

Can the early stage copepoda (Copepodites and Naupliies) abundance play important role on the fatty acid composition of *Sagitta setosa* (Chaetognatha) in the Southeastern Black Sea?

Güneydoğu Karadeniz'de erken aşamadaki kopepod (Kopepoditler ve Naupliiler) bolluğu *Sagitta setosa* (Chaetognatha) yağ asiti kompozisyonu üzerinde önemli rol oynayabilir mi?

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Abstract: In this study, the relationship between the fatty acid composition, abundance of carnivore *Sagitta setosa* (*S. setosa*) and total copepod abundance (copepodites and nauplii) which are the main diets of *S. setosa* was investigated. Sampling was conducted monthly during a year. During the sampling period, *S. setosa* and the total the copepod abundance showed a parallel distribution until November. Average total lipid was at the highest with 3% in spring and autumn, while the lowest was 2% in winter and summer. While DHA/EPA ratio (2.23) as carnivory index in *S. setosa* and the total copepod (copepodites and nauplii) abundance (1375 ind/m³) were at the highest in winter, but another carnivory index, 18:1ω9/18:1ω7 ratio did not show a parallel increase with copepod abundance. However, 18:1ω9 which increases the carnivory index, is among the main fatty acids in *S. setosa*. This might be indicated that *S. setosa* does not related to predation on the copepods, but it shows that feeding in a carnivorous style. Additionally, the herbivory index $\sum n-3/\sum n-6$ ratio was detected in spring and autumn at the highest level. Consequently, although there is no direct effect between the copepod abundance and *S. setosa* fatty acids, it is possible an indirect effect.

Keywords: Carnivory index, fatty acids, *Sagitta setosa*, Southeastern Black Sea

Öz: Bu çalışmada karnivor bir tür olan *Sagitta setosa*'nın yağ asiti kompozisyonu ve bolluğu ile üzerinden yoğun bir şekilde beslendiği kopepodların (kopepoditler ve kopepot naupliileri) bolluğu arasındaki ilişki incelenmiştir. Örneklemeler bir yıl boyunca aylık periyotlarda yapılmıştır. Örnekleme dönemi boyunca *S. setosa* ve toplam kopepod bolluğu, kış ayına kadar paralel bir dağılım göstermiştir. Ortalama toplam lipid miktarı %3 ile en yüksek ilkbahar ve sonbahar, en düşük ise %2 ile kış ve yaz aylarında belirlenmiştir. *S. setosa*'da karnivor indeksi olarak DHA/EPA oranı (2,23) ve kopepod bolluğu (1375 birey/m³) en yüksek değerlerini kış döneminde almışlardır. Bu dönemdeki yüksek kopepod bolluğunun *S. setosa*'daki karnivor indeksi yağ asitlerini artırmaya katkı sağladığı söylenebilir. Fakat diğer bir karnivor indeksi olan 18:1ω9/18:1ω7 oranı kopepod bolluğu ile papalel bir artış göstermemiştir. Ancak, karnivor indeksini artıran 18:1ω9 un *S. Setosa*'daki temel yağ asitleri arasında olması, *S. setosa*'nın her zaman kopepodlar üzerinden bir predasyon sergilemesi de karnivor beslenişine kanıt olarak gösterilebilir. Bunun yanında, herbivor indeksi olan $\sum n-3/\sum n-6$ oranı en yüksek ilkbaharda ve sonbaharda belirlenmiştir. Sonuç olarak, kopepod bolluğu ile *S. setosa*'nın yağ asitleri arasında direkt bir etki olmasa da indirekt bir etkinin varlığından bahsedilebilir.

Anahtar kelimeler: Karnivor indeksi, yağ asitleri, *Sagitta setosa*, Güneydoğu Karadeniz

INTRODUCTION

Chaetognaths are important zooplankton predators in marine environments (Reeve, 1980; Feigenbaum and Maris, 1984; Baier and Purcell, 1997). Their main diet consists of copepods (Feigenbaum and Maris, 1984; Feigenbaum, 1991; Duró and Saiz, 2000). On the other hand, they are noteworthy a link between the phytoplankton and many fish species, especially including commercially important fish species (Vinogradov et al., 1992; Kovalev et al., 1998).

