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Research Article

FOOD AND FEEDING HABITS OF CHAETOGNATHS FROM PARANGIPETTAI COASTAL WATER, SOUTHEAST COAST OF INDIA

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ABSTRACT

An investigation was carried out to know the food and feeding habits of Chaetognaths from Parangipettai coastal waters. The samples were collected and preserved immediately in 4% borax-buffered formalin-seawater (vol. /vol.). Totally, 12 Chaetognatha species were identified in this study. Among them, genera *Pterosagitta*, *Krohnitta* and *Sagitta* were dominant. Totally, 5719 chaetognaths individuals were analyzed to know the gut contents. Only 281 (4.9%) individuals have been found with food content and the remaining 5438 (95.1%) individuals had only empty guts. The food containing ratio (FCR), Number of Prey items Consumed (NPC) and Cannibalism were also analyzed. The maximum prey item was examined in *Sagitta enflata* and the minimum in *S. neglecta* and *Krohnitta pacifica*. Totally 705 numbers of preys were recorded during the study of which, the maximum (147 numbers) preys were observed during summer season and the minimum (23 numbers) in monsoon season. The maximum preys were copepods and the minimum prey was *Lucifer* sp. From the overall observation, the prey animal *Paracalanus parvus* was the most important prey for all the chaetognath species except the *Sagitta regularis*. The most frequently identified prey items were the copepods *viz. Oncaea* sp. and *Microsetella* sp. which could be easily identified as they undergo low degree of digestion in the facilitating measurement and classification. Other species such as *Paracalanus parvus*, *Centropages brachiatus*, *Acartia tonsa*, *Oithona* sp. and *Corycaeus* sp. were present in most cases. These could be identified easily by the mandible blade which was quite evident even during the advanced stage of digestion. The mean prey size was dependent on the total length of chaetognaths species.

Keywords: Food and feeding, Chaetognaths, *Pterosagitta*, *Krohnitta* and *Sagitta*, FCR, NPC, Cannibalism.

INTRODUCTION

Chaetognaths are considered to be the dominant predators of small zooplankton and fish larvae. They are the most abundant carnivorous zooplankton in the sea and may contribute substantially to total zooplankton abundance and biomass (Pakhomov *et al*., 2000). All Chaetognatha species are strictly carnivorous although there are occasional references to phytoplankton in Chaetognaths guts (Pearre, 1976) which may represent material ingested incidentally. As important predators of copepods and as a significant food source for a wide variety of larger organisms, they hold a central position in planktonic food webs (David Feigenbaum, 1991). This suggests that predation by them greatly impacts primary consumers and their predation may have a significant impact on copepod population dynamics. They are usually relatively abundant, ranking second or third after the copepods (Goswami, 2004).

Chaetognaths show selectivity in their feeding behavior and the selection may be based on size, shape, differential movement pattern or escape capability of prey (Alvarez Cadena, 1993). Their diet consists basically of

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copepods; these organisms are probably one of the main sources of predation pressure in the copepod community, sometimes having a considerable influence on the structure of the lower tropic levels (Pearre, 1980).

The majority of chaetognaths species feed mainly on copepods, and is therefore important in marine food webs. The Chaetognaths are frequently described as an important link food between the high numbers of copepods existing in the plankton and the larger predators, including many species of fish of commercial importance. Thus, these organisms may serve as good indicators of potentially important fishery areas (Boltovskoy, 1981). Small prey such as tintinnids and rotifers may be important in the diet of young chaetognaths, but the main diet consists of copepod nauplii and copepodites. Barnacle nauplii, appendicularians, chaetognaths, cladocerans and fish larvae all contribute to the diet periodically. Data on the feeding habits of chaetognaths, through analysis of the gut content of individuals collected in the field, have revealed important information about the diet of these organisms (Oresland, 1990).

Chaetognaths feeding studies carried out until now have been limited to a few species in coastal areas. There is a general lack of studies from open oceanic, tropical and polar areas, as well as from deep water. In the present study, the feeding of chaetognaths species was studied through gut content analysis. However, apart from a few early studies on the distribution and feeding habitat of various chaetognath species in different areas, but little is known about the chaetognaths community of this region. The present goal was to determine the importance of chaetognaths as predators and competitors of larval fish. For this reason, a study was undertaken to examine the feeding habitat of the most common chaetognaths species in the inshore waters in order to assess their importance as predators within the zooplankton community and to determine their impact on the copepod community.

