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Community structure and Spatio-Temporal Distribution of Chaetognatha near Coral Reefs on Hurghada coast, Red Sea, Egypt

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ABSTRACT

A Zooplankton survey was carried out between August 2015 and July 2016 along the Egyptian Red Sea coast of Hurghada to describe the species distribution of the arrow worms, Chaetognatha, in relation to the biological and physical factors. Monthly samples were collected by plankton nets of 350 and 500µm mesh size and 100cm mouth opening from four transects along the coast for one year. The average spatial and temporal variations, as well as diversity indices, were calculated. The correlation between Chaetognatha and physical parameters from one side and the biological factors from the other side was also investigated. A total of 17 species belonging to 3 genera and 3 families of the arrow worms were identified. The total abundance of Chaetognatha was 760 individuals/L, with an average of 126 individuals/L. The highest abundance of Chaetognatha was recorded in spring with a peak in April (378). The highest number of species was found in December (16 species). The most abundant species was *Sagitta neodecipinens*, with an average abundance of 159 individuals/L. Chaetognatha recorded a strong negative correlation with temperature and a strong positive correlation with pH and dissolved oxygen. They had a significant positive correlation with Copepods, Hydromedusa, and Tintinnids and a negative correlation with fish larvae.

INTRODUCTION

The Red Sea is a narrow semi-enclosed sea, characterized by high temperature and salinity as well as oligotrophic conditions **(Raitsos *et al*., 2013)**. It is a home of unique coral reef ecosystems which provides habitats for thousands of marine organisms. The Red Sea offers an opportunity to study the marine organisms influenced by the hydrographic conditions such as zooplankton **(Al-Aidaroos *et al*., 2017)**. Zooplankton forms an essential link in the marine food chain between phytoplankton and higher trophic levels such as fishes and whales **(Echelman & Fishelson, 1990; Wyatt *et al*., 2012**). It includes a wide variety of sizes from

micro-zooplankton to mega-zooplankton and ranged from small protozoans to large metazoans **(Dulepova, 2002)**. Zooplankton contains holoplanktonic organisms that complete their life cycle as plankton such as pteropods, chaetognaths, larvaceans, siphonophores, and copepods, in addition to meroplanktonic organisms that spend part of their life in the plankton such as larvae of molluscs, crustaceans, coral, echinoderms and fishes **(Vaissiere & Seguin, 1982, 1984; Echelman, & Fishelson, 1990; Baier, & Purcell, 1997; Khalil & Abdel-Rahman, 1997; Abu El-Regal *et al* 2008, 2018, 2019)**. The previous studies on the Red Sea zooplankton were restricted to offshore areas **(Beckmann, 1984; Kurten, *et al.*, 2016)** and the Gulf of Aqaba **(Cornils *et al*., 2007)**. Studies on zooplankton communities in the Red Sea are scarce and restricted to certain areas **(Echelman & Fishelson, 1990; Khalil & Abdel-Rahman, 1997; Cornils, *et al*., 2007; El-Sherbiny, *et al*., 2007)**.
Chaetognatha, known as arrow worms, repesents a major phylum in zooplankton community, comprising nearly 200 species of mostly planktonic forms. They are grouped in two orders, Phragmophora and Aphragmophora. The former has ventral transverse muscle bands while the latter lacks these bands. Chaetognaths are found mostly in marine waters, and some occur in estuaries. They have a vital role in the food web as important carnivores of the secondary producer (copepods) and as significant competitor with fish larvae **(Feigenbaum & Maris, 1984; Stuart & Verheye, 1991; Kehayias & Kourouvakalis, 2010)**. In addition, chaetognaths play a very important role as indicators of water quality **(Bieri, 1959; Nagai, *et al.* 2006)**. At a global scale, the biomass of chaetognaths is about 30% of that of their preys, the copepods **(Reeve, 1970)**. Consequently, they receive a considerable attention as a key carnivore zooplankton on Copepoda and Cladocera **(Stuart & Verheye, 1991; Kehayia & Kourouvakalis, 2010)**.
This is the first comprehensive study on the chaetognatha in the northern Red Sea in general and the Egyptian coasts, in particular. It aimed at addressing the distribution and the community structure of chaetognatha in the northwestern Red Sea. In addition, it was conducted to describe the relationships between temperature, salinity, pH, dissolved oxygen and the abundance of prey, predators, and competitors of the chaetognatha.

MATERIALS AND METHODS

1.1 Study area

Zooplankton samples were collected from Hurghada on the northern Egyptian coast of the Red Sea. The study area is located between 27°14.362´ N and 33 °51.235´ E and 27° 8.371´N and 33° 51.235´E, extending about 20 km long and 15 km wide–coastline to the borders of Big Giftun Island. It was divided into four transects, Arabia, Marina, Sheraton, and Magawish representing different habitats, coral reefs, sea grasses, shallow lagoons, etc… Samples were collected from three stations in each transect (Fig. 1 & Table 1).

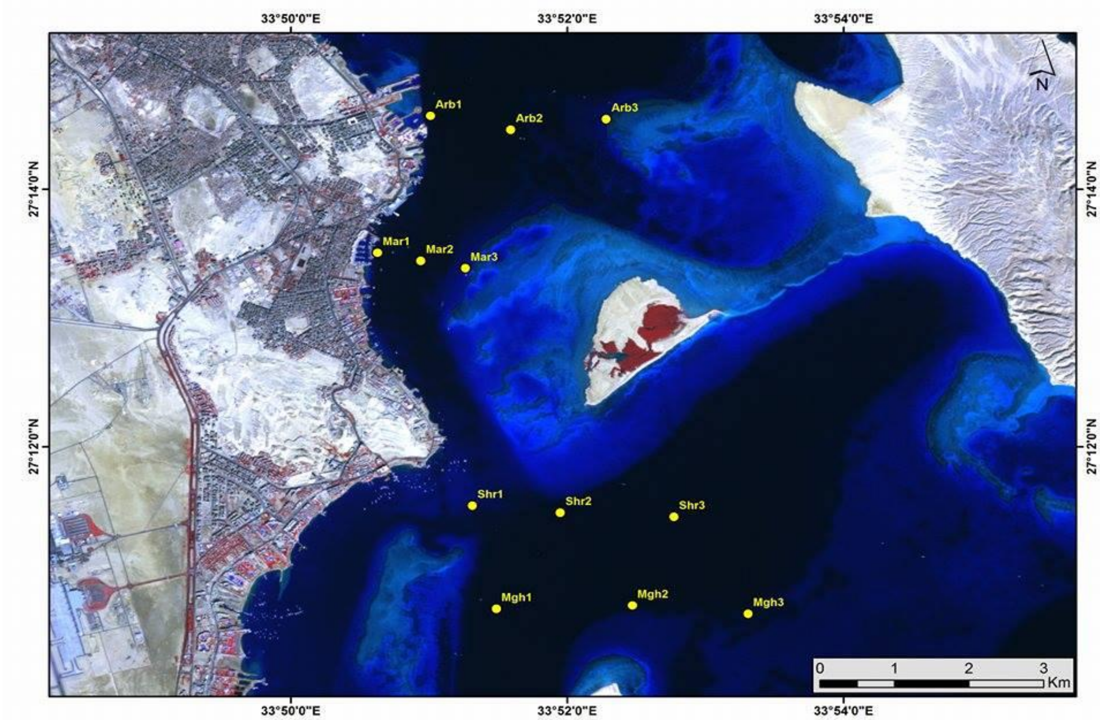

Fig. 1. The Red Sea Egyptian coast of Hurghada showing the study sites

Table 1. Description of the sampling sites of Chaetognatha on the Egyptian Red Sea coast of Hurghada

