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Research Article **Araştırma Makalesi**

Juvenile *Parasagitta setosa* (J. Müller, 1847) (Chaetognatha) from Shallow Waters of the Southern Black Sea: Temporal Size Structure, Gonad Maturity, and Gut Content

Güney Karadeniz'in Sığ Sularında Juvenil *Parasagitta setosa* (J. Müller, 1847) (Chaetognatha): Zamansal Boyut Yapısı, Gonad Gelişimi ve Mide İçeriği

Funda Üstün[1,*]

[1]Sinop University, Fisheries Faculty, Marine Biology Depertmant, Sinop, Türkiye.

*Corresponding author: fundaustun@gmail.com

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Abstract: The present study aimed to assess the abundance, body length, maturity stage, and gut content of *Parasagitta setosa* in the southern Black Sea, Turkey. The study was conducted twice a month from January 2008 to December 2008. Vertical hauls with a 112 µm mesh size plankton net were used from a depth of 50 m to the surface of the Sinop coast. During the study period, the abundance of this species was generally low, varying between 10 and 980 ind.m^{-2}. In particular, the abundance of *P. setosa* was low from December to July but increased from August. Small size individuals were predominated, with both 1 – 1.99 mm and 2 – 2.99 mm size classes accounting for 62% of the total *P. setosa* sample. Four developmental stages were determined based on ovary and seminal vesicle development. Stage I (immature) was the predominant developmental stage in the *P. setosa* population. A total of 1580 individuals were dissected; however, only 53 individuals had food items in their gut (3.4%), with copepods (54.73%) accounting for the predominant group the food content. It was determined that the abundance values and feeding ratios of *P. setosa* were low in the coastal area of Sinop and new individuals join in the population during the summer-autumn period.

Keywords
- Population structure
- Developmental stages
- Feeding
- Turkey

Özet: Mevcut çalışma, Türkiye'nin Güney Karadeniz bölgesinde *Parasagitta setosa* bolluğunu, vücut uzunluğunu, olgunluk evresini ve bağırsak içeriğini değerlendirmeyi amaçlamıştır. Çalışma, Ocak 2008 – Aralık 2008 tarihleri arasında ayda iki kez gerçekleştirildi. Sinop kıyısında, 50 m derinlikten yüzeye dikey çekimlerle 112 µm göz açıklığına sahip plankton kepçesi kullanıldı. Çalışma süresi boyunca, türün bolluk değerleri genellikle düşük olup, 10 ile 980 birey.m^{-2} arasında değişmiştir. Özellikle, *P. setosa* bolluğu Aralık'tan Temmuz ayına kadar düşüktü ancak Ağustos ayından itibaren artmıştır. *P. setosa* popülasyonuna küçük boyutlu bireylerin baskın olduğu belirlenmiştir. Toplam *P. setosa* örneğinin %62'sini oluşturan 1 – 1.99 mm ve 2 – 2.99 mm boy sınıflarına ile küçük boyutlu bireyler baskındı. Ovaryum ve seminal vezikül gelişimi kullanılarak dört gelişim evresi belirlenmiştir. *P. setosa* popülasyonunda evre I (olgunlaşmamış evre) baskın olmuştur. Toplam 1580 birey disekte edilmiştir. Bununla birlikte, sadece 53 bireyin (%3,4) bağırsaklarında besin maddeleri bulunmuştur. Besin içeriğinin başlıca grubunu kopepodlar (%54,73) oluşturmuştur. Sinop kıyısal alanında *P. setosa* türünün bolluk değerlerinin ve beslenme oranlarının düşük olduğu ve yeni bireylerin yaz - sonbahar döneminde populasyona katıldığı belirlenmiştir.

