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Composition and Spatio-Temporal Distribution of Zooplankton Community in the Egyptian Red Sea Coast at Hurghada

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ABSTRACT

Zooplankton survey was carried out between August 2015 and July 2016 along the Egyptian Red Sea coast of Hurghada to describe the species composition and spatial-temporal variations of zooplankton community in this region. The area of study was divided into four transects vertical on the shore line and three zones parallel to the shoreline. Plankton samples were collected bimonthly by plankton nets of 350 µ and 500 µ mesh size and 100cm mouth opening. Volume of water filtered in each tow was calculated by the flowmeter added to the plankton net and the density of zooplankton was calculated. The relationship between the abundance of different zooplankton groups and some environmental parameters in the area was studied. Diversity indices were determined using PRIMER5. A total of 415933 individuals/m^3 representing different groups of zooplankton were collected. Zooplankton were most abundant at MAR1 and had the lowest abundance of zooplankton at MAR^3 where 26338 individuals/m^3 were collected. Zooplankton community is dominated by copepods that formed about 53% of all zooplankton collected. Zooplankton was abundant in the warmest period of the year from May to August with a peak of abundance in July and August, where 91267 individuals/m^3 and 97466 individuals/m^3 were collected respectively. There was a significant relationship between temperature and the abundance of zooplankton.

INTRODUCTION

Red Sea is characterized by high temperature and salinity as well as oligotrophic conditions (Raitsos, *et al*., 2013). Combination of all of these parameters makes the Red Sea perfect to understand the distribution and diversity of zooplankton communities. Zooplankton is a term applied to the community of the tiny animals that live drift in the water. It 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 size from micro-zooplankton to mega-zooplankton and ranged from small protozoans to large metazoans (Dulepova, 2002). Zooplankton contains holoplanktonic organisms which complete their life cycle as plankton such as pteropods, chaetognaths, larvaceans, siphonophores, and copepods, and meroplanktonic organisms that spend part of their life in the plankton like larvae of molluscs, crustaceans, coral, echinoderms, and fishes (Vaissiere & Seguin, 1982, 1984; Echelman, & Fishelson, 1990; Khalil, & Abdel-Rahman, 1997; Baier, & Purcell, 1997).

In general, study of plankton is very important for the biological analysis of the marine ecosystem, monitoring and measuring the water quality. The abundance and the development of zooplankton are affected by the variations in the environmental factors (Suresh *et al.*, 2011; Paturej *et al.*, 2017).

A few studies on the diversity of zooplankton in the Red Sea have been conducted. These studies are very scarce and restricted to certain locations in the northern Red Sea and Gulf of Aqaba (Echelman & Fishelson, 1990; El-Sherbiny, 1997; Khalil & Abdel-Rahman, 1997; Cornils, *et al*., 2007; El-Sherbiny, *et al*., 2007), or groups (Khalil, & Abdel-Rahman, 1997). Only a few multi-taxonomic zooplankton studies have been conducted, including those by Schmidt (1973), Reiss *et al* (1977), Vaissiere and Seguin (1982, 1984), Echelman and Fishelson (1990) and Dowidar (1994). Data about the spatial and temporal distribution of zooplankton in relation to environmental parameters and biological parameters is very rare. The present study aims to investigate the structure and distribution of zooplankton community and the influence of physical parameters. It also aims to study the influence of different zooplankton on each other.

MATERIALS AND METHODS

Study area and plankton sampling

Zooplankton samples were collected from Hurghada on the northern Egyptian coast of the Red Sea. The area of study is located between 27°14.362' N and 33 °51.235' E and 27° 8.371' N and 33° 51.235'E and extended to 20 km long and 15 km wide, covering an area of about 300 km^2. It was divided into four transects, Arabia (touristic village), Marina (port), Sheraton (boats), and Magawish (control) representing different habitats, coral reefs, seagrasses, shallow lagoons, etc….. The area extended from coastline to the borders of Big Giftun Island. Samples were