Transect	**Site**	**Code**	**Distance from shore**	**Coordinates**	**Depth (m)**	**Type of substrate**
Arabia	Arabia 1	ARB1	In-shore	27°14.362´N 33° 51.235´E	5-10	Coral Reefs
	Arabia2	ARB2	Near-shore	27° 14.427´N 33° 51.556´N E	50-100	Navigational channel
	Arabia 3	ARB3	Off-shore	27° 14.467´N 33° 52.285´E	3-7	Sandy and dead coral
Marine	Marina 1	MAR1	In-shore	27° 13.320´N 33° 50.554´E	15-20	Sandy
	Marina 2	MAR2	Near-shore	27° 13.335´N 33° 51.122´E	50-100	Navigational channel
	Marina 3	MAR3	Off-shore	27° 13.345´N 33° 51.280´E	5-10	Sandy
Sheraton	Sheraton 1	SHR1	In-shore	27° 11.284´N 33° 50.749´E	5-10	Sandy, Seagrass
	Sheraton 2	SHR2	Near-shore	27° 11.926´N 33° 51.473´E	5-10	Sandy
	Sheraton 3	SHR3	Off-shore	27° 10.479´N 33° 51.235´E	30-35	Open water
Magawish	Magawish 1	MGW1	In-shore	27° 8.356´N 33 ° 50.509´E	25-30	Coral reefs
	Magawish 2	MGW2	Near-shore	27° 8.362´N 33 ° 50.146´E	30	
	Magawish 3	MGW3	Off-shore	27° 8.371´N 33° 51.235´E	30	

1.2 Field work

Physical parameters (temperature, salinity, pH and dissolved oxygen) were measured using a multiprobe device (Aquaread AP 5000). Samples of zooplankton were collected by plankton nets of 350µ and, 500 µ mesh size and 100 cm opening diameter equipped with a flowmeter. The nets were horizontally towed parallel to the coast for 10 minutes with a speed of 1.5 to 2.5 knots. The volume of water filtered by the nets was calculated according to the following equation:

$$V = \pi r^2 df$$

Samples were collected in the early morning to avoid the vertical migration of zooplankton-and were preserved in buffered- 5% formalin solution.

Where, *V* is the volume of water filtered; π is a constant, 3.14; r is the radius of the net mouth, d is the distance of towing, and f is the filtration efficiency of the plankton net.

1.3 Laboratory work

The representative taxa of other zooplankton groups were counted and Chaetognathsa were identified to the species level and counted. Identification of Chaetognatha was carried out following **Nair and Jayalakshmy (2002)** and **Kurten *et al.* (2016)**.

1.4 Data analysis

Abundance was expressed as the number of Chaetognaths in a liter of seawater based on the following equation:

$$A = N/V$$

Where, A is the numerical density of Chaetognatha; N, the number of Chaetognatha individuals–in the filtered water, and V is the volume of filtered water.

Univariate statistics were conducted using SPSS 22. ANOVA was conducted to determine differences in abundance and species number between months and sites. The analysis of community structure, diversity indices, similarity indices and SIMPER analysis were carried out on PRIMER v 0.6. Simple regression and Principal Component Analysis and Canonical Correspondence Analysis (CCA) were carried out by Statgraphics *V 16* to examine the relationship between Chaetognatha and physical parameters from one side and other important zooplankton groups from the other sides. All graphs were illustrated by Graphpad Prism 8.

RESULTS

1.5 Hydrographic conditions

The surface water temperature in the study area showed the seasonal variation experienced in the Red Sea between the highest summer value (29.1ºC) in August, and the lowest value in winter (21.3ºC). The surface water temperature showed that Sheraton had the highest annual average of temperature (25.9ºC). Salinity in Hurghada region was relatively high, displaying very narrow range of variation

(39.8 - 39.9) for the whole area of study. The dissolved oxygen concentration indicates well aeration all the year round, falling within a range of 7.2 to 7.5 $mgO_2/1$. Similarly, the pH slightly varied between 8.1and 8.3 (Fig. 2).

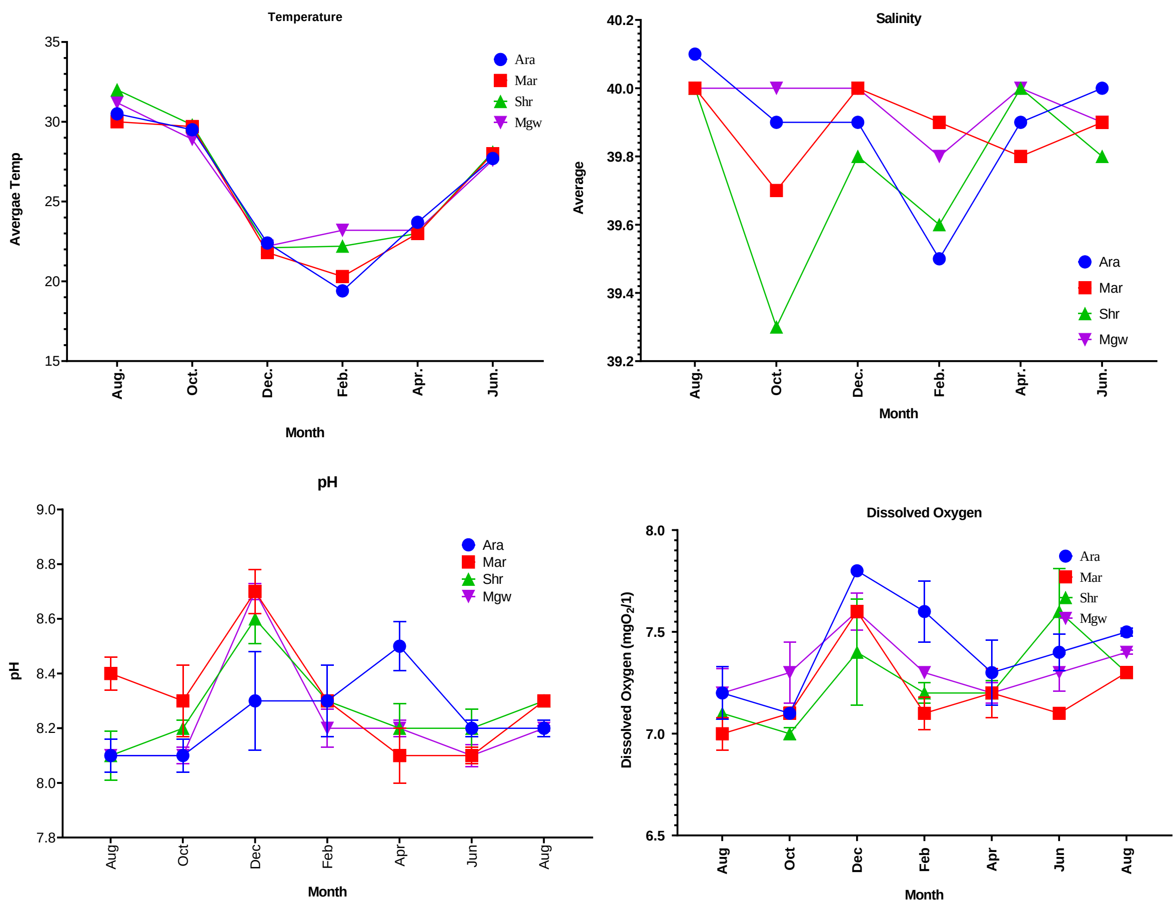

Fig. 2. Bi-monthly variations in the physical parameters in all sectors

1.6 General abundance and distribution of Chaetognatha

The zooplankton community in the present study was dominated by calanoid copepods (32.4%), followed by nauplius larvae (22%). Fish larvae were the least abundant group forming only 0.14% (Fig.3). Chaetognatha occupied the fourth order of abundance constituting about 13% of total zooplankton count (Fig. 3). A total of 761 individuals/L of Chaetognatha were collected throughout a year of sampling on a bi-monthly basis, with an average abundance of 126 individuals/L. Chaetognatha was abundant from December to April, with a peak in April, where 377 individuals/L were collected followed by December (204 individuals/L). On the other hand, Chaetognaths were less abundant in the warmer seasons of the year from June to October. The lowest abundance was recorded in June during which only 8 individuals/L were collected from all stations (Fig. 4 & Table 2).