Anahtar kelimeler
- Populasyon yapısı
- Gelişimsel evreler
- Beslenme
- Türkiye

1. INTRODUCTION

Chaetognatha is a small marine animal that consists of mainly pelagic species, except for the benthic genus *Spadella*. Chaetognatha has a wide distribution in marine waters, ranging from coastal waters to deep waters and from the surface to the bottom of the water. They are usually abundant in plankton and constitute a major component of the total zooplankton biomass (Alvarino, 1983; Bone et al., 1991). Chaetognatha are both primary and secondary consumers in marine ecosystems, playing a crucial role in the marine food web and contributing to the matter and energy cycles of the marine ecosystem. Chaetognatha feed on fish larvae (Johnson et al., 2006; Vdodovich et al., 2018) and other micro- and mesozooplankton, mainly copepods (Pearre, 1981; Kehayias et al., 1996; Fulmer and Bollens, 2005; Terbıyık Kurt, 2018; Wang et al., 2020), also chaetognaths (Pearre, 1982), whereas they serve as food for many large carnivorous organisms, including seabirds (Mehlum and Gabrielsen, 1993), amphipods (Marion et al., 2008), decapods, mysids (Hopkins et al., 1994), fish and fish larvae (Young and Davis, 1990; Johnson et al., 2008).

Chaetognatha are protandric hermaphrodite animals, and the seminal vesicule in these species mature earlier than their ovaries. Female gonads (in the trunk region) and male gonads (in the tail region) occur in different parts of the body (Alvarino, 1992; Kehayias et al., 1999). Fertilized eggs are released into the water, where they swim near the surface for a few days and then hatch as 'larvae'. The development of chaetognath larvae into adult form is direct without any metamorphosis process (Alvarino, 1990).

Parasagitta (Syn: *Sagitta*) *setosa* is a Chaetognatha species commonly found in the Black Sea (Moldoveanu and Timofte, 2004; Arashkevich et al., 2014; Lebedeva et al., 2015; Stefanova, 2015; Yıldız and Feyzioglu, 2016; Üstün et al., 2018; Üstün et al., 2019). Although their distribution and daily migration model (Vinogradov et al., 1985; Vinogradov et al., 1986; Besiktepe and Unsal, 2000; Erkan et al., 2000; Mutlu, 2006; Marinova and Stefanova, 2009) has been well studied in the Black Sea, studies on sexual development and morphological characteristics (Feyzioğlu et al., 1998; Feyzioğlu et al., 2010), gut content (Dirts and Utkina, 1988; Vdodovich et al., 2018), genetic characteristics (Peijnenburg et al., 2004; Peijnenburg et al., 2006) and fatty acid composition (Şen Özdemir et al., 2020) are still limited.

Coastal shallow waters with ecological and economic significance provide a variety of ecosystem services, including nutrient supply, nutrient conversion, protection from predators, and spawning (Hughes et al., 2014). Maybe, the most referred function among all is that it serves as a nursery where the offspring of numerous vertebrate and invertebrate species can grow and mature before migrating elsewhere during maturity (Lefcheck et al., 2019). The objective of the present study is to determine the population structure, gonad development, and stomach content of the juvenile stage of *P. setosa* which is one of the key species of the Black Sea living in the shallow waters of Sinop.

2. MATERIALS and METHODS

Samples were collected from a single station located in the coastal water of Sinop, Turkey (42°00′21″N, 35°09′32″E, and a depth of 50 m), twice a month from January 2008 to December 2008. A detailed description of the study area and a part of the abundance data were presented in Üstün et al. (2018). A plankton net with a 50 cm diameter and 112 μm mesh size was vertically towed from the bottom to the surface of the water column during the daytime. After sampling, the collected material was transferred into a bottle and preserved in a solution of borax-buffered 4% formaldehyde in seawater. In the laboratory, all *P. setosa* specimens were separated from the whole sample under a stereomicroscope Novex RZ 65500. Systematic classification and nomenclature of this species were performed according to the World Register of Marine Species (WoRMS 2022). The body length of *P. setosa* individuals was measured by metric ocular stereomicroscope. Body length was measured from the tip of the head to the end of the tail, excluding the tail fin. Size classes were arbitrarily set at 1 mm

intervals (the 2 mm size class includes individuals from 2.00 to 2.99 mm, etc.) (Zo, 1973). Abundance values were calculated as individuals per square meter (ind.m^{-2}).