Sagitta setosa (*S. setosa*) which is a chaetognath species, is commonly found in the Black Sea Sea (Zenkevitch, 1963; Vinogradov et al., 1990; 1992; Niermann and Greve, 1997). It accumulates more along rim current than shelf areas and in the central gyres of the Black Sea (Niermann et al., 1997). The most crucial factors affecting the growth of *S. setosa* in the Black Sea are temperature and food supply. (Beşiktepe and Ünsal, 2000; Yıldız and

Feyzioğlu, 2014). Additionally, the abundance of *S. setosa* was affected by the existence of appropriate food intensity during the previous month (about a month ago). Therefore, in this study, the purpose was to determine the relation between the seasonal fatty acid composition of *S. setosa*, which is one of the important zooplankton predators in the Black Sea ecosystem, and the seasonal abundance distribution of copepodites and copepod nauplii, which are the main diet of *S. setosa*. It was investigated in a different perspective on which periods/which fatty acids of *S. setosa* have a high level and whether or not there is a relationship between *S. setosa* fatty acids and copepod (copepodites and nauplii) abundance. Because, fatty acids (FA) are among the most important molecules transferred from plant to animal in aquatic food webs. Certain classes of FA, such as the omega-3 (ω 3; n-3), highly unsaturated fatty acids (HUFA) which are available in limited quantities and very important for herbivore zooplankton are transferred from phytoplanktonic organisms to upper trophic levels (Müller-Navarra, 1995; Müller-Navarra et al., 2000; Ravet et al., 2003). FA have three characteristics and storage patterns. These special features make them useful tracers of diets and aquatic food webs. First, organisms can establish biosynthesis, modify chain length, and introduce double bonds in FA. However, they are subject to biochemical limitations in these processes depending on the phylogenetic group and even species (Cook, 1996). Second, unlike other dietary nutrients (e.g., proteins and carbohydrates) which digestion is completely degraded, FA are released from the digestive amounts of digested lipid molecules, but are generally not deformed and taken up in basic forms by tissues. The important consequences of these restrictions within plants, bacteria, and animals, and the uptake of intact FA by consumer tissues, is that individual isomers as well as "families" of FA bioaccumulate through food chains, and they can be traced back to specific food web origins. Third, unlike most other nutrients, fat is stored as reservoirs in animal bodies. These often-substantial stores can later be mobilized to provide fuel for short or long-term energy demands (Pond, 1998). Therefore, FA accumulate over time and represent an integration of dietary intake over days, weeks, or months, depending on the organism and its energy intake and storage rates. In addition, it is important to know FA composition of the zooplankton which by taxonomic affiliation, changed by diet and modified by starvations or temperature (Arts et al., 2009).

MATERIALS AND METHODS

Location of expedition and sampling

R/V YAKAMOZ research boat, which belonged to Faculty of Marine Science, KTU was used in samplings. The zooplankton samples were collected monthly from the Southeastern Black Sea Sürmene Bay between March 2012-February 2013. The station was 3 sea miles far (40° 57' 12" N-

40° 09' 30" E) from the coast, and has a depth of 400 meters. The Exgolabur 7 GPS was used in determining of the station. The zooplankton samples were collected vertically with Hansen plankton net having 110cm mouth diameter and 200 μ m mesh width from 130m depth to the surface in determination of the abundance and fatty acid composition (Harris et al., 2000). A conductivity- temperature-depth-oxygen CTD profiler (CTD, General Oceanic Idranaut 316) was used in determination of temperature values.

Determination of abundance for the zooplankton species

The zooplankton samples were preserved in a 4% formaldehyde seawater solution buffered with sodium borate. Countings were done under stereomicroscopes (Olympus BH2 and Nikon) using 4 \times and 10 \times objectives and a Bogorov-Rass counting chamber. Quantitative analyses of species were performed by using 3 ml subsamples. Countings were repeated on 4 subsamples (Harris et al., 2000). The copepods (copepodites, copepod nauplii) were identified to species or genus level (Mauchline et al., 1998; Johnson and Allen, 2005). The zooplankton abundance was expressed as the number of the individuals in m³ (ind/m³). Zooplankton abundance was performed with monthly intervals, copepodites and nauplii of 5 species from copepoda were detected (*Calanus euxinus*, *Pseudocalanus elongatus*, *Acartia clausi*, *Paracalanus parvus*, *Centropages ponticus*): 1 species of cyclopoid copepod was detected (*Oithona similis*): and 1 species was detected from Chaetognatha (*S. setosa*).

Total lipid and fatty acid analysis

Lipids were quantitatively extracted from the samples using chloroform/methanol (2:1) (Folch et al., 1957). To determine the fatty acids methyl esters (FAME) is used 2 ml chloroform and 1 ml 0.21 N NaOH in methanol solution were used. Then, 0.5 N acetic acid solution was added. Lower phase was evaporated and 2 ml hexane was added on the lipid and the sample was transferred to a vial (Kates, 1986). The FAME were detected by Shimadzu GC-17 gas chromatograph (GC). Capillary columns with a length of 25 m, inner diameter of 0.25 μ m, and with a thickness of 25 μ m (Permabond) were used (Macherey-Nagel). Column temperature was set to 120-220 °C, with the increment of 5 °C/min until 200 °C and 4 °C/min to 220 °C. The column was kept for 8 min at 220 °C and the total time was determined as 35 minutes. Injection temperature is set to 240 °C and detector temperature to 280 °C. Nitrogen was used as the carrier gas.