MATERIALS AND METHODS

Field observation

All field observations were carried out during July-2010 to June-2011 at Parangipettai coastal water (Lat, 11°29'N; long, 79°46'E). Chaetognaths for gut content analyses were collected at monthly throughout the study period by horizontal hauls with standard plankton net (0.45 m mouth diameter, 148µm mesh size). The net was towed up to 2 NM, towing speed 0.5 ms^{-1} with help of mechanized boat. After the collection, samples were preserved immediately 4% borax–buffered formalin – sea water (vol./vol.) by Baier & Purcell (1997).

Gut content analysis

Data on the feeding habitat of chaetognaths were made through the gut content analysis (Pearre, 1974;Feigenbaum, 1979; Oresland, 1990). The gut content of chaetognaths may be examined in a relatively simple way, since these organisms, besides being transparent, swallow their prey whole (Pearre, 1980). Chaetognaths specimens suspected of food containing in the gut were transferred to separate receptacles. Each individual was measured with the help of a segmented plate under a Stereozoom Microscope. Body length was measured to the nearest from the anterior tip of the head to the end of the tail, excluding the tail fin by placing a piece of graph paper with 1 mm grid under a Petri dish. Head widths were measured against within closed position using an ocular micrometer and regression equation of head width verses body length was established from measurements of chaetognaths samples. The maturity stages were classified according to Reeve (1970). The food items were identified to species level where possible, independent of position in the gut. The food material was confirmed only after dissection of the gut with sharp needles and observed under an optical Compound Microscope.

The prey were measured only when shown in sufficient detail and classified at intervals of 0.1 mm. The percentage of chaetognaths population containing food in their gut was analyzed at each maturity stage. The food containing ratio (FCR = number of chaetognaths containing food/total number of chaetognaths x 100) was calculated, as well as the number of prey items per chaetognaths at each interval (NPC = total number of prey items / total number of chaetognaths). The prey organisms were removed from the guts and identified. Animals which contained food organisms were divided into three groups according to the position of food in the gut and the degree of digestion as follows: 1) those containing food organisms in the anterior part of the gut near mouth which have just been captured; 2) food organisms in the mid gut, not completely digested and shapes still clearly recognizable; 3) food organisms in the posterior part of the gut or near the anus, which are difficult to identify, because they have already lost their shape.

Group 1 and 2 were used as indicators of actively feeding chaetognaths (Pearre, 1973). Body widths of prey items in Group 1 were measured in order to relate prey size to Chaetognaths head width. Head width is considered to be more closely related to prey size than body length (Pearre, 1973). However, head width may underestimate the functional mouth size, since the mouth opening expands considerably during swallowing (Pearre, 1980). Gut contents in groups 2 and 3, which could not be identified by their shape on a Microscope slide. Staining with lignin red was used to facilitate the detection of copepod remains. The mandible parts of copepods were counted and the width of the mandible blades measured with the help of Compound Microscope. Identifications of the copepod species and developmental stages were made with the help of shape and size of the mandible. The zooplankton was identified by following authors are Kasturirangan, (1963) and Perumal *et al*.,1998). Chaetognaths were identified from standard author's identification keys (Alvarino, 1967 and Michel, 1984).

RESULTS

Totally, twelve species of Chaetognaths were selected for food and feeding habit during the present study. Among them, one species of genus *Pterosagitta*, one species of genus *Krohnitta* and 10 species from the genus *Sagitta* were selected. The *S. enflata* (Grassi) was the dominant species followed by others during the study period. The absolute numbers of chaetognaths individuals were analyzed.

Totally, 5719 individuals of chaetognaths species gut contents were analyzed. Only 281 (4.9%) individuals with have food content in their guts of the chaetognaths and remaining 5438 (95.1%) individuals were empty guts. In the chaetognaths species, there was usually only one prey in the gut, although some individuals contained from two to four preys (Figure 1). The maximum numbers of individuals were examined during summer (May) and minimum was examined during monsoon (November) in the study period. The average of individuals was examined by 476.58. Among them, maximum was examined in *S. enflata* (1166 numbers) because this was the predominant species and minimum was examined in *Krohnitta pacifica* (159 numbers) during the study period (Figure 2).

