H.Freeman and Company, San Fransisco. (p. 776).

Stefee, A.S., Westoby, M. & Bell, J.D. (1989). Habitat selection and diet in the two species of pipefish from seagrass: sex differences. *Mar. Ecol. Prog. Ser*. 55: 23–30.

Tasdemir, A. & Ustaoglu, M.R. (2005). Taxonomical investıgation of Lake District Inland Waters Chironomidae and Chaoboridae (Diptera) fauna. *Ege JFAS 22(3): 377–384.*

Taskavak, E., Gurkan, S., Sever, T.M., Akalın, S. & Ozaydın O. (2010). Gut contents and feeding habits of the Great Pipefish, *Syngnathus acus* Linnaeus, 1758, in Izmir Bay (Aegean Sea, Turkey) (Osteichthyes: Syngnathidae). *Zool. Mıddle East.* 50: 75–82. DOI: 10.1080/09397140.2010.10638414.

Teixeira, R.L. & Musick, A. (1995). Reproduction and food habits of the lined seahorse, *Hippocampus erectus* (Teleostei: Syngnathidae) of Chesapeake Bay, Virginia. *Braz. J.* Med. *Biol. Res*. 61(1): 79–90. DOI: 10.1007/BF00005862.

Tesh, F.W. (1971). Age and growth. In W.E. Ricke (Ed.), *Methods for assessment of fish production in fresh waters.* Oxford: The Blackwell Science. (pp. 98–130).

Tipton, K. & Bell, S.S. (1988). Foraging patterns of two syngnathid fishes: importance of the harpacticoid copepods. *Mar. Ecol. Prog. Ser.* 47: 31–43.

Tuna, M. (2015). Biodiversity and Environmental Problems of Lake Bafa. In H. Şaşı & M. Yabanlı (Ed.), *Determination of Community Supported Ecotourism Activities in Bafa Lake Basin*. Project Report, GEKA. (pp. 96–132). TR32-14/DFD/0043 Muğla Sıtkı Koçman University.

Turgutcan, B. (1957). Lake Bafa. *Balık ve Balıkçılık* 5(11): 19–22.

Vizzini, S. & Mazzola, A. (2004). Stable isotope evidence for the environmental impact of a land-based fish farm in the western Mediterranean. *Mar. Pollut. Bull*. 49: 61–70. DOI: 10.1016/j.marpolbul.2004.01.008.