Statistical analysis

STATISTICA 8.0 was used in statistical analysis. The data were analyzed using analysis of variance (one way ANOVA) method and comparisons among averages were carried out by using Tukey Test. Tukey test created by Post-

hoc, homogenous groups ($p < 0.05$). In definitions of the statistical differences, the Spearman Rank Correlation was applied ($p < 0.05$).

RESULTS AND DISCUSSION

Fatty acids have often been used to track energy transfer, as well as to study predator-prey relationships (Falk-Peterson et al., 1990: 2000; Litzow et al., 2006). In this study, the relation between *S. setosa* abundance and fatty acids and the total copepod abundance was examined in the sampling period to reveal the prey-predator relation. A constant increase was observed from Spring to Winter (Spring: 268 ind/m³, Summer: 398 ind/m³, Autumn: 814 ind/m³, Winter: 1375 ind/m³) in the total copepod (copepod nauplii and copepodite) abundance. While copepod nauplii reached the highest abundance in February (457 ind/m³), copepodites reached the highest abundance in January (1668 ind/m³). Although *S. setosa* and the total copepod abundance showed a parallel distribution until November, the total copepod abundance increased *S. setosa* abundance decreased when compared to the previous month in November and February. In December, the total copepod abundance decreased *S. setosa* abundance increased compared to the previous month. (Figure 1). This situation is common only in late summer and autumn." (Øresland, 1983, 1985; Yıldız and Feyzioğlu, 2014). Breeding and growth of *S. setosa* occur after the copepods reached the highest abundance (Niermann et al., 1997) because, copepods are the primary food source of *S. setosa* (Feigenbaum, 1991). Food and temperature are major factors affecting the growth of *S.*

setosa in the Black Sea (Beşiktepe and Ünsal, 2000). We determined that the average water temperature (°C) in the 100 m water column was based during the sampling period. The lowest average water temperature was determined in March (8 °C) and the highest average water temperature was determined in August (14 °C) during the sampling period.

It was reported that breeding of *S. setosa* was probably most intensive from June to November (indicated by the frequency of small individuals) in 1994-1996 in the different stations by Beşiktepe and Ünsal (2000). Øresland (1987) observed small individuals of *S. setosa*, indicating intensive spawning, from July to early October in the western English Channel. Niermann and Greve (2007) observed the replacement of the entire population of *S. setosa* by a new generation in August in the Black Sea. Microscopic observation suggested that two broods were produced abundance the breeding period, as most of the adults belonging to the new generation had eggs in their gonads in June (Beşiktepe and Ünsal, 2000). In this study, too, it is observed that based on the average weight per individual of *S. setosa*, the biggest individuals are in May (10 mg/ind) and June (9 mg/ind), and the smallest individuals are in November and February (2 mg/ind). *S. setosa* abundance and individual weights showed a parallel change in August, (Figure 2). It was found that the relationship between temperature and abundance and average individual weight of *S. setosa* was not significant ($r^2 = 0.5$; $r^2 = -0.5$, respectively) ($p < 0.05$). However, the relationship between the total copepod abundance and individual weight of *S. setosa* was significant ($r^2 = 0.8$) ($p < 0.05$).

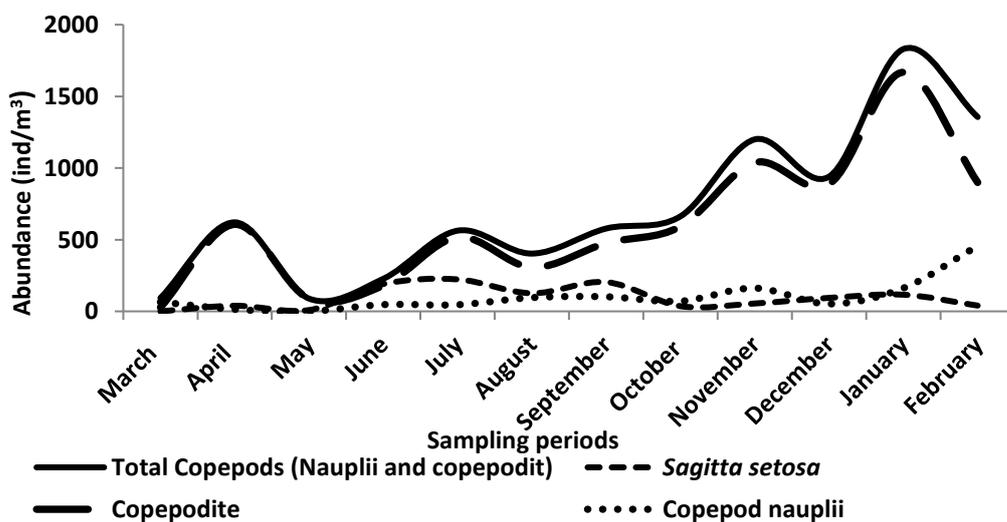


Figure 1. Abundance of the total copepods and *S. setosa* during the sampling period

