Preliminary Results on the Feeding and Gut Content of *Flaccisagitta enflata* in Coastal Areas of İskenderun Bay (Northeastern Mediterranean Sea)

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**ABSTRACT**

In this study, it was aimed to characterize the feeding and diet composition of the most common pelagic chaetognath *Flaccisagitta enflata*. Zooplankton samples were collected using a WP-2 zooplankton net (200 µm) at three stations in the İskenderun Bay in October 2016, December 2016 and March 2017. *F. enflata* was the most abundant chaetognath in all samples and its proportion varied from 42 to 94%. Younger stages (I and II) dominated the population of *F. enflata*. In total, 1663 specimens were examined, but only 185 contained prey in their guts. The total food-containing ratio and the number of prey items for this chaetognath species were 11% and 0.1, respectively. These values varied for different maturity stages. Most food items were unidentified due to digestion. Copepods were the main food resource (36.8%) for the species. Cannibalism was also observed.

This study is the first to describe *F. enflata* feeding behaviour in the coastal area of İskenderun Bay. The preliminary results show that the feeding ratios were within the ranges reported for other regions in the eastern Mediterranean Sea.

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**Research Article**

İskenderun Körfezi (Kuzeydoğu Akdeniz) Kıyısal Sularında *Flaccisagitta enflata* (Grassi, 1881)’ın Beslenmesi ve Bağırsak İçeriği Üzerine İlk Gözlemler

**ÖZET**


Bu çalışmada ilk kez İskenderun Körfezi’nin kıyısal alanında *F. enflata*’ın beslenmesi ile ilgili bilgiler elde edilmiş ve ilk gözlemler beslenen canlıların Doğu Akdeniz’in diğer alanlarından elde edilen sonuçlar ile benzer olduğunu göstermiştir.

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**Anahtar Kelimeler**
*Flaccisagitta enflata*, beslenme, FCR, NPC, İskenderun Körfezi

** Araştırma makalesi**

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INTRODUCTION

Chaetognaths are carnivorous organisms living in all marine and ocean habitats (Bone et al., 1991). Taking into consideration of their biomass and global distribution, this organism tends to be one of the most important groups in their ecosystems. The chaetognath biomass can be as high as 30% of the total biomass of copepods in all world oceans (Reeve, 1970).

The feeding is the main route for transferring energy and matter between communities from lower to higher trophic levels (Bamstedt et al., 2000). Chaetognaths are dominant zooplanktonic predators and generally affect the population of their food organisms in environmental conditions with low organic production (Kimmerer, 1984; Oresland, 1990), such as the Eastern Mediterranean Sea. They feed mainly on copepods (Oresland, 1987), however, they can occasionally consume a wide variety of other zooplankters (Feigenbaum, 1991). This group may cause problems in fish breeding regions due to consuming fish larvae and eggs as food. Another factor that makes these organisms important is that they contribute significantly to the matter and energy cycle by creating an important link between larger-sized predators, including commercial fish species, and smaller-sized animal organisms (Reeve, 1970; Nagasawa and Marumo, 1981).

Various studies on the distribution of chaetognath species have been conducted in world oceans (Itoh et al., 2006; Kosobokova and Hopcroft, 2010; Coston-Clements et al., 2009; Pierrot-Bults and Nair, 2010; Nobleza and Campos, 2008), especially in the Mediterranean Sea (Andreu, 1992; Kehayias et al., 1994, 1996; Duro and Saiz, 2000; Kehayias 2003, 2004; Batistic et al., 2003; Terbyyık et al., 2007; Kehayias and Ntakou, 2008; Kehayias and Kourovakalis, 2010). Besides studies on chaetognath distribution, the feeding and predation impact of chaetognaths on their prey has been the subject of several inadequate studies in the Mediterranean Sea (Kehayias et al., 1996; Duro and Saiz, 2000; Batistic et al., 2003; Kehayias et al., 2005; Kehayias and Kourovakalis, 2010). These studies were conducted in the Western Mediterranean, Aegean and Adriatic Seas. However, there is no study on the feeding behaviour and diet content of chaetognaths in the Levantine Sea. Additionally, studies on chaetognaths in the Mediterranean coasts of Turkey are rare. Available studies explored the distribution (Terbyyık et al., 2007, Terbyyık and Sarhan, 2008), ontogenetic stages (İşmen et al., 2003) and genetic structure (Hazar, 2006) of chaetognaths, but there are no studies on chaetognath feeding behaviour in the coast of Turkey.

More than twenty one chaetognath species are known to be distributed in the overall Mediterranean Sea (Kehayias et al., 1999b, Terbyyık et al., 2007; Terbyyık and Sanhan, 2008). Among the chaetognath species, F. enflata, which has a global distribution, is one of the most important contributors and is a generally dominant species among chaetognaths in Mediterranean coastal ecosystems (Kehayias et al., 1999b).