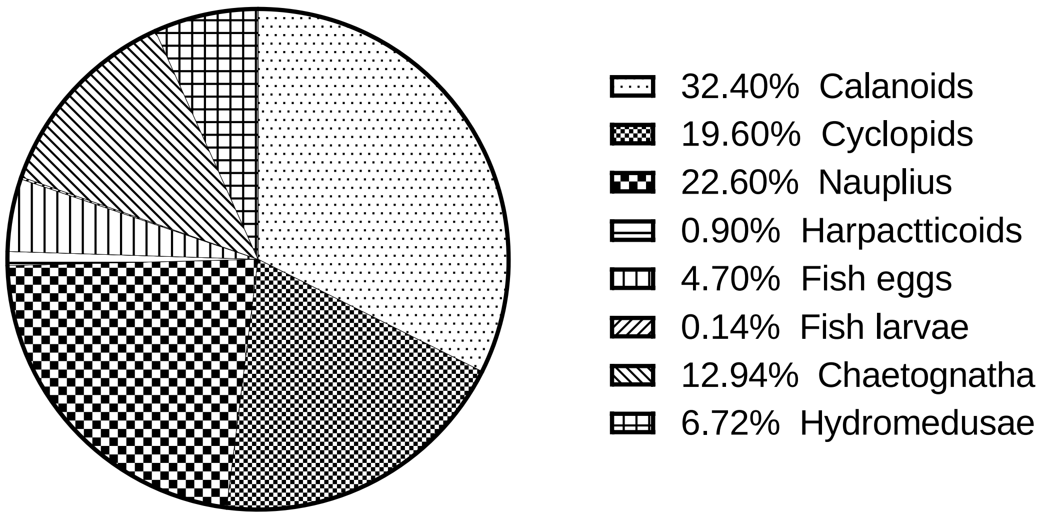

Fig. 3. Percentage contribution of different zooplankton groups

The average abundance of Chaetognatha varied significantly among months (F=13.3; *P*<0.05), but it was insignificantly different between sites (F= 0.97; *P*>0.05).

Regarding the spatial variations of abundance, arrow worms were abundant in most sites. Magawish transect harboured the highest number of Chaetognatha with 223 individuals/L, followed by the Sheraton transect (222 individuals/L). The Arabia transect recorded the lowest number of individuals and 151 individuals/L were caught. Chaetognatha had a peak of abundance in MGW2 where 101 individuals/L were collected, followed by SHR3 and MGW3 with 97 and 91 individuals/L, respectively. The lowest abundance was recorded in MAR1 (29 individuals/L) (Fig.5 & Table 3).

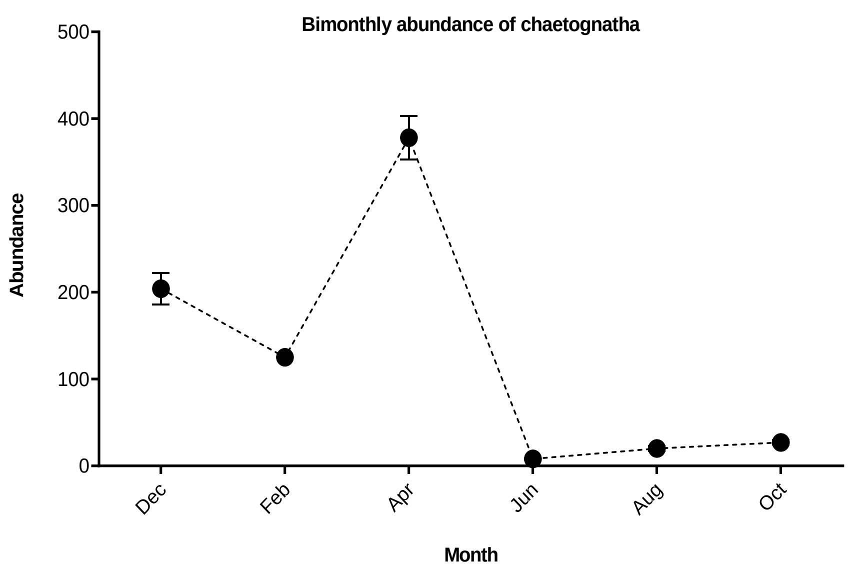

Fig. 4. Abundance of chaetognatha in months

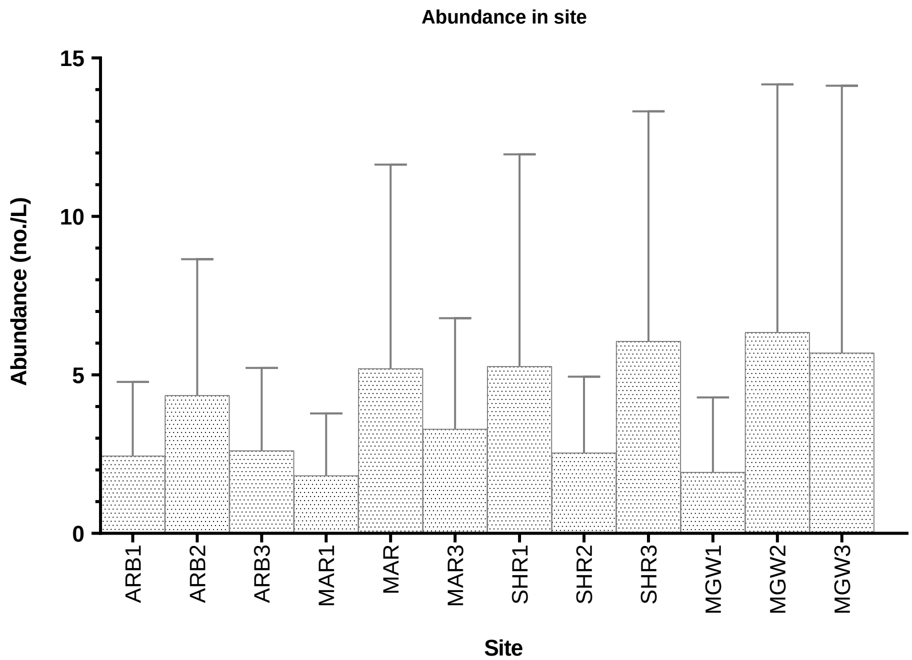

Fig. 5. Abundance of chaetognatha stations

Stations were grouped into 3 zones according to proximity to the shore; namely, In-shore, Middle and Off-shore sites. The highest abundance was recorded in the middle zone which represents the main navigation route in the area where the current is strong, followed by the offshore sites. On the other hand, the lowest number of chaetognatha were taken from the inshore sites. Chaetognatha were more abundant in the coral reefs and open waters than in the areas with sandy and seagrasses beds.

The highest number of species was recorded in December where 16 species were found, followed by February and April with 15 and 14 species, respectively. On the other hand, the lowest number of species was found in June (9 species) (Fig.6). Generally, slight differences in the number of species were detected between sites, and the maximum number (15 species) was found in three sites (ARB2, MAR2, and MGW1). Whereas, the minimum number of 12 species was found in SHR2. There was a significant variation between the number of species, richness, and diversity indices in sites (Fig.7).