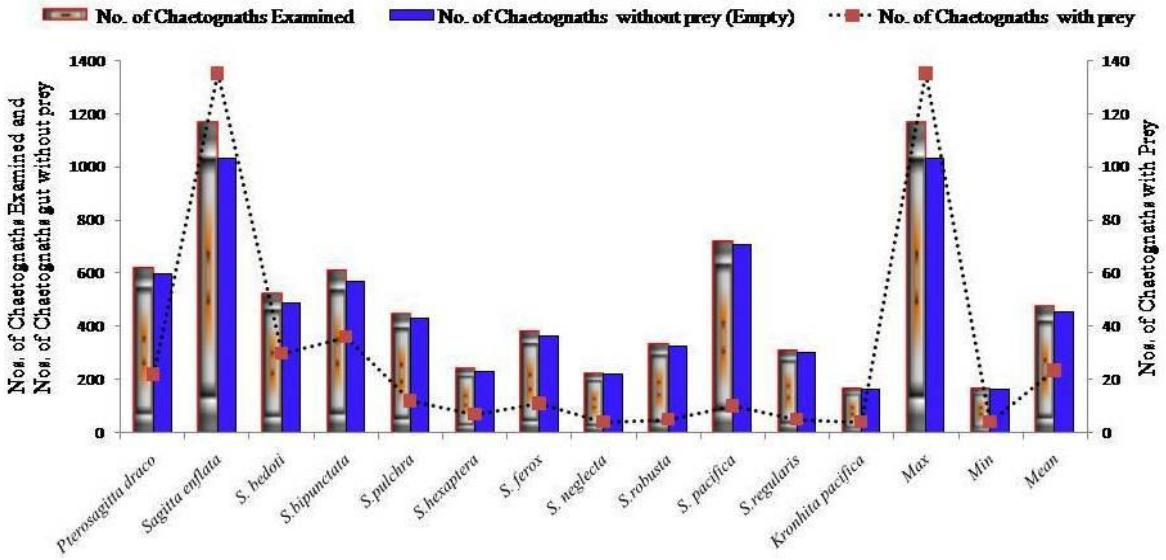

Figure 1. Variations in total number of chaetognatha Species examined, No. of individuals with prey and without prey from their guts during the present study.

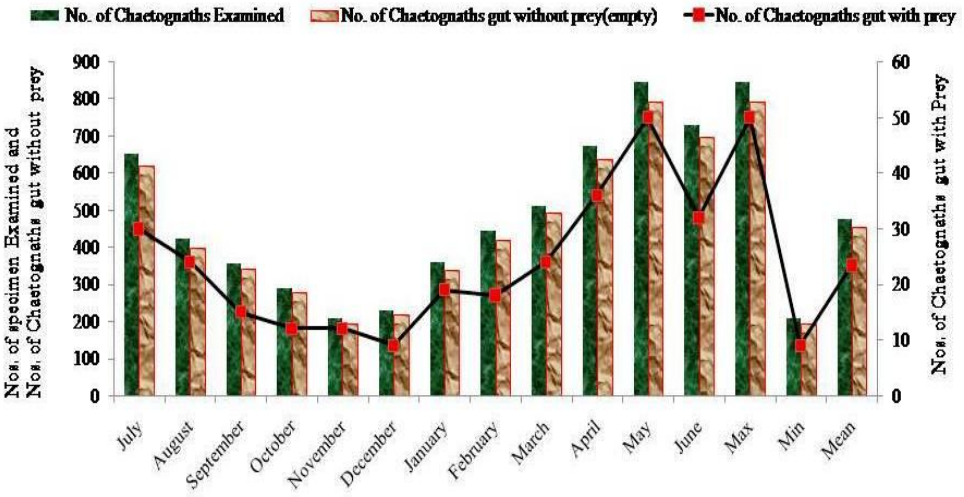

Figure 2. Seasonal variations in total numbers of Chaetognaths examined, No. of individuals with prey and without prey from their guts species viz. during the present study.

Numbers of chaetognaths were having food in their guts with a maximum of 50 individuals were identified during summer season (May) and the minimum of 9 individuals were identified during monsoon season (December). The maximum prey was observed in *S. enflata* (135 individuals) and minimum was observed in *S. neglecta* and *K. pacifica* during the present study.

Practically all prey items were identified in the guts of chaetognaths. Totally 705 numbers of preys were recorded. The maximum (147 numbers) preys were observed during summer (May) and the minimum (23 numbers) were observed during monsoon (December). The mean prey were 58.75 numbers and the total preys ranged from 12 to 301 numbers prey in the species, the maximum (301 numbers) prey was observed from the *S. enflata* and minimum (12 numbers) was observed from the *S. neglecta* guts during the study period.

Food Containing Ratio

The percentage of Food Containing Ratio (FCR) in the chaetognath species was found to be varied from 3.93% to 5.92% (mean 4.83%). The maximum FCR was observed during summer season (May) and minimum was observed during monsoon season (December). However, it is possible to observe that the chaetognath species with FCR range varied from 1.39% to 11.58 % (Mean 3.67%). The maximum FCR was observed in *S. enflata* and minimum was observed in *S. pacifica* during the study period (Figure 3).