The aim of this study was to provide new information about the ecological role of the chaetognath F. enflata as secondary consumers in the productive coastal areas of İskenderun Bay (northeastern Levantine Basin) by studying their diet and feeding ratio. Thus, the present study contributes to better understanding of the food web interaction in the pelagic ecosystem in order to provide basic information for future studies in the basin.

MATERIALS and METHODS

Study area

İskenderun Bay located in the north-eastern region of the eastern Mediterranean Sea covers approximately 2275 km² (Figure 1). The average depth of the Bay is around 70 m (Avşar, 1999) and it is known to have the largest continental shelf area after the Nile Delta in the eastern Mediterranean Sea. The Bay is affected by deep currents and wind movements because it has a wide opening connecting to open sea waters (iyiduvar, 1986). The largest stream that flows into the İskenderun Bay is the Ceyhan River with an average flow rate of 180 m³ sec. There is clear seasonal cycling in the İskenderun coastal area. The temperature drops to approximately 17.5 °C in the winter-spring periods, and begins to rise after spring, reaching the highest levels in the summer (29.23 °C). Moreover, the salinity values fluctuate between 36.96 and 41.12‰ due to fresh water and terrestrial inputs (Terbyyık Kurt and Polat, 2015).

Figure 1. Study area and sampling stations

Samplings

Zooplankton samplings were performed at three stations in October 2016, December 2016 and March 2017 in the western coastal waters of İskenderun Bay. Zooplankton samples were collected vertically with WP-2 zooplankton nets (200 µm mesh size) (Figure 1).
After sampling, the collected material was transferred into a bottle (200 ml) and fixed with sea water-formalin solution (4%). The examination and counting were performed under the SZX 16 Olympus Stereomicroscope.

In the laboratory, all specimens of *F. enflata* were sorted from zooplankton. Abundance values were calculated as individuals per meter cube (ind. m$^{-3}$). The volume of the filtered water was calculated with the following formula (formula 1) using the haul depth and the radius of the frame of the net:

$$\text{The volume of the filtered water} = \pi \cdot r^2 \cdot h \quad \text{(Formula 1)}$$

$r$: radius of frame of the net
$h$: haul depth

First, all specimens were classified according to the maturity stage (Table 1) as described by Kehayias et al. (1999a). Afterward, the specimens that contained food organisms in their guts were dissected and the food organisms were identified at the species or group level as much as possible. The food items in their guts were classified into three main categories of unidentified digested food, identified digested food and identified undigested food as described by Oresland (1987).

The food containing ratio (FCR), and the number of prey items per chaetognath (NPC) were calculated according to the method used by Batistic et al. (2003) for all maturity stages (Formula 2 and Formula 3, respectively)

$$\text{FCR} = \left( \frac{\text{Number of chaetognaths containing food}}{\text{total number of chaetognaths}} \right) \times 100 \quad \text{(Formula 2)}$$

$$\text{NPC} = \frac{\text{total number of prey items}}{\text{total number of chaetognaths}} \quad \text{(Formula 3)}$$

<table>
<thead>
<tr>
<th>Maturity stages</th>
<th>Characteristic features</th>
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<tbody>
<tr>
<td>Stage 1</td>
<td>Small individuals without eggs</td>
</tr>
<tr>
<td>Stage 2</td>
<td>Small seminal vesicle is absent</td>
</tr>
<tr>
<td>Stage 3</td>
<td>Ovaries and seminal vesicles are visible, but small</td>
</tr>
<tr>
<td>Stage 4</td>
<td>Seminal vesicle is full, ovaries are big</td>
</tr>
</tbody>
</table>

**RESULTS**

During the study period, six chaetognath species were observed in the study area: *Mesosagitta minima, F. enflata, Ferosagitta galerita, Serratosagitta serratodentata, Pseudosagitta lyra* and *Sagitta* sp. Among the chaetognaths, *F. enflata* was the most abundant species in all sampling periods (60 ± 33%), and the proportion varied from 42–94% (Figure 2).

The mean abundance of chaetognaths was 92 ± 133 ind. m$^{-3}$ and varied during the sampling periods (Figure 3). Younger stages (I and II) dominated the population of *F. enflata* (Figure 4).

In total, 1663 specimens were examined, but only 185 contained prey in their guts. The FCR and NPC for this species were 11% and 0.1, respectively. These values varied between sampling periods and maturity stages, and the highest FCR (Figure 5) and NPC (Figure 6) values were observed in immature specimens. Most food items were unidentified due to digestion. The proportion of identifiable food organisms within digested and undigested foods was about 39.5%. Copepods were the main food resource (36.8%) for this species, including the genera *Oithona, Microsetella, Centropages, Oncaea, Euterpinia, Paracalanus,*....
copepodists, and nauplii. Cannibalism was also observed (Table 2).