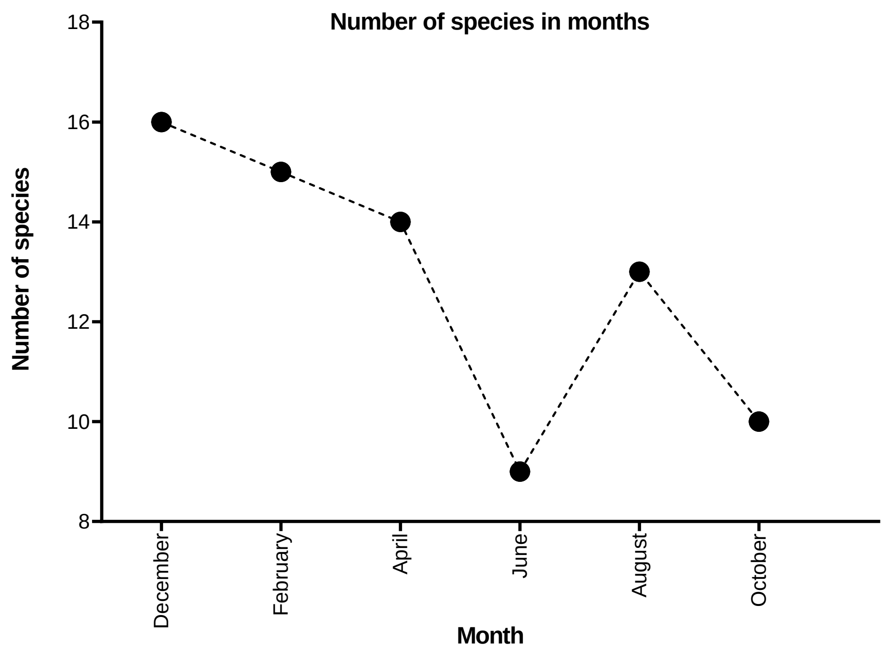

Fig. 6. Number of species of chaetognatha in months

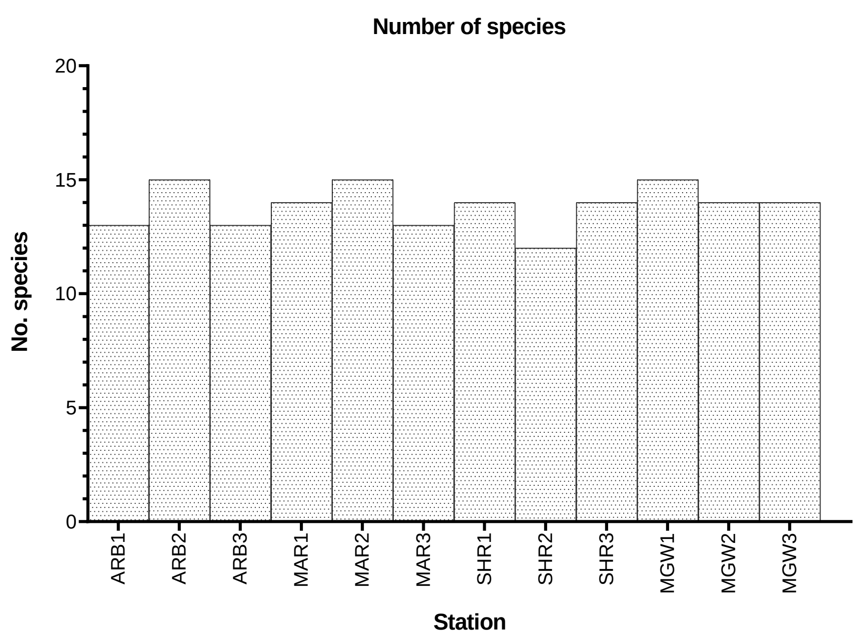

Fig. 7. Number of species of chaetognatha in stations

Table 2. Bimonthly abundance of chaetognatha from December 2015 to November 2016

Species	**Dec.**	**Feb.**	**Apr.**	**Jun.**	**Aug.**	**Oct.**
Serratosagitta pacifica	8.22	3.56	32.33	0.17	0.44	0
Sagitta erythraea	25.89	11.89	53.83	0.33	2	0.83
Aidanosagitta neglecta	2.33	1.44	44.17	0	0.22	0
Flaccisagitta enflata	66.33	8	13.83	0.67	12.67	2
Ferosagitta galerita	6.78	8.89	0.5	0.33	0.22	0
Ferosagitta ferox	1	0.11	1.5	0	0	0
Aidanosagitta regularis	2.78	6.56	15.5	1	0.22	10.17
Decipisagitta decipiens	2.78	0.11	21.83	0	0.11	2.67
Sagitta neodecipiens	46.33	17.56	88	1.5	0.56	4.83
Zonosagitta bedoti	20.56	40.78	57.5	2.5	2.56	3.17
Ferosagitta robusta	9.11	12.89	30	0.17	0.33	1.67
Flaccisagitta hexaptera	0.11	0	0	0.17	0	0
Heterokrohnia angel	5.94	1.22	13.83	0	0.11	0.5
Krohnitta pacifica	1.11	3.67	0.17	0	0	0
Krohnitta subtilis	3.44	2.89	0	0	0.11	0.67
Unknown	1.61	5.56	4.67	0.67	0.33	0

Table 3. Bimonthly abundance of chaetognatha collected from Hurghada from December 2015 to November 2016 at different sites

Species	ARB1	ARB2	ARB3	MAR1	MAR2	MAR3	SHR1	SHR2	SHR3	MGW1	MGW2	MGW3
Sagitta neodecipiens	7.05	11	4.78	4.89	13.72	6.11	24.17	3.78	16.39	6.11	26.56	34.22
Zonosagitta bedoti	6	9.56	6.33	6.11	23.11	6	15.56	4.78	13.72	8.33	16.39	11.17
Flaccisagitta enflata	5.44	12.72	0.44	4.89	12.56	11.78	11.11	4.89	7	4.22	17.61	10.83
Sagitta erythraea	4.88	8.89	7.44	2.56	7	7.5	7.44	7.17	26.33	1.67	8.5	5.39
Ferosagitta robusta	3.5	7	2.44	1.89	9.11	1.39	7.78	1.61	3.89	1.44	6.89	7.22
Aidanosagitta neglecta	3.5	4.44	6.44	0.83	2.28	5.83	2.94	5.78	5.72	1.89	6.28	2.22
Serratosagitta pacifica	2.33	3	4.61	3.28	3.17	4.94	2.78	4.56	8.61	1.89	3	2.56
Aidanosagitta regularis	1.11	1.5	1.33	1.11	2.17	4.78	2.28	2.83	4.61	1.22	10.06	3.22
Decipisagitta decipiens	1.77	6.22	2.17	0.83	1.83	0.17	4.44	0.33	0.44	2	0.11	7.17
Heterokrohnia angel	1	0.5	0	0.61	3.56	2	1.89	3.28	5.17	0.5	1.39	1.72
Ferosagitta galerita	0.33	2.33	4.06	1	0.33	0.56	1.06	1.22	0.89	0.28	1.22	3.44
Unknown	0.5	0.11	0.61	0.89	1.44	0.94	1.89	0.44	2.11	0.78	1.72	1.39
Krohnitta subtilis	1.66	0.78	0.44	0.11	0.89	0	0.78	0	1.67	0.28	0.28	0.22
Krohnitta pacifica	0	0	0	0.11	1.61	0.67	0.22	0	0.44	0.11	1.44	0.33
Ferosagitta ferox	0	1.5	0.67	0	0.44	0	0	0	0	0	0	0
Flaccisagitta hexaptera	0	0.11	0	0	0	0	0	0	0	0.17	0	0
Mean	**39**	**70**	**42**	**29**	**83**	**53**	**84**	**41**	**97**	**31**	**101**	**91**
SD	**2.3**	**4.2**	**2.5**	**1.9**	**6.2**	**3.4**	**6.5**	**2.3**	**7.0**	**2.3**	**7.6**	**8.2**

1.7 Community structure of Chaetognatha

A total of 16 species were identified from Hurghada belonging to three genera and three families; namely, Sagittidae, Krohnittidae and Eukrohniidae. The highest number of species (16 and 15) was found in December and February, respectively, while the lowest number occurred in October. A positive relationship between the number of species and diversity index was found from February to June. On the contrary, the number of species and richness from one side had a negative relationship with diversity index from the other side in August and October. Moreover, evenness values increased from December to June, reaching its maximum in June (0.83) and decreased suddenly in August to 0.52, then increased again in October to 0.82.

Diversity and richness indices showed slight spatial variations. The diversity index ranged from the smallest value of 2.05 in MGW3 to the largest value of 2.29 in ARB1. The highest species richness was recorded in MGW1 (1.74), and the lowest richness was found in SHR2 (1.3). The evenness value (equitability) varied from 0.78 in MGW3 to 0.91 in SHR2 (Fig. 8).