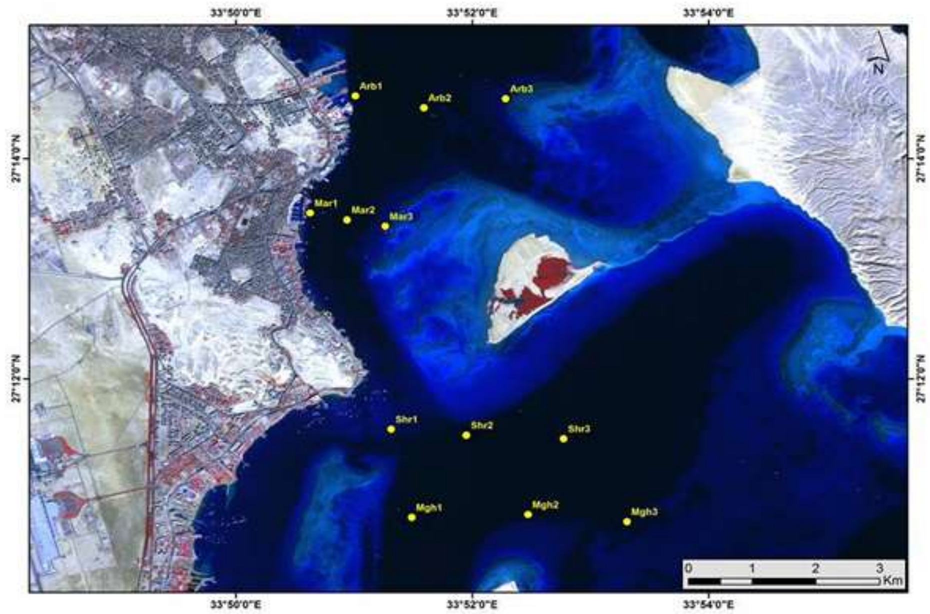

Fig. 1: Area of study and sampling sites at Hurghada region.

Table 1: Description of Study area at the Red Sea Egyptian coast of Hurghada

Site	Sites name	Distance From shore	Lat. (N)	Long. (E)	Depth (m)	Type of substrate
Sector 1 (off Arabia Village)	Station 1	In-shore	27°14.362 '	33° 51.235'	3-50	Coral Reefs
	Station 2	Near-shore	27° 14.427'	33° 51.556'		Navigational channel
	Station 3	Off-shore	27° 14.467'	33° 52.285'		Sandy and dead coral
Sector 2 (off Hurghada marina)	Station 4	In-shore	27° 13.320'	33° 50.554'	3-70	Sandy
	Station 4	Near-shore	27° 13.335'	33° 51.122'		Navigational channel
	Station 6	Off-shore	27° 13.345'	33° 51.280'		Off Abu Munkar Island
Sector 3 (off Sheraton Village)	Station 7	In-shore	27° 11.284'	33° 50.749'	7-50	Sandy, Seagrass
	Station 8	Near-shore	27° 11.926'	33° 51.473'		Sandy
	Station 9	Off-shore	27° 10.479'	33° 51.235'		Open Water
Sector 4 (off Magawish Island)	Station 10	In-shore	27° 8.356'	33 ° 50.509'	15-70	Coral Reefs
	Station 11	Near-shore	27° 8.362'	33 ° 50.146'		
	Station 12	Off-shore	27° 8.371'	33° 51.235'		

Field work

Some environmental parameters (temperature, salinity, pH and dissolved oxygen) were measured using a Multi-Probe device (Aquaread AP 5000). Samples of zooplankton were collected by plankton nets of different mesh size (64 µ, 150 µ, 350 µ, 500 µ) that were towed horizontally parallel to the reef about 10-50 m away from the reef edge for 10 minutes with a towing speed of 1.5 to 2.5 knots. Nets were equipped with a flowmeter to calculate the volume of water filtered by the following equation: $V = \pi r^2 df$

Samples were collected in the early morning and in the afternoon to avoid the vertical migration of zooplankton. Samples were then preserved in buffered 5% formalin solution in seawater for further examination.