In the study, the total lipid was at the highest in Spring and Autumn with 3%, and at the lowest in winter and summer with 2% during the sampling period. The average lipid per

individual was at the highest in spring (0.21 mg/ind) and in summer (0.17 mg/ind), and at the lowest in autumn (0.16 mg/ind) especially in winter (0.07 mg/ind). The average

individual weight showed parallelism to Σ lipid (mg/ind) level, and there is a linear relation between them ($R^2=0.9$). The average individual weight was determined at the highest in spring (6.4 mg) and in summer (6.7 mg), and at the lowest in autumn (4.7 mg) and winter (3.2) (Figure 3). When the fact that small individuals enter the population in periods when the individual weight was low in *S. setosa* is considered, we may claim that this period continues during autumn when the onset of this period was observed. This shows that in *S. setosa*, there is a relation between the time-dependent change of the lipid level and the development periods. It is observed that the lipid levels are high in adulthood periods. Choe et al. (2003) found that chaetognath *Parasagitta elagans* lipid levels were relatively high in spring and summer and low in the fall and winter from the hyperbenthic zone of Conception Bay,

Newfoundland. Their results showed that *P. elegans* (Copepoda) had rich lipid while maturing abundance spring and summer. This increase in lipid when mature copepods increased in the spring and summer rather than when total abundance of copepods increased in the fall (Choe et al., 2003). However, it was unlike this situation in our study. And it was determined that the abundance was low in the copepod individuals at all stages in periods when total lipid was high. This made us consider that in these periods, *S. setosa* feed on other zooplanktonic species, which are abundant in this period, rather than copepods. Şen Özdemir (2013) reported in Southeastern Black Sea Region that the most abundant zooplankton group was the cladocerans in 2012-2013 period in June (581 ind/m³) and in July (1748 ind/m³; 52% of the total zooplankton).

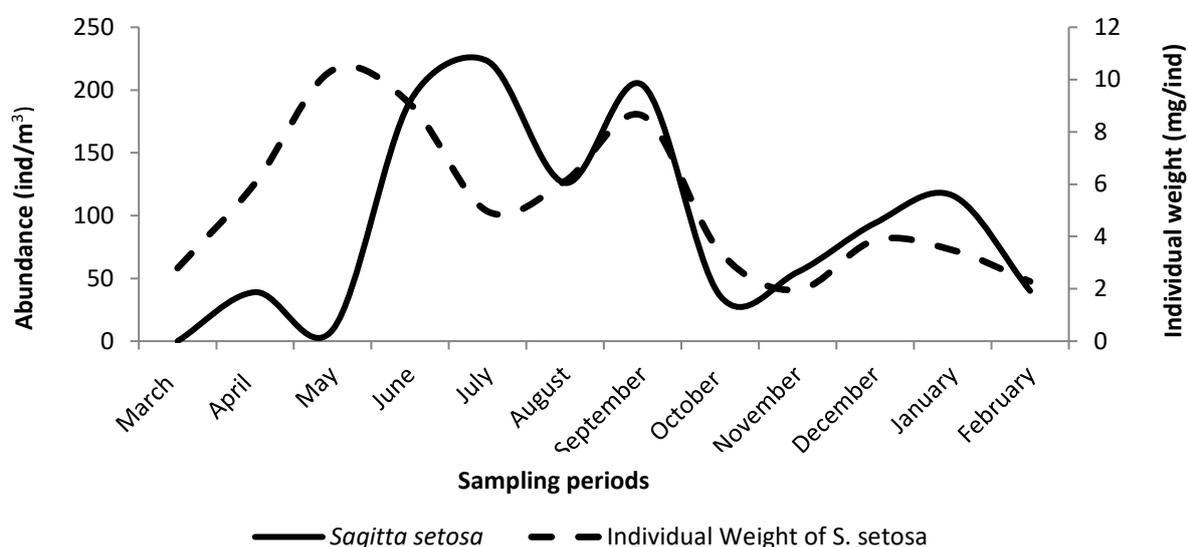


Figure 2. The changes in the average individual weight (mg/ind) and abundance of *S. setosa* during the sampling period