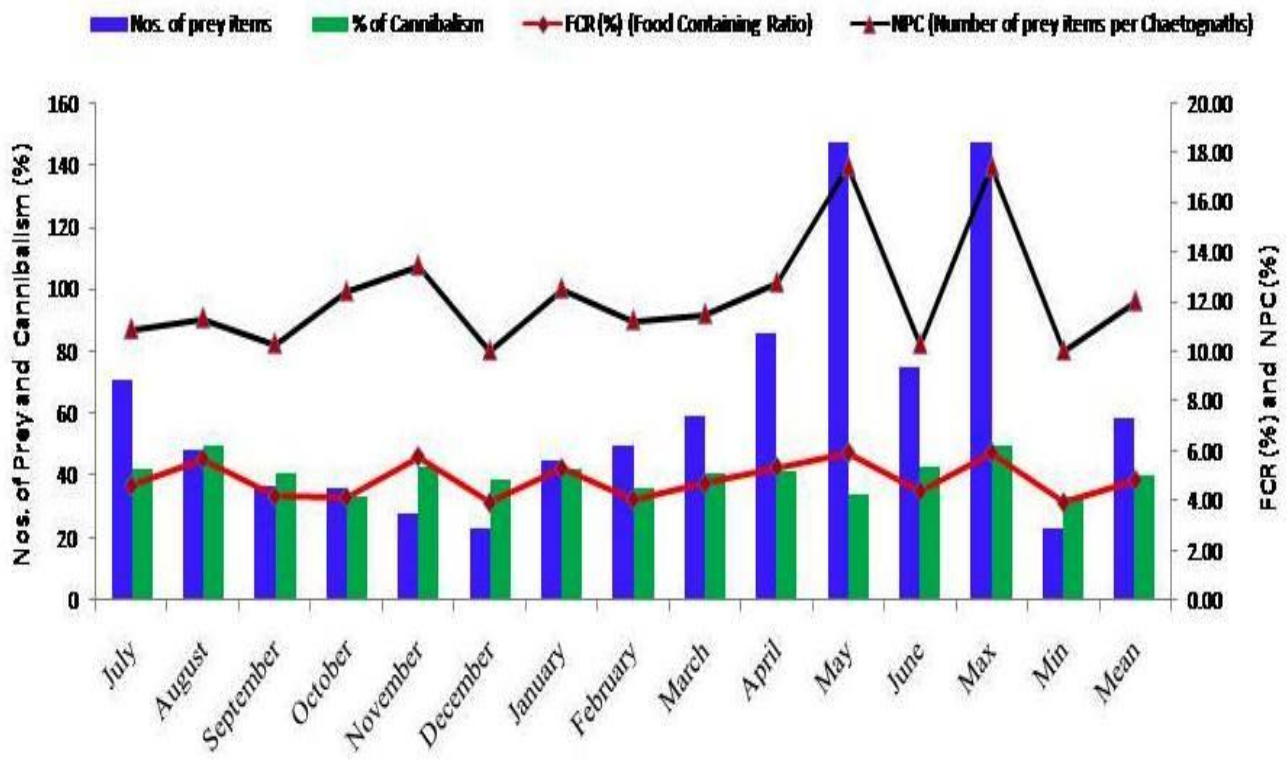

Figure 3. Seasonal variation of total numbers of prey items, percentage of cannibalism, percentage of food containing ratio (FCR) and numbers of prey items per chaetognaths during the study period.

Number of Prey per Chaetognaths (NPC)

Number of Prey per Chaetognaths (NPC) percentage was found to be varied from 10.04% to 17.42% (mean 12.07 %) during the study period. The maximum NPC was observed during summer season (May) and minimum was observed during post - monsoon (February). However, the species NPC of chaetognaths percentage varied from 4.17% to 25.81% (mean 10.20%), the maximum was observed in *S. enflata* and minimum was observed *S. pacifica* (Figure 4).

Percentage of cannibalism

Percentage of cannibalism was found to be varied from 33.33 % to 50.00 % (mean 40.46 %) during the study period. The maximum was observed during pre-monsoon season (August) and minimum was observed during summer (May). The percentage of cannibalism varied from 15.63 % to 44.85 % (mean 34.46 %), the maximum was observed in *S. enflata* and minimum was observed in *S. robusta* during the study period (Figure 4).