Laboratory work

Zooplankton groups were counted and identified to the lowest possible taxonomic level using the relative literature and experience of other scientists (Nair, 2002; Rao; Kurten *et al.*, 2016). Abundance of zooplankton was expressed as the number of individuals in liter based on the following equation: **A=N/V**

Where A is the density of zooplankton; N is the number of the collected zooplankton; V is the volume of filtered water.

Univariate statistics were conducted using SPSS 22. ANOVA was used to determine differences in abundance and species number between months and sites. The analysis of community structure, diversity indices, similarity indices were carried out on PRIMER v 0.5. Simple regression and Principal Component Analysis in Statgraphics v 16 and PAST were used to examine the relationship between zooplankton and physical parameters.

RESULTS

Hydrographic conditions

The surface water temperature in the study area as a warm area showed the seasonal variation experienced in the Red Sea. The temperature attained its highest value during summer reaching 30.9º C in August, and its lowest value of 20.4º C in winter. Very slight variations in temperature between sites were observed. Monthly average of salinity during study period showed very low amplitude (1‰) ranging between 39.70±0.12‰ in October and 40.03±0.04‰ in August. Absolute values of salinity didn't illustrate neither clear seasonal trend nor spatial variation, with significant monthly differences ($p \leq 0.05$) but insignificant differences ($p > 0.05$) among stations. Values of salinity ranged between 39‰ in October and 40.4‰ at station 2 in August. The dissolved oxygen concentration in the study area indicated well oxygenation conditions all the year round. Variations of dissolved oxygen seasonally and in different sectors showed a very narrow range (7.2- 7.5 mgO_2 /1) (7.3- 7.5 mgO_2 /1) respectively, reflecting the stability of the oxygenation conditions in the study area. Variations of pH showed a very narrow range seasonally and in different sectors ranging from (8.1- 8.3) seasonally and ranged from (8.2- 8.3) in different sectors (Fig. 2).

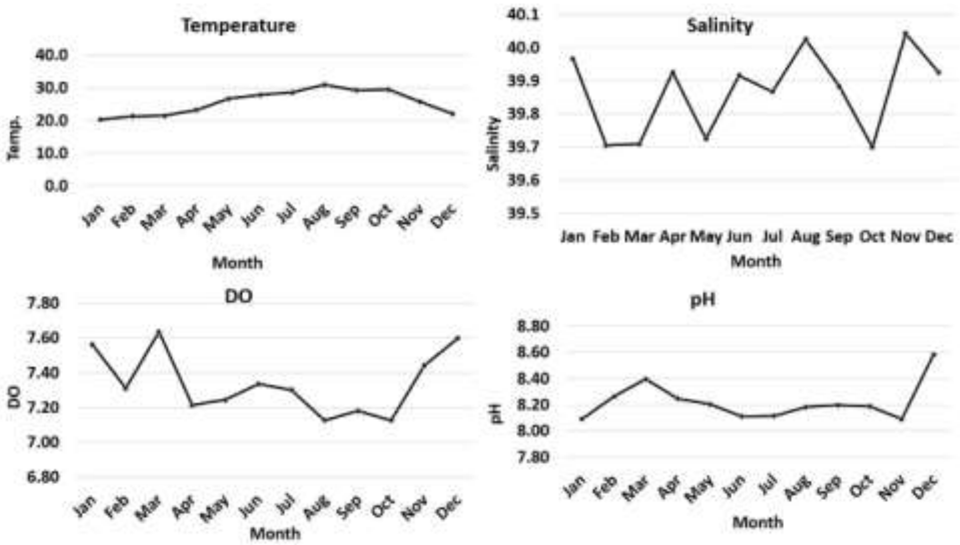

Fig. 2: Monthly variation of environmental parameters at Hurghada

Abundance and diversity of zooplankton

A total of 415933 individuals/m^3 of zooplankton were collected at the 12 stations with an average abundance of 34661 individuals/m^3. The analysis of the spatial distribution of zooplankton showed that MAR1 had the highest abundance of zooplankton with 76242 individuals/m^3, followed by ARB2 with 64547 individuals/m^3 and MGH3 (47300). The lowest abundance of zooplankton was recorded at MAR3 where 26338 individuals/m^3 were found. Stations ARB2, ARB3 and MAR1 had the highest abundance of zooplankton. All the important groups of zooplankton were represented in the collection. Zooplankton community is dominated by copepods that formed about 53% of all zooplankton community and they were represented by the main groups, calanoids, cyclopoids, and Harpacticoids. Nauplius larvae were added to the microzooplankton (Fig. 3).