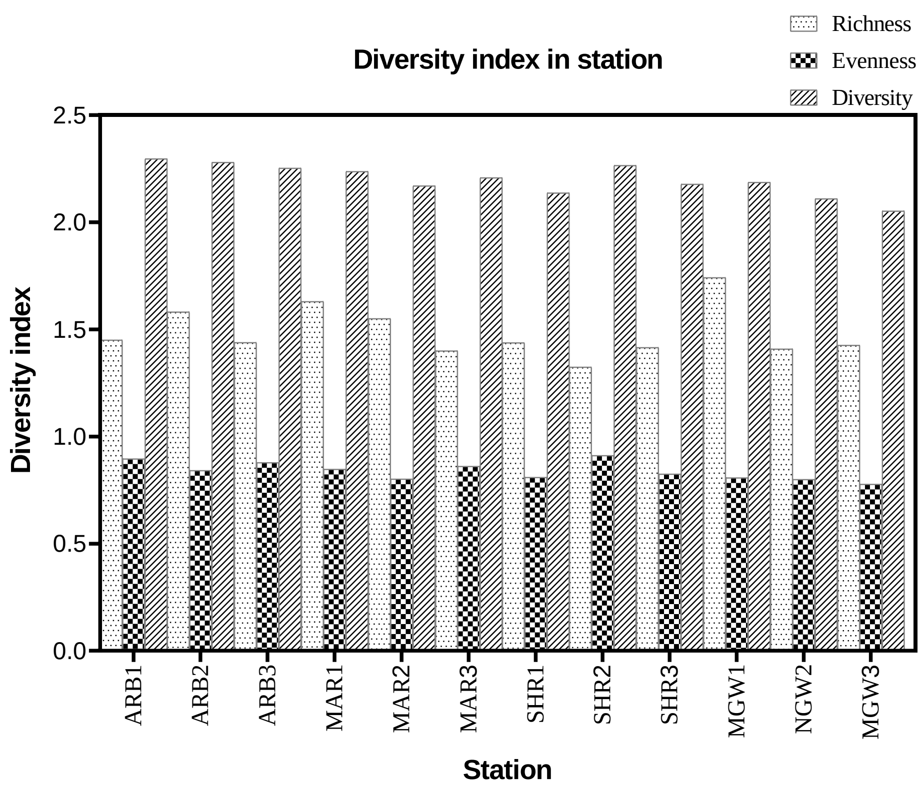

Fig. 8. Diversity index at different stations

1.8 Species composition

All the collected Chaetognatha except one could be identified to species level. The most abundant five species formed 72% of all all collected Chaetognatha. Sixteen species belonging to three genera and three families (Sagittidae, Krohnittidae and Eukrohniida) in two orders were recorded. Order Aphragmophora was represented by Sagittidae and Krohnittidae; whereas, order Phragmorpha was represented by one family

(Eukrohniidae). Family Sagittidae was the most speciose family with 12 species (Table 6). Family Krohnittidae was represented by one species. Family Eukrohniidae was represented by one species, *Heterokrohnia angeli*. The most abundant species was *S. neodecipiens*, with 15,878 individuals/L forming 21% of all Chaetognatha. With 12,707 individuals/L, *Zonosagitta bedoti* was the second abundant species constituting 17% of all Chaetognatha. *Flaccisagitta enflata*, the third most abundant one formed 14% where 10,350 individuals/L were collected. *Heterokrohnia angel* was the least abundant species forming 3% of all Chaetognatha collected (Fig 7). Six species were found year-round whereas, one species, *Flaccisagitta hexaptera* occurred in two occasions. Most species occurred in all stations; whereas, *F. hexaptera* occurred in two sites, and *S. ferox* appeared in three stations (Fig. 9).

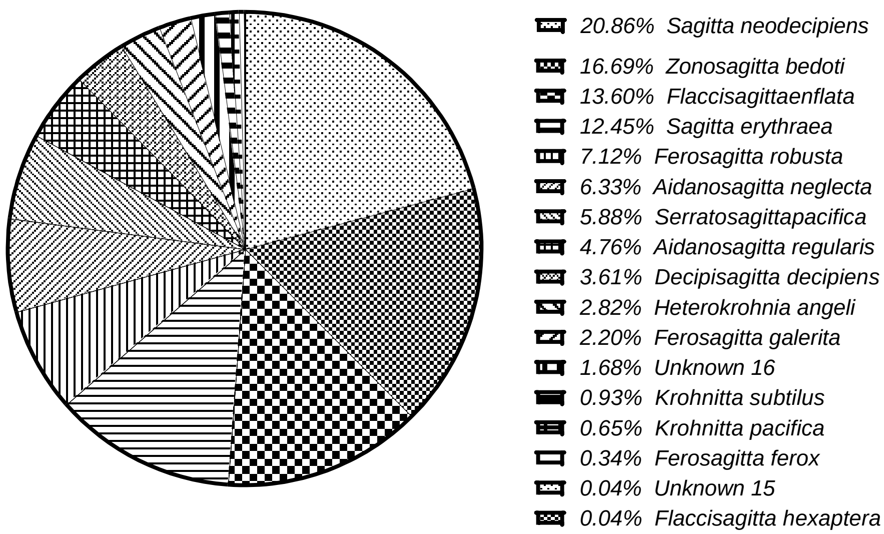

Fig. 9. Percentage contribution of different chaetognatha species from Hurghada

At a similarity level of about 75, sites could be classified into two main clusters, each of which contains 6 stations. The first cluster includes SHR1,3, MGW2,3, ARB2 and MAR2. The second cluster is composed of ARB1,3; MAR1,3; MGW1 and SHR2. In cluster I, MGW3 and SHR1 showed the highest similarity level in all stations with a 92% similarity. Both stations had a similarity level of 82% with MGW 2. Cluster 2 contains three coastal stations which are close to the coral reefs. The highest similarity level in this cluster was recorded for MAR1 and MGW1 (89%) (Fig.10)

The analysis of Multidiminionsional Scale (MDS) showed that stations are classified into three groups. Mar3 and Shr2 are grouped together and Mgw1, Arb1 and mar which represent the coastal stations are grouped together. The third group is composed of the largest number of stations (5) (MGW2, MGW3, MAR2, ARB2, SHR 1), which may lie in the main navigational channel. Both SHR3 and ARB3 are distant from other stations because they may represent the shallow sandy stations (Fig. 11)