The maturity stages were classified according to Kehayias et al. (1999), based on the development of the ovaries and seminal vesicles: Stage I — young without visible ovaries; Stage II — immature with visible ovaries but not visible seminal vesicles; Stage III — both ovaries and seminal vesicles visible; and Stage IV — seminal vesicles filled with sperm, large ova in ovaries.

Individuals containing food items in their gut were dissected, and food organisms in the gut were classified by their species or genus whenever microscopic examination was possible. Food items in the first third section of the gut were not taken into account while counting the amount of food items as they may have been captured in the collector of the mesh (Øresland, 1987; Kehayias et al., 2005). The feeding ratio was indicated as the food-containing ratio (FCR; percentage of chaetognaths containing food in their gut) and the number of prey per chaetognath (NPC) (Batistić et al., 2003).

3. RESULTS

The annual mean abundance of *P. setosa* was calculated as 329.2 individuals (ind.)m^{-2} in the study area in 2008. The low abundance of *P. setosa* was observed from January 2008 to the end of May 2008. Then, the increase in abundance that started at the end of May 2008 continued until the end of December 2008 (Figure 1). The minimum abundance value was recorded on 26 February 2008, 16 April 2008, and 8 May 2008 (10 ind.m^{-2}), while the maximum values were determined on 23 September 2008 and 21 November 2008 (980 ind.m^{-2} and 975 ind.m^{-2}, respectively). Specimen of *P. setosa* was not found on 30 April 2008 in samples (Figure 1).

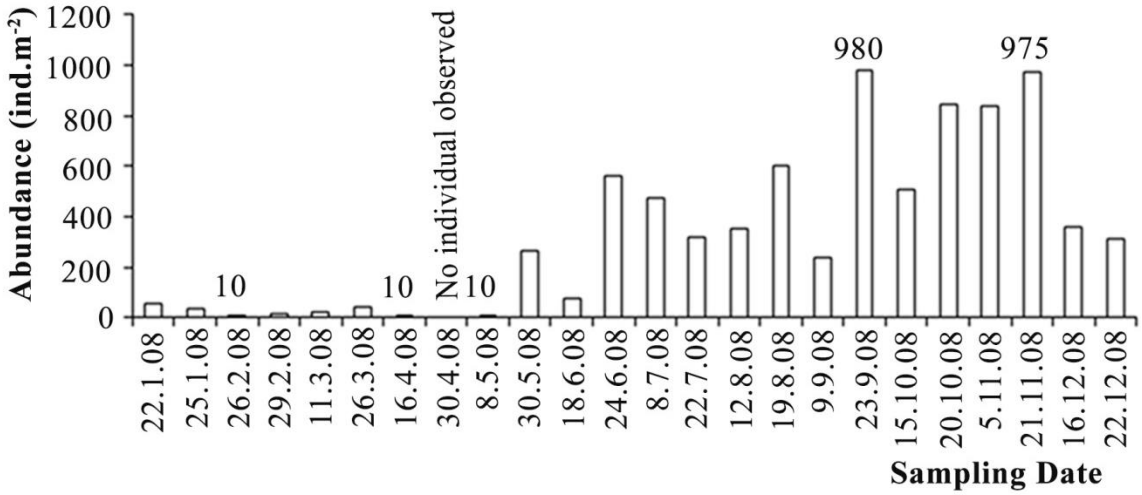

Figure 1. Abundance (ind.m^{-2}) values of *P. setosa* in Sinop, southern Black Sea.

Table 1. Length group (mm) and size frequency (%) of *P. setosa* in Sinop, southern Black Sea.