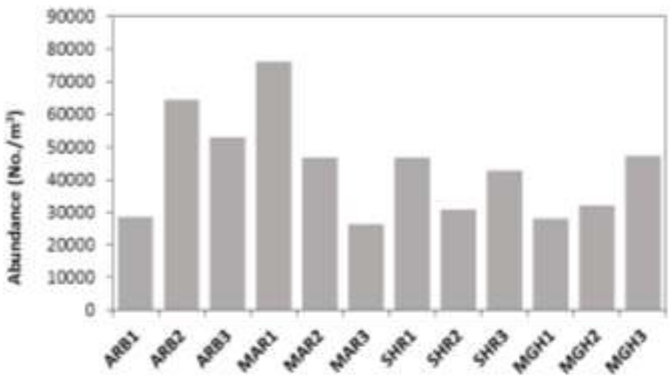

Fig. 3: Abundance of zooplankton in different sites

Zooplankton was abundant in the warmest period of the year from May to August with a peak of abundance in July and August where 91267 individuals/m^3 and 97466 individuals/m^3 were collected respectively, followed by 63548 individuals/m^3 in May. Surprisingly, abundance of zooplankton decreased dramatically in June reaching its lowest value in the year (22032 individuals/m^3). On the other hand zooplankton was less abundant in the period from September to April and start to increase in May (Fig.4). The analysis of variance (ANOVA) indicated that abundance of zooplankton varied significantly with months ($F=7.816$, $P<0.05$) but insignificantly with sites ($F= 0.3$ $P>0.05$).

Abundance of different zooplankton was significantly different between months but insignificantly different with sites.

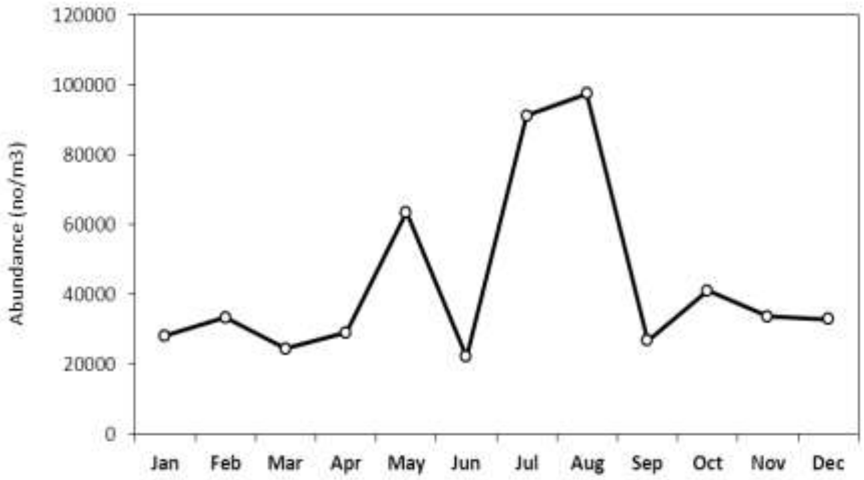

Fig. 4: Abundance of zooplankton in different months

Diversity of zooplankton in the area seems to be very high where most of the major zooplankton taxa are represented. Tintinnids, foraminifera, copepods, fish eggs and larvae, hydromedusa as well as chaetognatha are found in high abundance. Other zooplankton groups than the above-mentioned groups such as shrimp larvae, crab larvae, crustacean larvae, mollusks larvae, and chordates larvae were also recorded in large numbers during this survey where 24507 individuals forming 6% of all zooplankton were collected. Ichthyoplankton as expected was the least abundant group forming less than 1% of all zooplankton. Fish eggs were much more abundant than fish larvae (Fig.5).