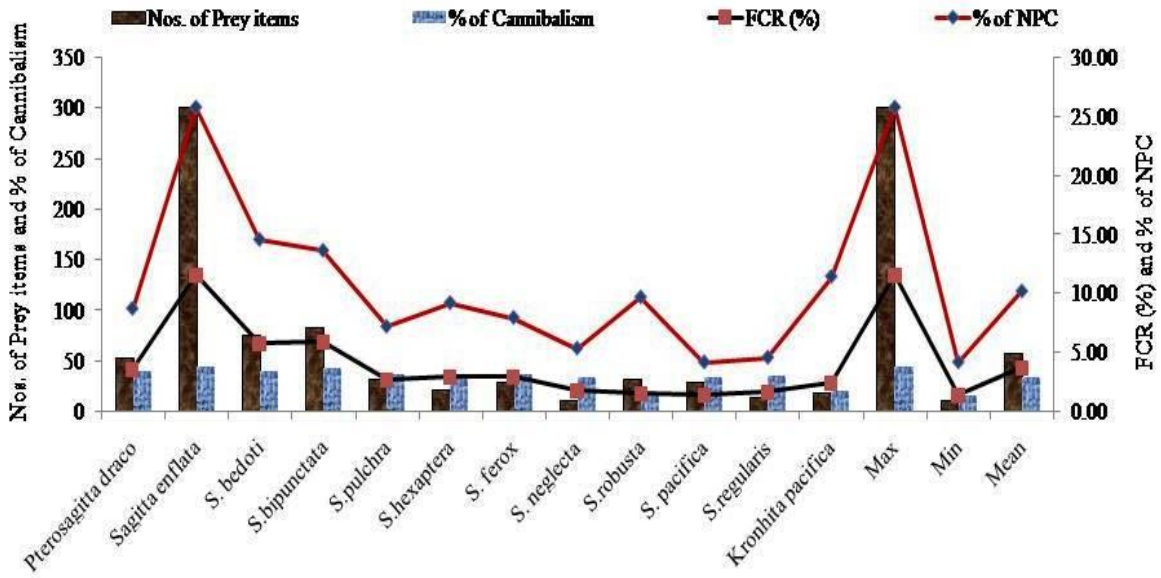

Figure 4. Variation in total nos. of prey items, percentage of cannibalism, percentage of food containing ratio (FCR) and numbers of prey items per Chaetognaths Species during the study period.

Prey items of Chaetognaths

Chaetognath species preyed upon a wide variety of organisms during the study period. The food organisms most frequently found in their guts were copepods viz. *Paracalanus parvus* (12.8%), *Acartia tonsa* (6.5%), *Temora stylifera* (6.4%), *Centropages orsinii* (4.7%), *Nannocalanus minor* (4.5%), *Oithona* sp. (4.0%), *Corycaeus* sp. (4.0%), *Microsetella* sp. (3.8%), *Oncaea* sp. (3.8%), *Eucalanus* sp. (3.7%), *Centropages brachiatus* (3.5%), *Oithona similis* (2.8%), *Candacia* sp. (2.6%), *Macrosetella gracilis* (2.4%), *Copepods nauplii* (2.3%), *Calanopia* sp. (2.0%), *Oithona rigida* (1.3%), Chaetognaths such as *Sagitta* eggs (1.3%), *Sagitta* sp. (0.3%), *Lucifer* (Decapoda) (0.4%), Crustacean larvae (5.1%), Ostracoda (3.8%), Polychaet larvae (1.0%), fish eggs (2.0%) and some unidentified prey (15.0%). In all cases, the most important prey in the local diet is the copepods, although these preys were consumed only by the adult chaetognaths. The cannibalisms were also observed during the study period.

Large quantities of well-digested food and considerably high number of unidentified preys were also detected in the gut contents of the chaetognaths. The diet of chaetognaths was basically composed of copepods, overall summing of *S. pulchra*, *S. hexaptera* and *S. neglect* have been 100% of copepods, because this species prey only on copepods followed by 85.71% for *S. regularis*, 78.31% for *S. bipunctata*, 77.63% for *S. bedoti*, 73.33% for *S. ferox*, 72.22% for *Pterosagitta draco*, 70.0% for *S. pacifica*, 65.12% for *S. enflata*, 47.37% for *Kronhita pacifica*, 37.50% for *S. robusta* during the study period.

Hence, the overall percentage of prey items in Chaetognath species viz. 7.66% for *Pterosagitta draco*, 42.70% for *S. enflata*, 10.78% for *S. bedoti*, 11.77% for *S. bipunctata*, 4.54% for *S. pulchra*, 3.12% for *S. hexaptera*, 4.26% for *S. ferox*, *1.70* for *S. neglecta*, 4.54% for *S. robusta*, 4.26% for *S. pacifica*, 1.99% for *S. regularis*, 2.70% for *Kronhita pacifica*. The chaetognaths also fed on other items viz. crustacean larvae, lucifer, ostracods, chaetognaths, annelids and fish eggs and larvae, although these prey were consumed only by the adult Chaetognaths. Only *S. enflata* have shown cannibalism representing 0.66% of its total feeding (Figure 5).