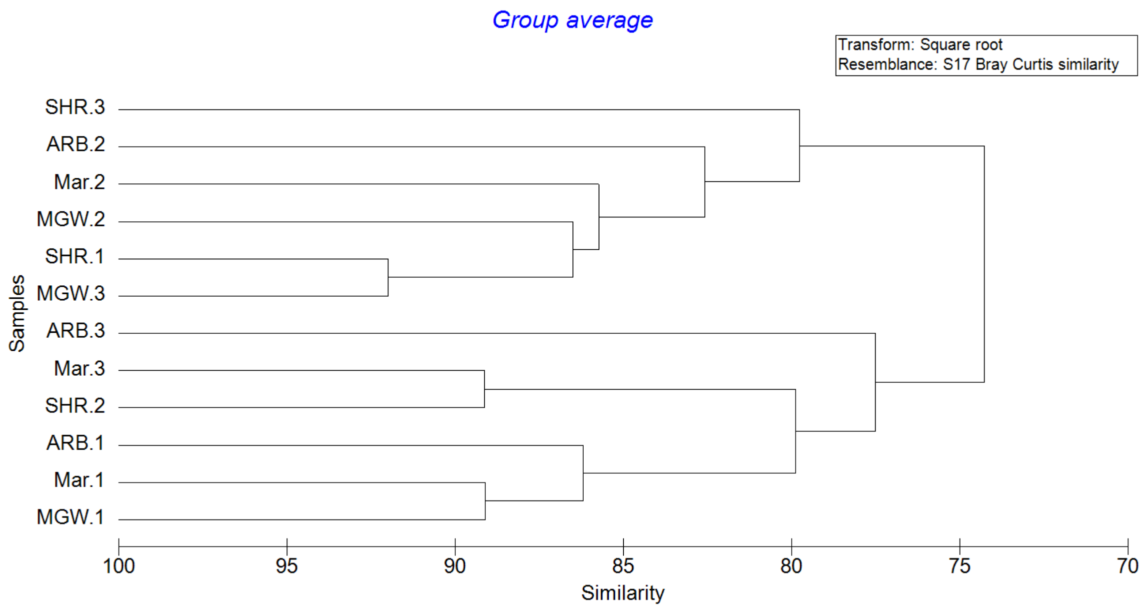

Fig. 9. Bray-curtis similarity dendrogram of the stations

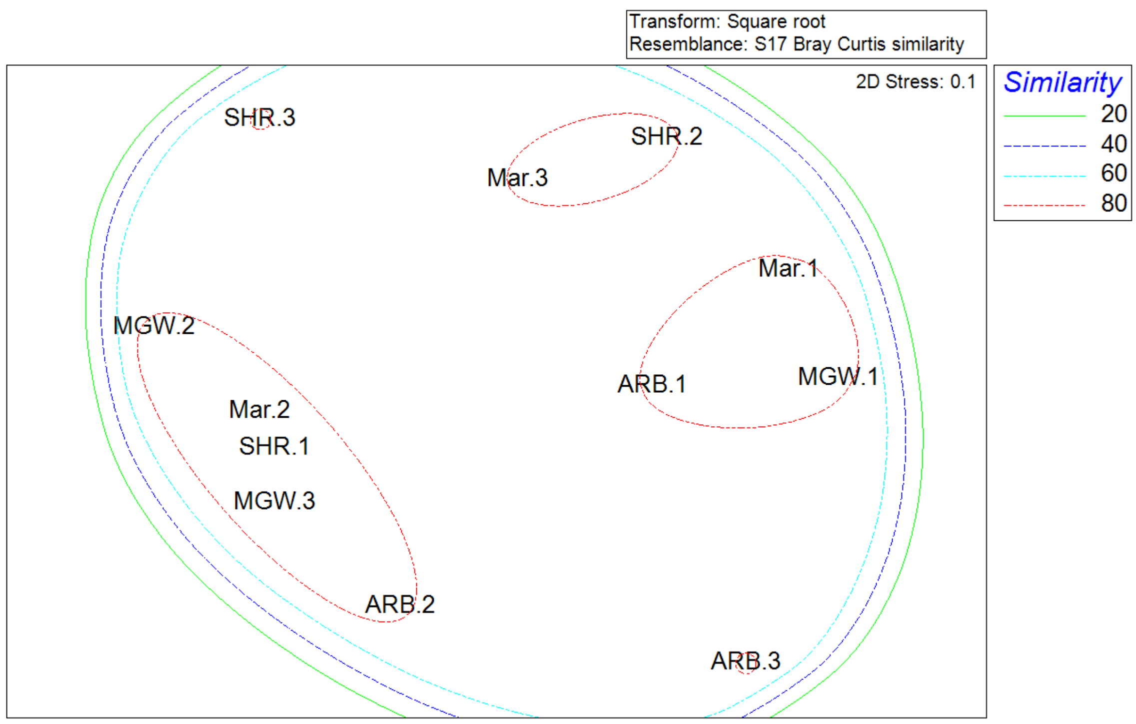

Fig. 10. Euclidean distance non-metric multi-dimentional scaling of stations

Species in sites could be classified into 4 clusters with a general similarity of 8%. *K. subtilus* and *K. pacifica* represented the first cluster, with a similarity of 55%. The second cluster is composed of four species *D. decipiens, F. galerita*, unknown and *H. angeli* with similarity of 70%. The third cluster is composed of 8 species *Ferosagitta robusta, S. erythraea, A. neglecta, K. pacifica, Aidanosagitta regularis, Zonosagitta bedoti, S. neodecipiens* and *Flaccisagitta enflata*, with a similarity of 77%. These species have high abundance and are recorded in all stations. The fourth cluster is composed of 2 species (*Flaccisagitta hexaptera* and *Ferosagitta ferox*) (Fig.12).

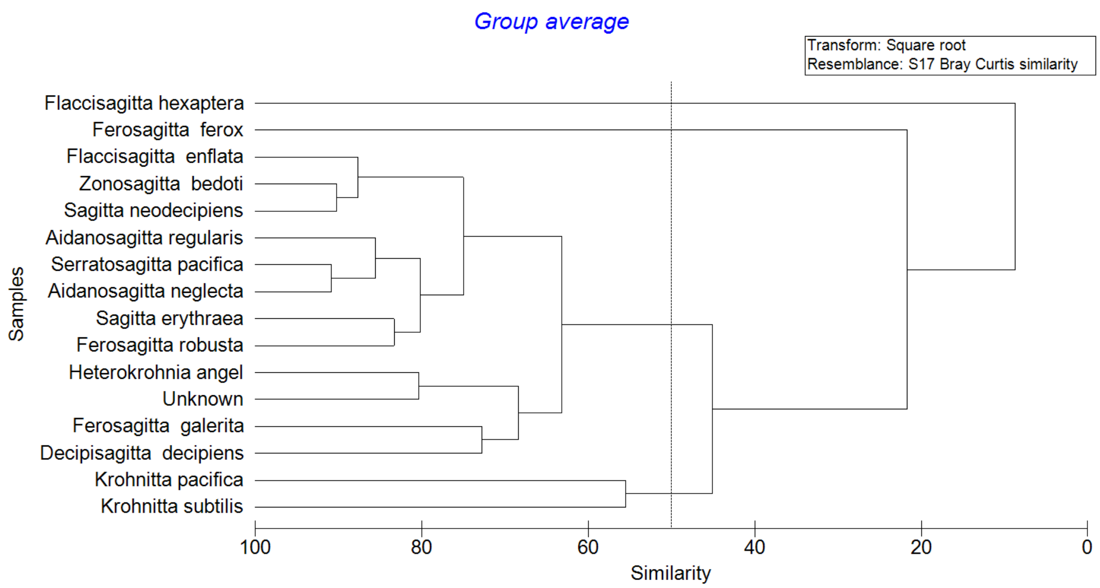

Fig. 11. Bray-curtis similarity dendrogram of chaetognatha species at stations

Multi-dimentional scaling (MDS) showed that *Flaccisagitta hexaptera* and *Ferosagitta ferox* are different from all other species because they were absent in most stations (Fig. 13).

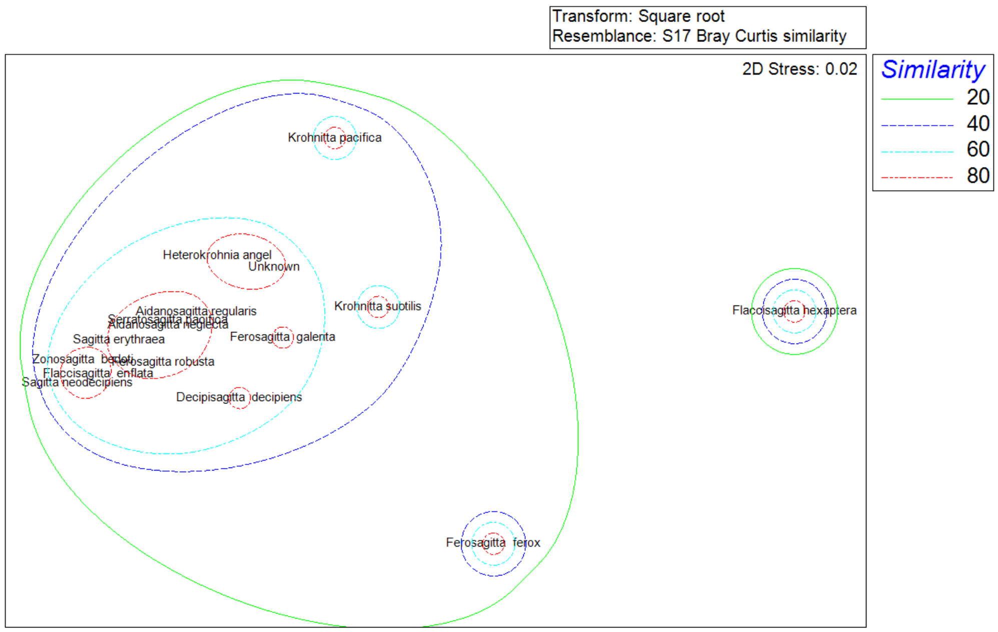

Fig. 12. Euclidean distance non-metric multi-dimentional scaling of the species of Chaetognatha

1.9 Chaetognatha-physico-chemical parameters relationship

A strong negative correlation was detected between the abundance of Chaetognatha and temperature (r= -0.84, *P*-value <0.05). chaetognatha had the highest abundance when temperature values were low (Dec-April). On the other hand, pH (r= 0.77; *P*-value <0.05) and dissolved oxygen (r = 0.705, *P*-value <0.05) had strong positive correlation with the the abundance of Chaetognatha and the effect of salinity on the distribution; the abundance of Chaetognatha was insignificant (Figs.14, 15).