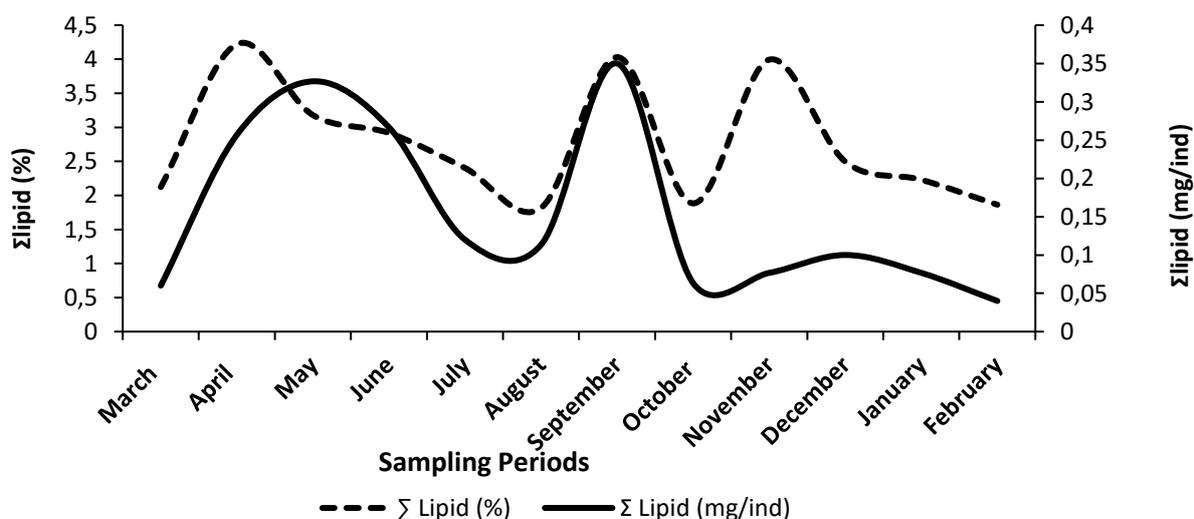


Figure 3. Changes of total lipid (Σ lipid) (%: mg/ind) of *Sagitta setosa* during the sampling period

Beşiktepe and Ünsal (2000) observed the highest abundance in September. Similar observations were made in Crimea coastal area in the Black Sea. It was reported that in periods when *S. setosa* is abundant at the highest level, the copepods, which are their primary feed, are also abundant (Feigenbaum, 1991). Large numbers of copepods appear in June. This period of high copepod density and higher temperature is followed by the growth and maturity of *S. setosa*, suggesting that food and temperature are major factors affecting the growth of *S. setosa* in the Black Sea (Beşiktepe and Ünsal, 2000). Ünal (2002) determined that the *S. setosa* abundance increased together with the increase in copepods in Summer and early Autumn in the coastal and open stations. A similar situation was also determined by Yıldız and Feyzioğlu (2014).

Öztürk (2002) determined the highest abundance in November in 1999, and reported that the highest values were determined in summer months in 2000-2001. It was reported in this study that the highest abundance between 1999-2001 (4.451 ind/m²) in 2000 July. Yıldız and Feyzioğlu (2014), reported that *S. setosa* reached its highest abundance in October in 1999 (82.618 ind/m²), in May in 2000 (93.768 ind/m²), in summer months in 2001, in August in 2002, (9.713 ind/m²), in June in 2005 (3.699 ind/m²) and in 2006, in September (17.752 ind/m²). The findings that were obtained about the *S. setosa*, which was reported to have been determined with the highest abundance level in summer, are in agreement with the data obtained by Beşiktepe and

Ünsal (2000), Öztürk (2002) and Yıldız and Feyzioğlu (2014). However, when the changing environmental conditions in time are considered in sampling periods and according to stations, it is normal that there are several differences.

In this study, during the sampling periods, the following values were determined in *S. setosa*, which is a carnivore species: Σ SFA 21.65%, Σ MUFA 19.87%, Σ PUFA 58.47% . 18:0 is a major fatty acid in animals and some fungi, and a minor component in most plants (Rustan and Drevon, 2005). Saturated fatty acids (SFA) including 16:0, 18:0 and 14:0 are typical calanoid copepods (Prah et al., 1984; Harvey 1987; Sargent and Falk-Peterson, 1988; Veloza et al., 2006). In this study, 18:0, 14:0 and 16:0 were among the most important SFA (Table 1). When the copepod abundance is considered along the sampling period, it is observed that 16:0, which is at the highest level in March in *S. setosa*. Therefore, it is considered that the species that might be preferred as nutrient by copepods are these, because the fatty acid composition is affected by the changes in nutrient sources and variety along the year (Morris, 1971; Ackman et al., 1974; Lee et al., 1971). Veloza et al. (2006) indicated that 16:0 was one of most abundant SFA in *A. tonsa*. Similarly, Şen Özdemir et al. (2017) 16:0 was the most abundant fatty acid in *C. euxinus* of the Eastern Black Sea. In this study, all the copepod species that might be preferred by *S. setosa* except for *O. similis* (Cyclopoid) are being calanoid copepods might indicate the predation of *S. setosa* over these copepod species in this intensity.