Density of prey items found in the Chaetognaths

Total numbers of prey items found in the Chaetognaths is shown in the figure no 6. The variety of prey organisms is ranged from 3 to 501 individuals. The maximum prey was copepods and minimum prey was *Lucifer* sp. The maximum prey was found in *S. enflata* and minimum prey was found in *S. neglecta* compared with other species. Seasonal changes of prey organism are varied from 23 to 147 (mean 58.75 numbers) individuals, the maximum was observed during summer season (May) and minimum was observed during monsoon season (December).

In over all observation, the prey animal *Paracalanus parvus* was the most important prey of all chaetognath species except the *S. regularis* during the study period and it's shown in the (Figure 6). The most frequently identified prey were copepods, species like *Oncaea* sp. and *Microsetella* sp. were easy to identify, because they were usually displayed a low degree of digestion in the gut, facilitating measurement and classification. Other genera, such as *Paracalanus parvus*, *Centropages brachiatus*, *Acartia tonsa*, *Oithona* sp. and *Corycaeus* sp. were, present in most cases, which could be identified easily by the mandible blade due to the advanced stage of digestion.

Mean prey size was dependent on the total length of chaetognaths species (Figure 6).

Prey size in relation to predator size

Prey size and the size range of prey were increased with increasing head width of chaetognath species. In order to detect any functional relationship between chaetognaths size and prey size, chaetognaths head widths were divided into size classes of 0.1 mm. Regressions were calculated within each size class between maximum and average prey body width and the average chaetognaths head width. Both relationships were best described by power curves and shown in the (Figure 7).

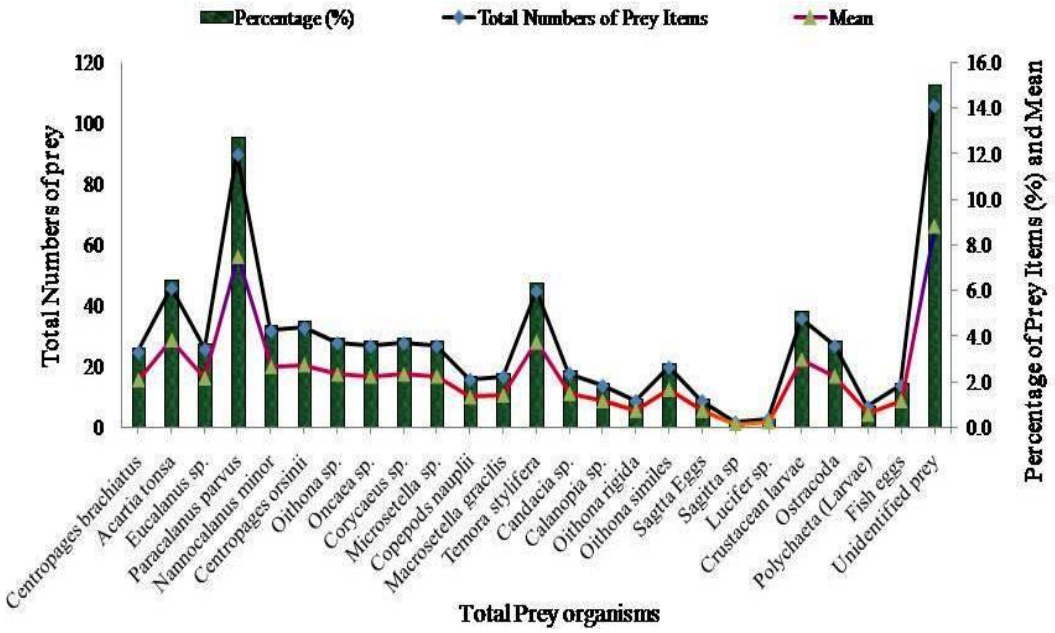

Figure 5. Seasonal variation of total numbers of prey items, Percentage of prey items and mean values of total pry organisms from Parangipettai coastal water during the present study.