1.10 Chaetognatha-zooplankton link

Chaetognatha had a significant positive correlation with Copepoda, Hydromedusa and Tintinnids. On the other hand, this phylum had significant negative correlation with fish larvae (Figs. 9, 10). Both Cahetognatha and copepods have peaks of abundance in winter and spring which witness a decrease in summer. On the other hand, fish larvae start to increase in late spring, with a peak of abundance in summer (Figs.15, 16).

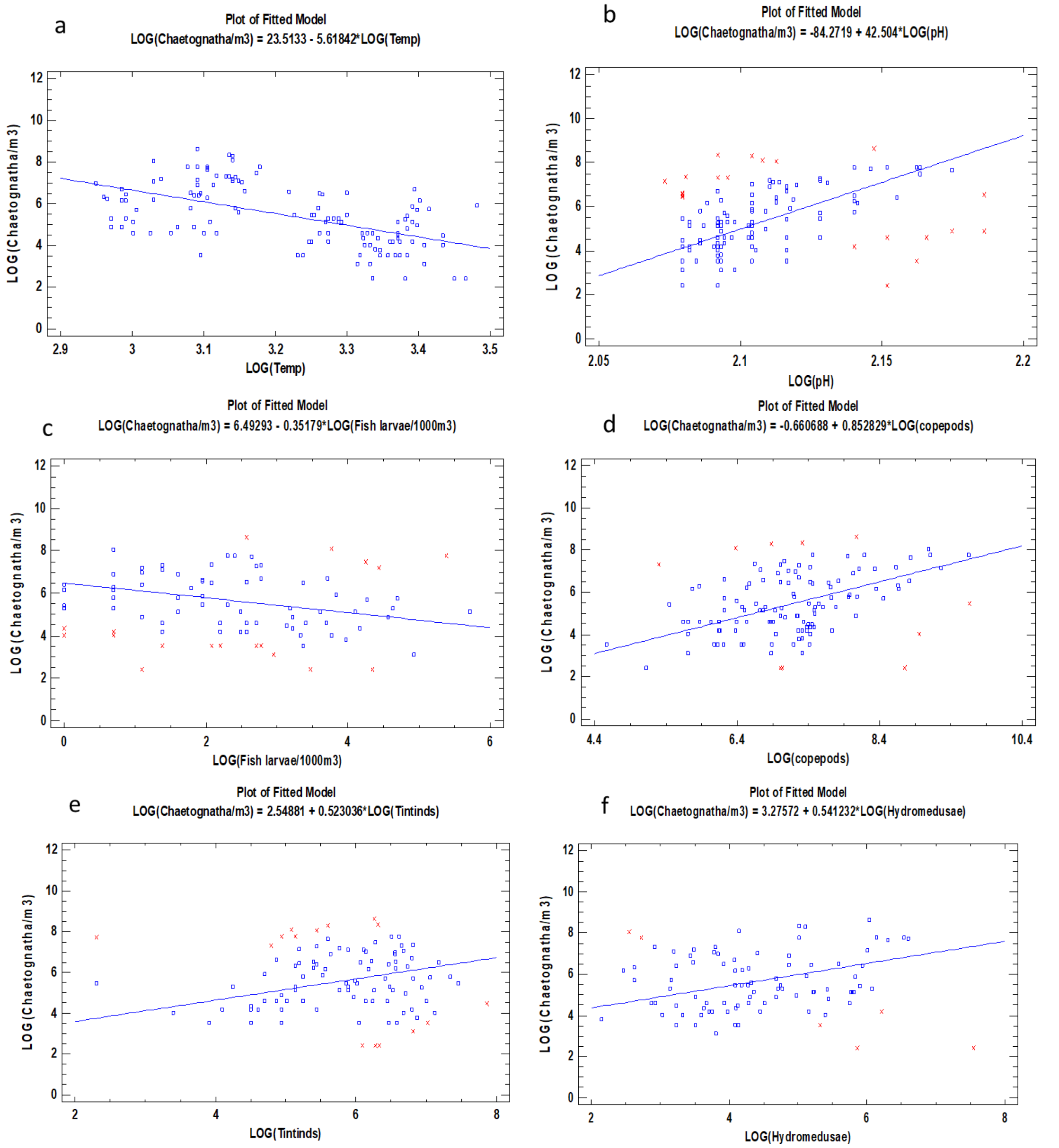

Fig. 13. Plot of fitted model showing: a) Log Chaetognatha*Log. Temp, b) Log Chaetognatha*Log pH and c) Log Chaetognatha*Log Fish larvae, d) Log Chaetognatha*Log. Copepods, e) Log Chaetognatha*Log Tintinids, f) Log Chaetognatha*Log Hydromedusa

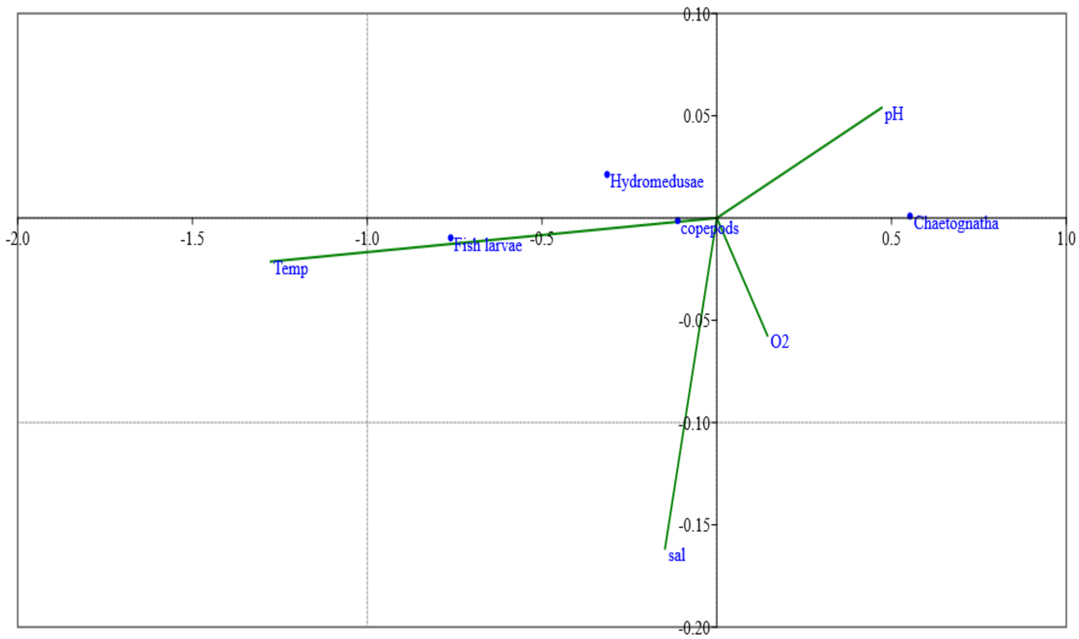

Fig. 14. Canonical correspondence analysis (CCA) by (Past 3) of Zooplankton biodiversity