Table 1. SFA composition of *Sagitta setosa* during the sampling season (% determined total FAME)

FA	March	April	May	June	July	August	September	October	November	December	January	February
14:0	-	1.21±0.06 ^b	1.73±0.35 ^b	2.62±0.09 ^{ab}	2.75±0.10 ^{ab}	1.86±0.08 ^b	3.01±0.99 ^{ab}	-	4.52±2.51 ^a	1.75±0.03 ^c	1.34±0.08 ^c	1.00±0.21 ^e
15:0	-	0.42±0.03 ^b	-	0.66±0.04 ^a	-	-	-	-	-	-	-	-
16:0	18.87±0.56 ^a	16.54±0.24 ^b	15.14±0.62 ^{bc}	14.58±0.07 ^{cd}	13.88±0.36 ^{cd}	11.85±0.09 ^c	14.99±0.29 ^{bcd}	14.52±0.64 ^{cd}	12.93±1.02 ^{ac}	13.97±0.28 ^{cd}	13.89±0.64 ^{cd}	14.12±0.16 ^c
17:0	-	1.36±0.05 ^{ab}	-	0.60±0.02 ^c	1.12±0.32 ^b	1.48±0.03 ^a	-	-	1.27±0.04 ^{ab}	1.49±0.02 ^a	-	1.13±0.13 ^{cd}
18:0	-	3.40±0.03 ^d	3.93±0.13 ^{defg}	3.87±0.06 ^{efg}	3.78±0.04 ^{dg}	4.70±0.03 ^{abde}	4.38±0.25 ^{bdef}	5.59±0.38 ^a	4.74±0.74 ^{abd}	5.20±0.02 ^{abc}	5.22±0.06 ^{ab}	4.30±0.09 ^{efg}
20:0	-	0.83±0.01	-	-	-	-	-	-	-	-	-	-
22:0	-	0.52±0.09	-	-	-	-	-	-	-	-	-	-
24:0	-	0.99±0.03 ^a	-	-	-	-	-	-	-	1.25±0.39 ^a	-	0.96±0.08 ^a
Σ SFA	18.87±0.53 ^a	25.27±0.04 ^a	20.80±0.84 ^{defg}	22.34±0.14 ^{bcd}	21.53±0.63 ^{efg}	19.89±0.0 ^{eg}	22.38±0.46 ^{bcd}	20.10±1.01 ^{eg}	23.75±0.78 ^{ab}	23.67±0.19 ^{abc}	20.45±0.61 ^{deg}	21.91±0.65 ^{cdf}

Values in the same line follows by different letters are significantly different (P<0.05), n=3, mean ±SD

PUFA are synthesized by primary producers and then consumed and incorporated into the tissues of grazers and secondary consumers (Dalsgaard et al., 2003). In particular, the PUFA such as 20:4 n-6 (ARA: Arachidonic acid), EPA and DHA cannot be synthesized by most heterotrophs, but are essential components of membranes, and as such are termed essential fatty acids (EFA). The source of these EFA are of significant interest in aquatic food web studies and can provide fundamental information about plankton condition and trophodynamics. Furthermore, the relative quantities of

marker fatty acids in consumers, including 22:6 n-3, 20:5 n-3 (EPA), 18:1 n-9, and long chain monounsaturated fatty acids (MUFA), are often used as indicators of specific food sources (Falk-Petersen et al., 2000; Dalsgaard et al., 2003). For example: ratios 18:1 n-9/18:1 n-7, DHA/EPA and 16 carbon/18 carbon fatty acids (Σ 16C/ Σ 18C) are also useful when determining the relative contributions of animal prey or different phytoplankton groups (e.g. dinoflagellate versus diatom food) to consumer diets (Dalsgaard et al., 2003). Σ n-3/ Σ n-6 ratio represents an herbivory index (Sargent and Falk-

Petersen, 1981), and the ratios 18:1 n-9/18:1 n-7 and DHA/EPA are carnivory indexes (Cripps and Atkinson, 2000; Dalsgaard et al., 2003). Σ PUFA/ Σ SFA ratio can be a useful freshness (Derieux et al., 1998) or diatom index for suspended particulates (Claustre et al., 1989), or a potential carnivory index in some consumers (Cripps and Atkinson, 2000). In this manner, fatty acid profiles can inform us about the predominant food and feeding plasticity of herbivorous and omnivorous zooplankton. Alterations in fatty acids occur from one trophic level to the next, but valuable dietary information can be retained despite these metabolic modifications (Dalsgaard et al., 2003). In the study, DHA/EPA changed between 1.62-2.49 as carnivory index, and winter is seen that it is the period with highest values with an average of 2.29 (Table 2). When the fact that the total copepod abundance is at the peak level in winter (2549 ind/m³) is considered, it might be thought that the carnivory index of *S. setosa* being high may stem from the copepods it feeds on. As

a result of the statistical analyses, it was observed that the EPA level (whose increase decreases carnivore index) was at the lowest level in *S. setosa* in autumn (9.15%), which is different from the other seasons ($p < 0.05$). 18:1 n-7 is not considered as the dominant MUFA during the sampling period in *S. setosa*. 18:1 n-9 is considered as the most dominant MUFA (8.57-12.20) in *S. setosa* (Table 3). However, unlike DHA/EPA, 18:1 n-9/18:1 n-7 ratio had its lowest average value (8) in winter, and had its highest average value (11) in summer.