Length group (mm)	Frequency (%)
0.5 – 0.99	2.97
1 – 1.99	32.53
2 – 2.99	29.18
3 – 3.99	15.70
4 – 4.99	6.77
5 – 5.99	4.05
6 – 6.99	1.90
7 – 7.99	2.22
8 – 8.99	1.39
9 – 9.99	1.46
10 – 10.99	1.08
11 – 11.99	0.63
12 – 12.99	0.13

In this study, the body lengths of 1580 individuals were measured and varied between 0.53 mm (24 June 2008) and 12.80 mm (25 January 2008). The small-sized individuals of *P. setosa* (1 – 1.99 mm and 2 – 2.99 mm) dominated the population and comprised 32.53% and 29.18%, respectively, of the whole population in Sinop. The mean body length of *P. setosa* was 2.98 mm, ranging between 0.81 mm and 6.27 mm (Table 1, Figure 2). A high fraction of individuals of *P. setosa* were between 1 mm and 3 mm long, which was recorded between late May 2008 and December 2008.

In total, 93% of the population was in developmental stage 1, with the proportion decreasing towards higher developmental stages (3.5% in stage 2, 3.2% in stage 3, and 0.32% in stage 4). Individuals in stage 1 were present year-round and dominated the population between the end of May 2008 and the end of November 2008. The maximum number of individuals in stage 1 was determined on 23 September 2008 (186 ind.) and 21 November 2008 (190 ind.). Individuals in stage 2 and stage 3 were detected from the end of June and to be beginning of December 2008. The highest number of individuals in stage 2 was detected on 5 November 2008 (22 individuals, 13%). The highest number of individuals in stage 3 was detected on 8 July 2008 (16 individuals, 17%) followed by 5 November 2008 (15 individuals, 9%). Individuals in stage 4 were found on 8 July 2008 (1 individual), 23 September 2008 (1 individual), and 5 November 2008 (3 individuals, 2%). Individuals in stages 2, 3, and 4 were not observed at the end of December 2008 or in the middle of June 2008. Stage 2 was represented by 1 individual on 29 February 2008. Individuals in stage 1 were also found in a very number on 29 February 2008. The size of individuals in stage 1 ranged between 0.53 mm and 12.8 mm (mean: 2.7 mm); in stage 2, between 2.5 mm and 12 mm (mean: 6.65 mm); in stage 3, between 3.25 mm and 11.3 mm (mean: 6.6 mm) and stage 4, between 5.9 mm and 11.8 mm (mean: 9.4 mm) (Figure 2).