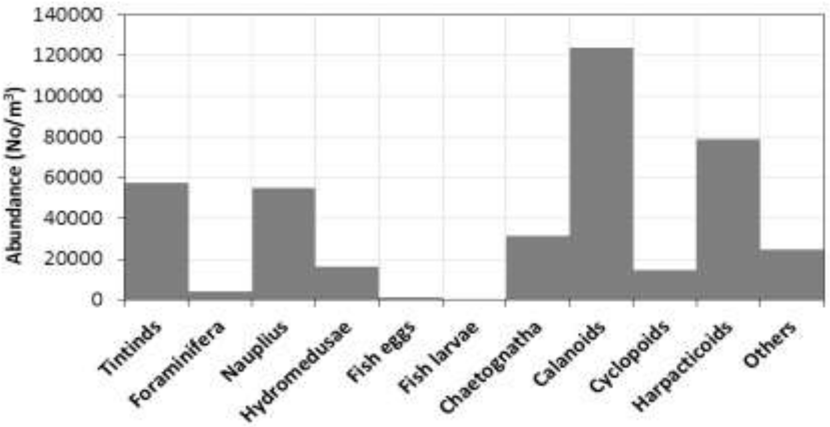

Fig. 5: Abundance of zooplankton groups at Hurghada area

Micrpzooplankton

The examination of the collected microzooplankton in the current survey revealed the presence of 206 species belonging to 44 families and 113 genera. Microzooplankton was dominated by tintinids that were represented by 142 species followed by foraminfera that were represented by 61 species. Radiolaria had the lowest number of species where only three radiolarian species were recognized.

Tintinnids and Foraminifera

A total of 57290 tintinnids have been collected during this survey and 4150 individuals representing 64 species of foraminifera were collected from the whole area. Although foraminifera had the highest abundant in August, the highest number of species was recorded in August where 52 species were collected. Number of species was very variable in other months (Fig. 6).

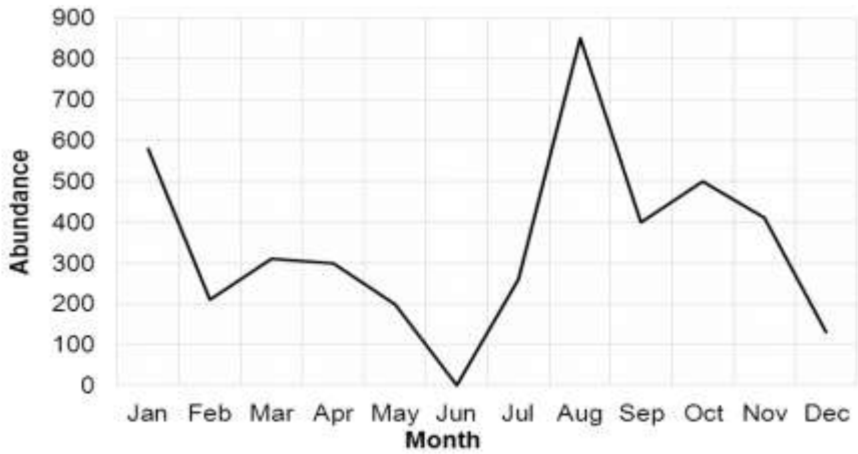

Fig. 6: Abundance of foraminifera at different months

Mesozooplankton

Copepods

A total of 217101 copepods were collected from the whole area of study throughout a year of sampling. Copepods formed about 53% of all zooplankton recorded in the present survey. The analysis of the community composition of copepods showed that calanoids dominated the copepod community constituting about 57% of all copepods collected followed by harpacticoids that formed 36% (Fig.7).