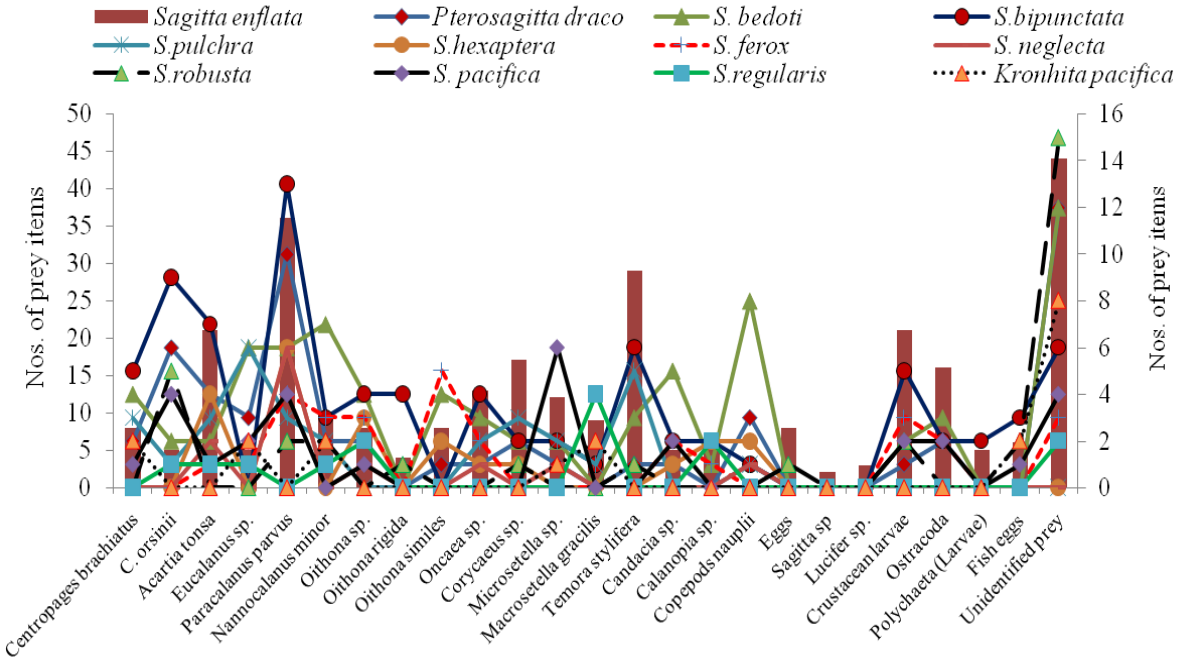

Figure 6. Seasonal variation of total numbers of prey items in all chaetognaths species from Parangipettai coastal water during the study period.

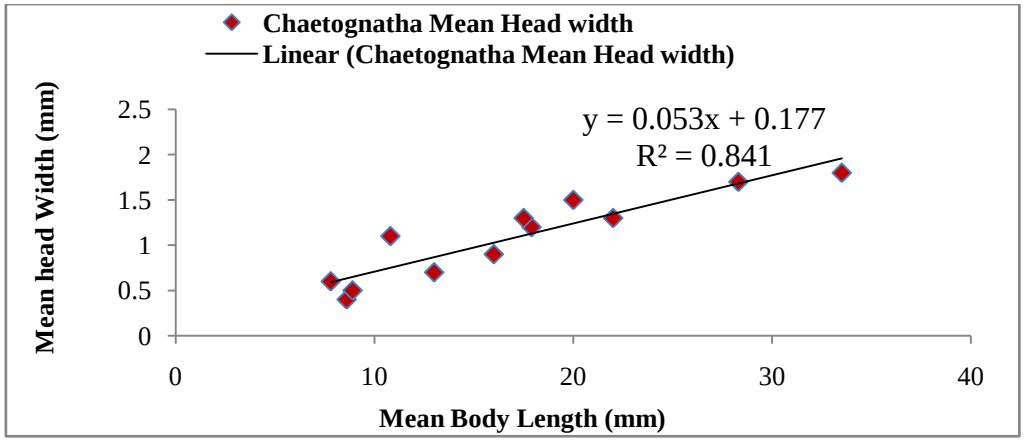

Figure 7. Prey size in relation to predator size from chaetognaths.

DISCUSSION

Chaetognaths feed on a wide variety of food organisms (Alvarino, 1985), however, the gut content is dominated by few zooplankton groups. Thus, the gut content analysis reported here which shows that the patterns of feeding habits correspond well with the chaetognaths feeding habits reported from other regions. From the Central Equatorial Pacific and appendicularians, ostracods and other chaetognaths were documented in the chaetognaths diet (Froneman & Pakhomov, 1998; Oresland, 1990).