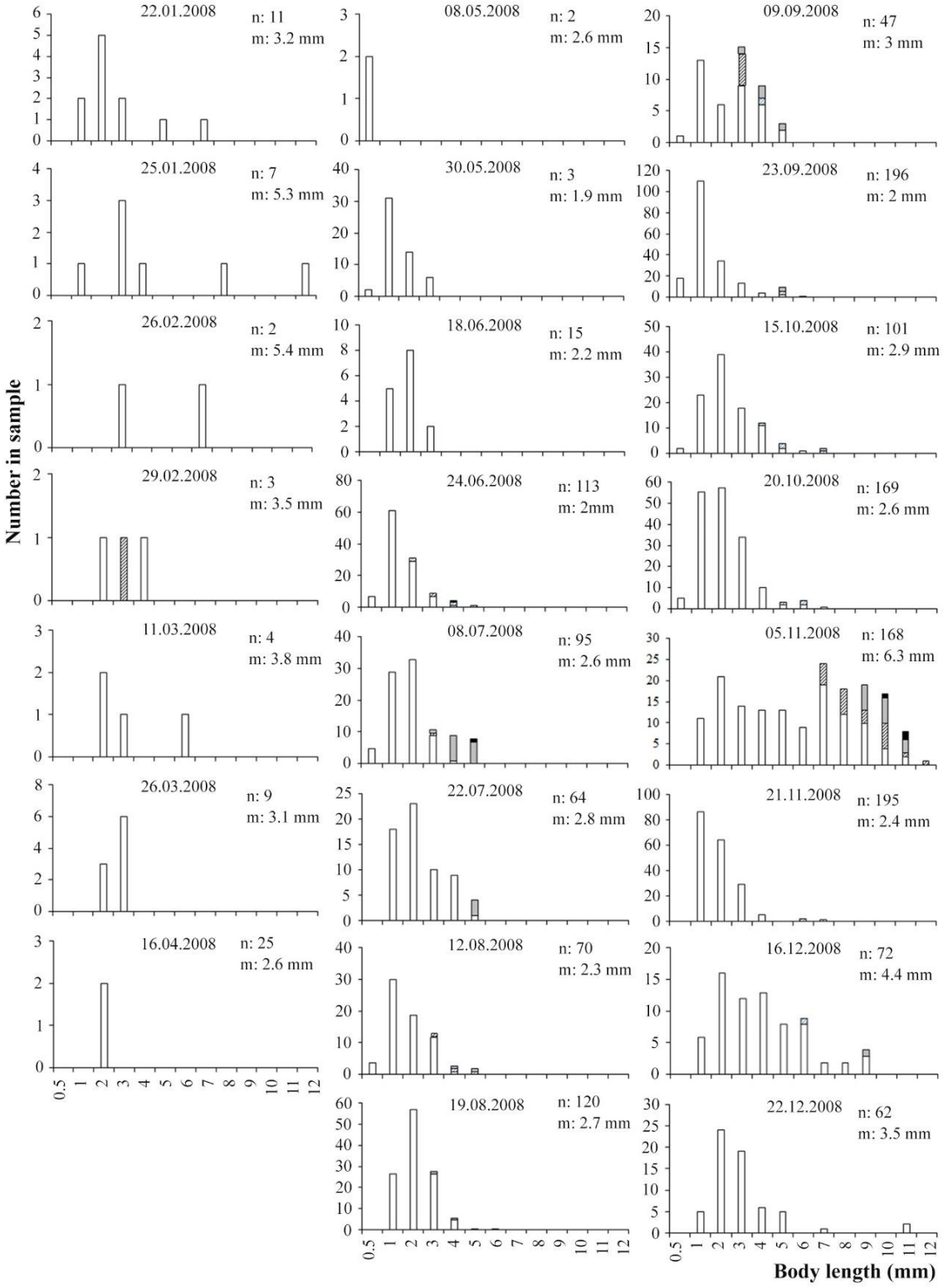

Figure 2. Distribution of different maturity stages of *P. setosa* in Sinop, southern Black Sea. Values are represented in body length (mm) versus the number in the sample. N: number of sampled specimens, m: mean body length, white bar: stage 1, crisscross bar: stage 2, grey bar: stage 3, black bar: stage 4.

Table 2. The number of food items in gut content, FCR (the food containing ratio), and NPC (the number of prey items per chaetognath) of *P. setosa* in the sampling period in Sinop, southern Black Sea.

Date	DUF	UC	Cn	Ac	Pp	FCR	NPC
30/5/08	1					1.9	0.019
18/6/08	1					6.7	0.067
24/6/08	4			1		4.4	0.044
8/7/08	2	2				4.2	0.042
22/7/08	4	1				7.8	0.078
12/8/08		2				2.9	0.029
19/8/08	4					3.3	0.033
9/9/08	2	2			1	11	0.11
23/9/08			2			1	0.01
15/10/08		5	1	1		7	0.07
20/10/08		5	1			3.6	0.036
5/11/08	2	2		1		3	0.03
21/11/08	1			1		1	0.01
22/12/08	3	1				6.5	0.065

* DUF: Digested unidentified food; UC: Unidentified Copepoda; Cn: Copepoda nauplii; Ac: *Acartia clausi*; Pp: *Paracalanus parvus*

Table 3. Food composition of the gut content of *P. setosa* in Sinop, southern Black Sea