**DISCUSSION and CONCLUSION**

In the present study, the feeding ratio and diet composition of different maturity stages of *F. enflata* were investigated in the coastal waters of İskenderun Bay and importantly, information to help predict the impact of chaetognath feeding behaviour on the ecosystem was obtained.

![Figure 3. Changes in *F. enflata* abundance in sampling stations and periods (ind., individuals)](image)

![Figure 4. Graph of proportional distribution of different maturity stages of *F. enflata*)

![Figure 5. Food containing ratio (FCR) of the maturity stages of *F. enflata*)

![Figure 6. Number of foods per chaetognath (NPC) according to the maturity stages of *F. enflata*)
**Table 2. Gut content of F. enflata**

<table>
<thead>
<tr>
<th>Taxas</th>
<th>Proportion (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digested unidentified foods</td>
<td>60.5</td>
</tr>
<tr>
<td>Copepoda</td>
<td></td>
</tr>
<tr>
<td>Adult</td>
<td>14.2</td>
</tr>
<tr>
<td>Copepodite</td>
<td>2.7</td>
</tr>
<tr>
<td>Nauplii</td>
<td>4.2</td>
</tr>
<tr>
<td>Eggs</td>
<td>0.5</td>
</tr>
<tr>
<td>Calanoida</td>
<td>4.2</td>
</tr>
<tr>
<td>Centropages furcatus</td>
<td>1.6</td>
</tr>
<tr>
<td>Paracalanus sp.</td>
<td>0.5</td>
</tr>
<tr>
<td>Oithona sp.</td>
<td>0.5</td>
</tr>
<tr>
<td>Oithona oculata</td>
<td>2.1</td>
</tr>
<tr>
<td>Oithona plumifera</td>
<td>0.5</td>
</tr>
<tr>
<td>Oncaea sp.</td>
<td>3.2</td>
</tr>
<tr>
<td>Corycaeus sp.</td>
<td>0.5</td>
</tr>
<tr>
<td>Harpacticoida</td>
<td>0.5</td>
</tr>
<tr>
<td>Euterpina acutifrons</td>
<td>0.5</td>
</tr>
<tr>
<td>Microsetella sp.</td>
<td>1.1</td>
</tr>
<tr>
<td>Chaetognatha</td>
<td></td>
</tr>
<tr>
<td>F. enflata</td>
<td>1.1</td>
</tr>
<tr>
<td>Appendicularia</td>
<td>1.6</td>
</tr>
</tbody>
</table>

*F. enflata* was similarly reported as a dominant species among chaetognaths in previous studies conducted in Iskenderun Bay (Terbyik et al., 2007; Terbyik and Sanhan, 2008; Terbyik Kurt and Polat, 2013). There are few studies on chaetognath feeding behaviour in the Mediterranean Sea and most of these studies reported data from the Aegean Sea (Kehayias et al., 2005; Kehayias and Kourovakalis, 2010), Adriatic Sea (Batistic et al., 2003) and Western Mediterranean Sea (Duro and Saiz, 2000). The feeding ratios (FCR, NPC) determined in the present study are in agreement with the data reported from other regions of the Mediterranean Sea (Table 3). The FCR and NPC values, which were considered to be quite low, are indicative of low abundance values of fodder zooplankton (Stuart and Verheyen, 1991). Indeed, the reported values of zooplankton abundance and biomass in similar seasons in the previous studies were lower than in other seasons (Terbyik Kurt and Polat, 2013; Terbyik Kurt and Polat, 2015).

It has previously been reported that copepods are the main food organisms for chaetognaths (Reeve, 1970; Pearre, 1974; Øresland, 1987; Duro and Saiz, 2000). Additionally, the taxonomic diversity of food organisms in this study was much lower than in other studies. The lower diversity of food organisms could be related to their low availability or abundance (Kuhlmann, 1977).

In conclusion, the data obtained in this study is similar to the results from other studies conducted in different regions of the Mediterranean Sea. The values related to feeding activity were considered low, and therefore, their effect on population of food organisms is rather limited. In this study, we obtained information for the first time regarding chaetognath feeding behaviour in the coastal waters of Iskenderun Bay. The information could help researchers better understand the function and structure of the marine ecosystem. This data will also serve as a source for upcoming related studies. Conducting similar studies in different species and different areas and revealing the temporal and spatial changes in relation to environmental variables will help researchers better understand the importance and conditions in the pelagic ecosystem.

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<tbody>
<tr>
<td>FCR</td>
<td>0.134%</td>
<td>10% (in total)</td>
<td>14% (in total)</td>
<td>2-10%</td>
</tr>
<tr>
<td>NPC</td>
<td>0.17</td>
<td>0.1 (in total)</td>
<td>0.1 (in total)</td>
<td>0.4-0.6</td>
</tr>
</tbody>
</table>

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