However, the fact that the 18:1 n-7, which will decrease the carnivore index, was not detected in the fatty acids during the sampling period. 18:1 n-9 being among the most important fatty acids of *S. setosa* may be shown as the proof that although *S. setosa* does not always show a predation on copepods, it feeds in a carnivorous manner. In addition, the $\Sigma n-3/\Sigma n-6$ ratio, which is the herbivore index, was determined in spring and autumn at the highest levels.

Table 2. PUFA composition of *S. setosa* during the sampling period (% determined total FAME)

FA	March	April	May	June	July	August	September	October	November	December	January	February
18:2n6c	-	1.92±0.04 ^d	2.41±0.02 ^{bc}	2.19±0.06 ^{cd}	2.25±0.09 ^{cd}	3.69±0.26 ^a	2.23±0.02 ^{cd}	3.48±0.20 ^a	2.28±0.44 ^{cd}	2.10±0.08 ^{cd}	2.82±0.24 ^b	1.42±0.02 ^e
18:3n3c	-	1.70±0.02 ^{bc}	1.37±0.08 ^{cd}	1.13±0.04 ^{efg}	0.96±0.01 ^g	2.44±0.42 ^a	-	-	1.12±0.012 ^{efg}	1.97±0.52 ^b	1.44±0.33 ^{ce}	1.05±0.02 ^g
20:2n6	-	2.51±0.04 ^a	1.40±0.01 ^d	-	-	-	-	-	-	1.64±0.01 ^b	2.15±0.05 ^b	1.29±0.07 ^d
20:3n6	-	0.25±0.03 ^c	-	-	-	2.77±0.33 ^a	-	-	-	0.70±0.03 ^b	-	-
20:4n3	-	1.79±0.01 ^c	1.53±0.01 ^{ce}	-	-	2.49±0.16 ^d	-	3.29±0.01 ^e	-	1.41±0.13 ^{de}	1.76±0.24 ^c	1.13±0.03 ^d
20:4n6	-	0.53±0.01 ^d	-	0.75±0.02 ^b	0.88±0.02 ^b	-	-	-	1.10±0.02 ^a	0.77±0.02 ^c	-	0.58±0.04 ^d
22:2	-	0.51±0.01 ^a	-	-	-	1.57±0.04 ^a	-	-	-	-	-	-
20:5n3(EPA)	19.26±0.34 ^a	16.45±0.12 ^{de}	16.90±0.30 ^a	17.92±0.14 ^{abc}	17.42±0.17 ^{bcd}	15.62±0.39 ^{ef}	18.68±0.33 ^{ab}	16.82±0.69 ^{de}	14.43±0.43 ^f	15.98±0.08 ^{de}	16.99±0.40 ^{ode}	18.75±0.27 ^{ab}
22:5n3	-	0.57±0.01 ^b	-	-	-	-	-	-	-	0.68±0.05 ^a	-	-
22:6n3(DHA)	39.24±1.23 ^a	26.61±0.18 ^d	32.45±0.84 ^b	34.99±0.28 ^{ab}	35.41±0.86 ^{ab}	32.39±0.47 ^b	37.75±0.91 ^{bc}	39.30±1.34 ^a	32.38±2.52 ^b	38.20±0.41 ^{bc}	39.94±1.32 ^a	37.23±0.15 ^{cc}
Σ PUFA	58.49±1.57 ^{cc}	52.84±0.29 ^{df}	56.06±1.22 ^{de}	56.98±0.36 ^d	56.91±0.93 ^d	60.97±0.52 ^{bc}	58.65±0.57 ^{dc}	63.41±1.57 ^{ab}	51.31±2.55 ^f	63.47±0.48 ^{ab}	65.45±1.12 ^a	63.01±0.34 ^{ab}
DHA/EPA	2.04±0.03 ^{cd}	1.62±0.01 ^e	1.92±0.04 ^d	1.95±0.01 ^d	2.03±0.03 ^{cd}	2.07±0.03 ^{cd}	2.02±0.06 ^{cd}	2.34±0.02 ^{ab}	2.24±0.10 ^{bc}	2.39±0.01 ^{ab}	2.49±0.11 ^a	1.99±0.02 ^d

Values in the same line follows by different letters are significantly different ($P < 0.05$), n=3, mean ±SD