Gut contents	(%)	Stage 1 (%)	Stage 2 (%)	Stage 3 (%)
Digested unidentified food	45.28	37.74	5.66	1.89
Unidentified Copepoda	37.74	28.30	7.55	1.89
Copepoda nauplii	7.55	5.66	1.89	
Acartia clausi	7.55	3.77	3.77	
Paracalanus parvus	1.89		1.89	

In the present study, a total of 1580 individuals were investigated, and food items were found in the gut contents of only 53 individuals. Individuals containing food items in their gut were observed from the end of May 2008 to the end of December 2008. The FCR varied between 1% and 11%, and the NPC was between 0.01 and 0.11, according to the month. In total, the FCR and the NPC of *P. setosa* were calculated as 3.4% and 0.034, respectively. As a result of the food content analysis, it was determined that the majority of individuals had an empty gut (96.6%). Most of the prey items in specimens who had prey items in their guts were digested. However, most food items could not be identified due to digestion. The ratio of identifiable food organisms within digested and undigested foods was approximately 54.7%. Copepods dominated the diet of *P. setosa*. Cannibalism was not observed. The highest feeding intensity was determined in stage 1 of *P. setosa*. Stage 4 individuals had no food in their gut (Table 2, Table 3).

4. DISCUSSION

The annual mean abundance of *P. setosa* in the current study (329 ind.m^{-2}) was quite low compared to previous studies conducted at the same station in 1999 (1748 ind.m^{-2}) and 2002 – 2006 (680 ind.m^{-2} in 2002, 455 ind.m^{-2} in 2003, 736 ind.m^{-2} in 2004, 435 ind.m^{-2} in 2005, 541 ind.m^{-2} in 2006) in Sinop coastal waters, whereas these values were higher than data obtained in 2007 (116 ind.m^{-2}) in the same area. The highest abundance values were always observed in autumn period both in current (980 ind.m^{-2} in September 2008) and previous studies (13300 ind.m^{-2} September 1999, 2050 ind.m^{-2} in September 2002, 1700 ind.m^{-2} November 2003, 3585 ind.m^{-2} October 2005, 2600 ind.m^{-2} September 2006, 295 ind.m^{-2} September 2007) in this region. Only, in 2004, the maximum value was observed in August

(3900 ind.m^{-2}) (Ünal, 2002; Üstün et al., 2016; Üstün et al., 2018). The maximum abundance values obtained from other studies conducted in the coastal regions of the eastern Black Sea (Trabzon) and the western Black Sea were higher than those obtained in this study. In addition, the peak values in the Trabzon region were determined during summer months (Beşiktepe, 1998; Feyzioğlu et al., 2010; Yıldız and Feyzioğlu, 2014). Food and temperature are the principal factors affecting the growth of *P. setosa* in the Black Sea (Besiktepe and Unsal, 2000). A high abundance of *P. setosa* was detected in the summer and autumn months when copepod abundance and temperature are high (Besiktepe and Unsal, 2000; Ünal, 2002). Coastal regions are highly sensitive and variable systems against environmental factors (such as precipitation, and terrestrial inputs). Therefore, the abundance values of species may vary in coastal areas which have different topographical and hydrographic structures (Calbet et al., 2001; Terbıyık Kurt and Polat, 2013).

The peak *P. setosa* abundance in the Black Sea was reached in July/August and September when most of the smaller individuals (juvenile) settle in the upper strata. Spawning begins in July, and the number of adult individuals decreases rapidly and is replaced by young individuals in July/August (Niermann et al., 1998; Besiktepe and Unsal, 2000). In the summer and early autumn, populations distributed in the upper strata were dominated by *P. setosa* juveniles. Adult *P. setosa* carry out diel vertical migration from the oxygen minimum zone to the surface layers (Niermann et al., 1998; Besiktepe and Unsal, 2000; Mutlu 2006).

In the present study, based on the number of immature individuals (stage 1) in the Sinop coastal area, it was determined that the breeding period continued from June to December. Microscopic examinations revealed that the number of individuals with eggs (stages 2, 3, and 4) was high in early July, early September, and early November. After these months, the number of immature individuals increased, whereas the number of individuals with eggs decreased. Qresland (1983) suggested that *P. setosa* died after breeding.