The present result on Chaetognaths feeding revealed that a copepod based diet, although *Lucifer*, Crustacean larvae, ostracode, polychaetes, fish eggs and chaetognaths may altogether be found in the Chaetognaths guts. Copepods are readily detected by chaetognaths via sensory hairs (Feigenbaum & Reeve, 1977). Based on this fact and due to the dominance of copepods, Chaetognaths feed largely on copepods. Apart from copepods was the most frequent food items were found in the guts of chaetognatha from the present study. Due to the high degree of digestion, only the main parts of copepods were found. Even the few mandible remains and the one complete copepod in the Chaetognaths guts could not be identified even to species level.

In the present study, copepods constituted most of the prey item of chaetognath. This result is in agreement with those described for many other species of Chaetognaths (Gibbons & Stuart, 1994; Stuart & Verheye, 1991) as well as for *S. friderici* in the Ubatuba region, Brazil (Vega Perez & Liang, 1992). They are the main constituent of the diet of juvenile and adult chaetognaths, due to their abundance in the water column of most marine ecosystems. According to Sullivan, (1980), the food taken by Chaetognaths is closely related to the abundance and specific composition of copepods in the plankton. The present results confirmed this pattern of feeding, where the species of copepod consumed mostly by Chaetognaths which are most abundant ones in the water column. Therefore, chaetognaths may be opportunistic carnivores, consuming any type of prey available. The high consumption of copepods would be a response to the great availability of this food in the environment. Understanding how the copepod populations are affected by climatic variability is an important step towards knowing the mechanism that link climate and higher tropic levels. Recent attention has focused on the importance of predation mortality on copepods populations. The chaetognaths are abundant carnivores that feed on a variety of zooplankton and fish larvae, but their main prey is copepods this result was suggested by David Feigenbaum, (1991).

Generally, the frequency of chaetognaths with gut content is low in the present study. This report was agreed earlier reviewer by Lancraft *et al.* (1991) and Oresland, (1995). The gut contents (FCR and NPC) found in the present study are among the highest values ever recorded in the field studies of Chaetognaths reviewed (Baier & Purcell, 1997; Terazaki, 1998).

Cod-end feeding in plankton net hauls is another problem when applying gut content analysis (Baier & Purcell, 1997). Therefore, prey items found in the foreguts were excluded from the present analysis and also not exclude regurgitation in chaetognaths. Regurgitation and defecation might occur as a stress reaction on capturing or on preservation. Baier & Purcell (1997) presumed that the prey loss in chaetognaths guts during sampling was due to stress- induced gut evacuation rather than to contained digestion. This could explain generally the low NPC. Prey loss seems rather to occur at the beginning of the catch, whereas cod-end feeding may take place throughout the tow (Baier & Purcell, 1997). It is tried to reduce the stress during the catch by using large cod-ends, thus avoiding crowded samples. Nevertheless, the sampling method seems to have a strong effect on the results of chaetognaths feeding and hence it is difficult to draw any conclusions on seasonal and species-specific differences in diet composition and feeding activity only on the basis of gut analysis.

Although the possibility of prey loss during sampling has received little attention, some researchers have speculated that chaetognaths may evacuate their gut contents during sampling due to stress-induced regurgitation or defecation (David Feigenbaum & Reeve,

1977) and (Oresland, 1995). In the only previous direct test of prey loss, (Szyper, 1978) compared the samples which preserved immediately after towing with duplicate samples at 20 to 30 min. later and found that the percentage of chaetognaths food decreased with and time. Preservation *persee* may cause chaetognaths to evacuate their guts, but this cannot be distinguished from towing effects under normal sampling procedures. Sullivan, (1980) reported that no evidence of prey loss upon preservation was found.

Results of gut content analyses indicated that copepods were the most important prey item consumed by the chaetognaths, *E. hamata*, *S. gazellae* and *S. zetesios*. This result is consistent with the published literature which has demonstrated that chaetognaths can be regarded as non-selective predators generally consuming the most abundant prey, mainly copepods (Lukac, 2005; Qresland, 1995). Cannibalism has been documented for a number of chaetognath species (Johnson & Terazaki, 2004; Oresland, 1990). The low frequency of occurrence (<10% of all prey identified) of chaetognaths in the gut contents of selected chaetognaths during this investigation, suggests that cannibalism by chaetognaths did not represent important source of mortality for the chaetognaths.

CONCLUSION

Information on the feeding ecology of the chaetognaths is essential to understand energy flow within the pelagic ecosystem of study area has been attempted. The report on the prey-predator relationship between the chaetognaths and zooplankton were studied from this study area. For this reason, a study was undertaken to examine the feeding habitat of the most common chaetognaths species in the inshore waters in order to assess their importance as predators within the zooplankton community and to determine their impact on the copepod community. Our results clearly showed that the chaetognaths were believed to play an important role as a secondary consumer in the food web.

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