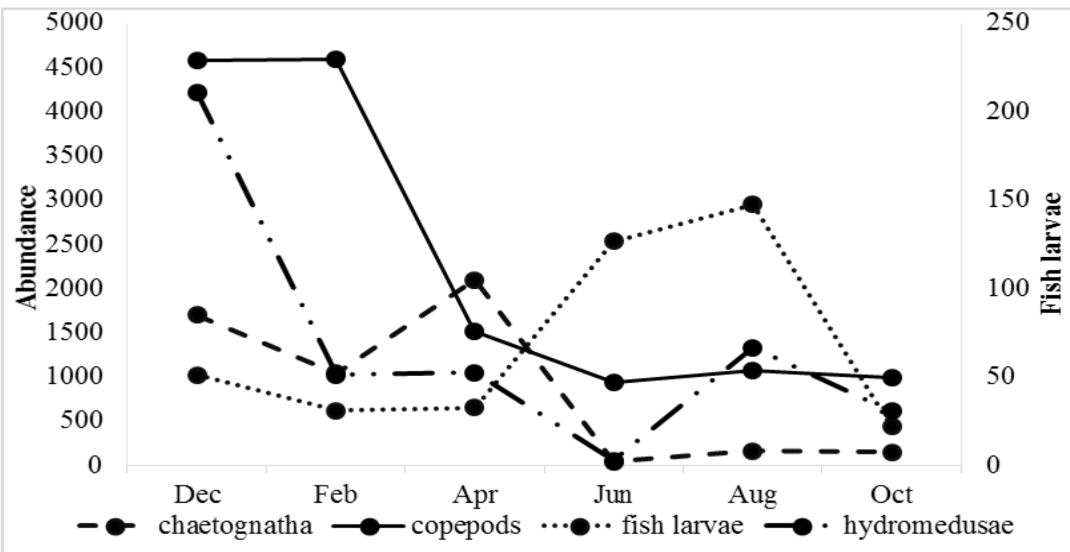

Fig. 15. A bi-monthly abundance of Chaetognatha fish larvae, - hydromedusa, and copepods

DISCUSSION

Chaetognatha constituted about 10% of all zooplankton recorded during the present study with 761 individuals/L. This abundance seems higher than any values recorded in the area although it is not comparable with any previous study in the area due to sampling strategies and the duration of sampling. **El-Sherbiny *et al* (2016)** recorded an abundance of 43.4 individuals/m^3, which is much lower than that recorded in the present study. This may be attributed to the very limited sampling period, which was restricted to a few days in summer and the small mesh size (180µ) used by **El-Sherbiny *et al* (2016)** in comparison two 350 µ and 500 µ used during the present study. **Al-Aidaroos *et al*. (2016)** recorded an abundance of 756 to 1527 individuals /m^3 in September/October period along the Red Sea coast of Saudi Arabia. During the current study, chaetognaths have a peak of abundance in the colder months of the year (December to April).
Khalil and Abdel-Rahman (1997) studied Chaetognatha among other zooplankton groups in the Gulf of Aqaba bi-monthly for a year and found a low abundance of chaetognatha, where they formed only about 1% of all zooplankton collected. They recorded higher density of zooplankton in winter from November to May.
In the oligotrophic waters of the eastern Mediterranean, the highest abundance of chaetognaths was in the surface areas at 0–50m depth layer, and the abundance decreased with depth **(Batisti'c *et al*., 2003; Kehayias, 2004)**. **Kehayias and Ntakou (2008)** stated that, in this surface layer of the eastern Aegean Sea, the most abundant chaetognaths follow the horizontal and vertical distribution of their prey (copepods and cladocerans) and occupy different niches to reduce the interspecific competition.

The community was dominated by epipelagic species, *Sagitta neodecipiens*, *Zonosagitta bedoti*, *Flaccisagitta enflata*, *Sagitta erythraea* and *Ferosagitta robusta*, which is in agreement with reports on distribution of chaetognaths in the Indian Ocean **(Al- Varino, 1965; Nair, *et al.*, 2002)**.
The present collection of chaetognaths was dominated by *S. neodecipiens*, forming about 20% of all chaetognaths, followed by *Z. bedoti* with 14% of Chaetognatha. *F. enflata*, which dominated the collection of Chaetognatha from Anadman Sea **(Nair & Gireesh, 2010)** and the eastern Mediterranean Sea **(Kehayias & Kourouvakalis, 2010)**, which was the third in the term of abundance forming 13% of all chaetognaths.
Heterokhronia angeli and *Decipisagitta decipiens* are mesopelagic species. Whereas, *krohnitta pacifica* and *Krohnitta subtilis* of the family krohnittidae had two epi-mesopelagic and may perform vertical migration with *Ferosagitta ferox*, *Serratosagitta pacifica*, and *Ferosagitta robusta* near the reef to feed on copepods. These species were mainly collected from collected from the upper 100m of the water column from the Pacific Ocean **(Nair, 1972; Nair *et al*., 2002)**.

The number of species of Chaetognatha varied significantly from area to another, based on the method and the depth of sampling. **Al-Aidaroos *et al.* (2016)** identified 13 species of Aphragmophora Chaetognatha belonging to Sagittidae and Krohnittidae from the southern Red Sea. Whereas, **Khalil and Abdel-Rahman (1997)** recorded only three species, *Flaccisagitta enflata, Aidanosagitta neglecta and Krohnitta subtilis* in the order Aphragmophora, belonging to two families (Sagittidae and Krohnittidae) from the Gulf

of Aqaba. On the other hand, **Nagai *et al*. (2006, 2008**) recorded 19 species from the Japan Sea throughout a year collection; whereas, **Nair,*et al*. (2002)** collected 23 species from the Indian Ocean at a depth that ranges from 0- 1000m.
In the present study, only 16 species of Chaetognatha were collected from the surface coastal waters in the Red Sea. Most species are pelagic species. However, some epi-mesopelagic or even mesopelagic species, such as *K. pacifica* and *K. subtilis* of the family Krohnittidae were collected in large numbers from the surface waters near the reef areas.

The highest species diversity of chaetognatha was recorded in middle zone which is in the navigational channel where water currents are strong. This current may help drift chaetognatha from the oceanic waters to the coast. The richness of plankton species follows the trend of coral reefs and density of plankton in the Red Sea (**Beckmann, 1984; Halim, 1984; Kurten, *et al*., 2014; Kurten, *et al*., 2016**). In the present study, diversity index showed a distinct pattern especially in August where evenness values decreased suddenly due to the dominance of *F. enflata*. The high abundance observed during winter and spring are in accordance with the studies from Brazilian coastal regions (**Liang, & Vega-Pérez, 2002**). The highest abundance in winter and spring may be due to the high abundance of *F. enflata.*

Chaetognatha is indicator of water masses and effects of physical processes on zooplankton populations (**Bieri, 1959; Pierrot-Bults, 1982; Dur & Saiz, 2000**). Abiotic factors as temperature, salinity, pH, and dissolved oxygen are considered as significant factors in the growth of zooplankton (**Dejen *et al*., 2004; Malik & Panwar. 2016**). Chaetognatha are sensitive to changes in temperature and salinity The Red Sea is characterized by oligotrophic conditions (**Sofianos, & Johns, 2007; Acker *et al*., 2008; Kurten, *et al*., 2014; Kurten, *et al*., 2016**) with high water temperature and salinity. During the period of study, temperature varied from 21.3 ºC in winter to 29.1 ºC in summer whereas fluctuations in salinity were very tight with a limited influence on the distribution of chaetognata. Chaetognatha had a significant relationship with two important factors in the hydrological regime, the temperature and pH. There was a negative relationship between Chaetognatha and temperature as the abundance increases with low temperature in the period from December to April. This finding is not in agreement with **Al-Aidaroos *et al* (2016)** who observed an increasing abundance of Chaetognatha from north to south waith increasing temperature. There was no significant correlation between chaetognatha and salinity in the northern Red Sea.
Most of sites sampled during this study are close to coral reefs. Higher abundance of zooplankton near the reef reflects the diversity of the reef environment. The higher abundance of Chaetognatha near the coral reef may be due to the high abundance of copepods, the main prey of Chaetognatha, in winter. There was a positive correlation between the abundance of the arrow worms and the abundance of copepods. Fish larvae are competitor with Chaetognatha on the copepods and at the same time they are potential prey for Chaetognatha and other zooplankton groups such as ctenophores and hydromedusae. There was a positive relationship between abundance of Chaetognatha and the primary prey (copepods) (**Baier, & Purcell, 1997; Fernandes, *et al*., 2005; Kürten, *et al*, 2016**) that also reported in the western Mediterranean and with

hydromedusa that present in the same level in food web chain. However, there was a negative relationship between the abundance of Chaetognatha and fish larvae in the higher level (**Wyatt, et al., 2012**).

CONCLUSION

This is the first comprehensive study on one of the most important zooplankton groups. The predator of most zooplankton groups. Chaetognatha are more abundant in the colder periods of the year. Chaetognatha have positive correlation with copepods and negative correlation with larvae of fish because they compete with larvae and feed on them. More studies on the relationship between chaetognatha and zooplankton groups are required.

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