The body length of *P. setosa* ranged from 1.4 to 20.6 mm in the eastern Black Sea (Feyzioğlu et al., 1998), 1 to 19 mm in the western Black Sea (Beşiktepe, 1998) and 0.5 – 1mm to > 20mm in Sinop (Ünal, 2002). The body lengths recorded in the present study were shorter than those recorded in the previous studies. However small-sized individuals were found to be dominant in all these studies. These differences may be due to the use of different sampling mesh and larger mesh sizes, as well as the fact that other studies have been carried out in deeper regions. Ünal (2002) mentioned that large/adult individuals showed a higher distribution density in deep waters, whereas small/young individuals were more abundant in coastal waters.

The very low number of adults and large-sized individuals in the present study could be attributed to the possibility that these were present in deep waters and were thus unnoticed during sampling or were dead after breeding. Therefore, the abundance and body length of *P. setosa* recorded in the present study were compared with those recorded in studies conducted in the coastal area.

The feeding rates (values of FCR and NPC) determined in this study were lower than those recorded by studies carried out on other seas (Table 4). Drits and Utkina (1988) examined the nocturnal feeding of *P. setosa* in the deep waters of the Black Sea during April-May 1984. They found that copepodite V and *Calanus* and *Pseudocalanus* females formed the stomach contents of members with lengths ranging from 16-21 mm. In the current study, *A. clausi* and *P. parvus*, which are characteristic of coastal areas, were detected in the stomach contents of *P. setosa*, while Drits and Utkina (1988) detected the presence of deep-water copepod species. In the present study, copepods (54.7%) provided the main food source of *P. setosa*, which aligns with the well-documented fact that copepods are the preferred prey of chaetognaths (Duro and Saiz, 2000; Batistić et al., 2003; Kehayias and Ntakou, 2008).

Table 4. Reported FCR and NPC values for *P. setosa* in other regions.

	Duró and Saiz (2000) **Catalan Sea Mediterranean Sea**	**Batistić¤ et al. (2003) South Adriatic**	**Tönnesson and Tiselius (2005) West Sweden**	**Kehayias et al. (2005) North Agean Sea**	**Kehayias and Ntakou (2008) East Agean Sea**
FCR	8.2 – 10.7% (in day)	0 – 6% (5.9% in total)	52.5% (in total)	8.3% (in total)	39.3% (in total)
NPC	0.08 – 0.11 (in day)	0 – 0.04	0.28 – 0.56 (in day)		

Significant amounts of unidentified food items were detected in the gut contents of *P. setosa*. Similarly, a high percentage of unidentified food items was noted in the diet of this species; it consisted of a high population of stage 1 individuals in the eastern Aegean Sea (Kehayias and Ntakou, 2008). Smaller prey selected by small-sized individuals can be digested relatively quickly; therefore, the identification of food in the gut contents is a difficult task (Pearre, 1974). Thus, the high proportion of unidentified food items in the present study can be attributed to the high prevalence of small-sized individuals.

In conclusion, the abundance and length composition values obtained in this study are lower than the results obtained in other studies conducted in the Black Sea. Feeding ratio values that are low suggest that it has a quite limited effect on the creatures that constitute its food. Conducting studies also on the deep water column and determining the relationship between the results found and the environmental parameters (such as temperature, and salinity) will help to better understand the place and importance of the species in the pelagic ecosystem of the Black Sea to explain the population structure and feeding regime of *P. setosa* in a better way.

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CONFLICT OF INTEREST

The author declares that she has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

AUTHOR CONTRIBUTIONS

Funda Üstün is only author in the paper.

ETHICAL STATEMENTS

Local Ethics Committee Approval was not obtained because experimental animals were not used in this study.

DATA AVAILABILITY STATEMENT

Data supporting the findings of the present study are available from the corresponding author upon reasonable request.

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