Table 3. MUFA composition of *S. setosa* during the sampling period (% determined total FAME)

FA	March	April	May	June	July	August	September	October	November	December	January	February
15:1	-	-	-	-	-	-	-	-	-	-	-	1.16±0.05
16:1n7	10.74±0.63 ^a	7.35±0.17 ^{bc}	6.28±0.01 ^{fg}	5.51±0.09 ^{deg}	6.61±0.20 ^{df}	6.23±0.29 ^{fg}	6.11±1.00 ^{fg}	7.73±0.64 ^b	5.19±0.01 ^{de}	4.97±0.25 ^e	5.09±0.08 ^e	6.33±0.18 ^{fg}
18:1n7	-	3.51±0.07 ^a	2.86±0.12 ^b	-	-	-	-	-	-	1.83±0.02 ^c	1.67±0.04 ^c	1.61±0.08 ^c
18:1n9f	-	-	1.04±1.02 ^c	1.02±0.01 ^c	1.07±0.01 ^c	-	-	-	1.61±0.05 ^a	-	-	1.23±0.08 ^b
18:1n9c	11.90±0.42 ^a	9.98±0.15 ^{bc}	9.30±0.36 ^c	10.90±0.58 ^{ab}	11.13±0.5 ^{ab}	8.57±0.09 ^{cd}	10.93±0.22 ^{ab}	9.28±0.24 ^c	7.67±1.37 ^d	7.30±0.27 ^d	8.77±0.57 ^{cd}	7.36±0.03 ^d
20:1 n9	-	0.43±0.01 ^d	1.21±0.01 ^{bc}	1.25±0.07 ^b	0.90±0.01 ^c	-	1.94±0.06 ^a	-	1.79±0.13 ^a	-	-	-
20:1nX	-	-	2.45±0.03 ^b	1.39±0.06 ^c	0.95±0.01 ^d	-	-	-	3.18±0.12 ^a	-	-	-
22:1n9	-	0.63±0.04 ^{cd}	-	0.62±0.02 ^{cd}	0.91±0.02 ^c	2.64±0.19 ^b	-	-	6.62±0.19 ^a	0.73±0.04 ^{cd}	-	-
24:1	-	-	-	-	-	1.70±0.16 ^a	-	-	-	-	-	-
Σ MUFA	22.64±1.00 ^b	21.89±0.26 ^{def}	23.13±0.38 ^b	20.69±0.49 ^{bcd}	21.57±0.30 ^{bcd}	19.14±0.59 ^{ode}	18.97±0.11 ^{de}	17.01±0.81 ^{efg}	26.06±1.77 ^a	14.83±0.43 ^a	15.54±0.84 ^{fg}	17.69±0.05 ^e

Values in the same line follows by different letters are significantly different ($P < 0.05$), n=3, mean ±SD

Seas and oceans that are located in temperate zones are characterized with two seasonal peaks, which are spring and autumn, in terms of phytoplankton concentrations (Lalli and Parsons, 2004). Chlorophyll-a (Chl-a) concentration decreases in winter in the coastal areas of Trabzon in

Southeastern Black Sea Region, and increases in autumn. Two main peaks are observed, which are late winter-early spring, and early summer (mostly June) (Alkan et al., 2013). Şen Özdemir et al. (2017) indicated that average chl-a concentration increased in spring (May-late spring) and winter

(December-early winter). Chl-a is used as the indicator of the phytoplankton abundance. This shows that the herbivory index being high in *S. setosa* in this period stems from the herbivorous nutrients that are consumed due to high chl-a levels. In addition, it is clear that the reproduction cycles in chaetognaths are synchronized with the intense energy input that occurs with the spring phytoplankton blooms (Choe et al., 2003).

As a conclusion, we may say that although there is no direct relation between the copepod abundance and the fatty acids of *S. setosa*, it has an indirect effect. As a result, we can say that copepod abundance and *S. setosa* have an indirect effect, although there is no direct relationship between fatty acids. This indirect effect can be defined as contributing to the higher trophic levels, especially when copepods are abundant, *S. setosa* receives herbivory index fatty acids by feeding on copepods. Choe et al. (2003) indicated that the temporal variation in the abundance of adult copepods was highly correlated with the biochemical levels of chaetognath

species (*Parasagitta elegans*). In aquatic food webs, FAs are synthesized by phytoplankton and bacteria, and then transferred via zooplankton to higher trophic levels (Parrish, 2009). Additionally, Choe et al. (2003) suggested that there was tight coupling of energy transfer from primary producers to carnivorous hyperbenthic chaetognaths following the spring phytoplankton bloom in Newfoundland coastal waters. Therefore, if we consider the food chain as a whole, not only copepods, but also the abundance changes of the main nutrient sources (phytoplankton) of the copepods can be said to have an effect on the fatty acid composition of *S. setosa*.

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