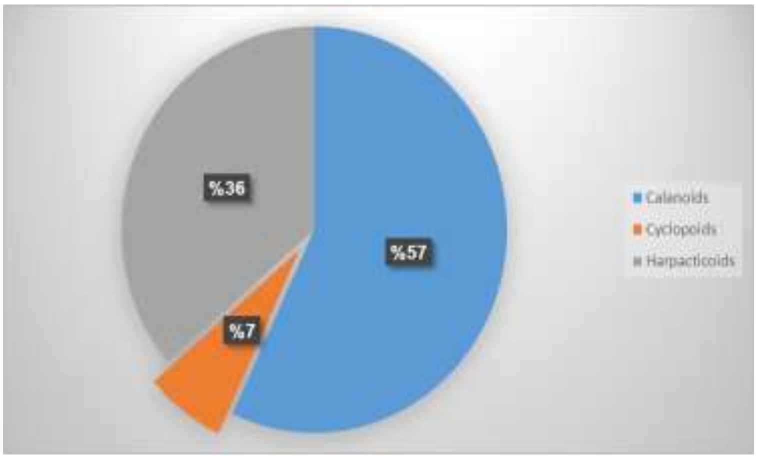

Fig. 7: Percentage contribution of different copepod groups

Copepods had the highest abundance in ARB2 where 40561 individuals/m^3 were taken. They recorded the lowest abundance in MGH1 with 10568 individuals/m^3 (Fig. 8).

Temporally, there is no clear pattern of copepod abundance throughout the whole year. Copepods have high abundance in May (47962 indiv./m^3) then decreased gradually in June and July. They have the lowest abundance in June (7384 indiv./m^3) and increase again to its second peak in August with 35060 indiv./m^3 (Fig. 9).

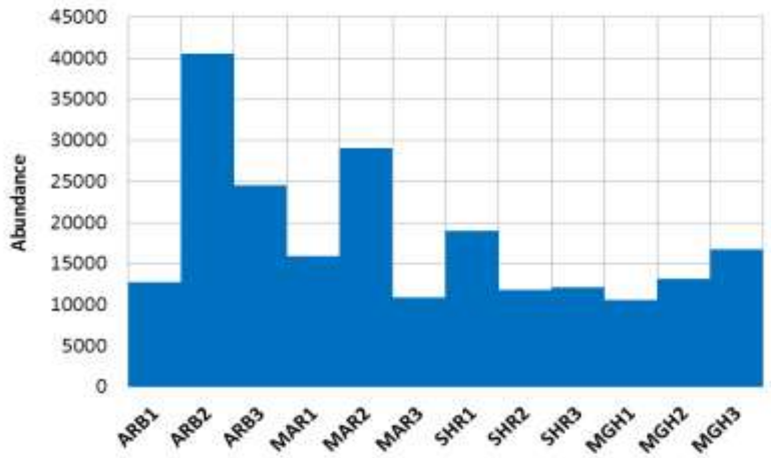

Fig. 8: Abundance of copepods at different sites

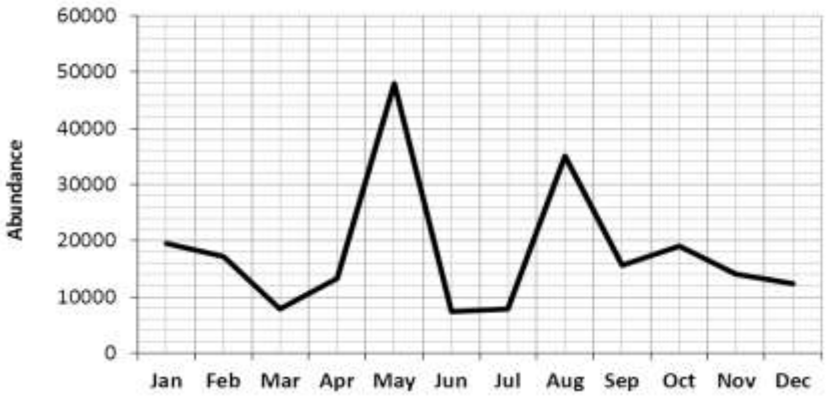

Fig. 9: Abundance of copepods at different months

Gelatinous zooplankton

Chaetognatha

A total of 76132 individuals of chaetognatha representing 16 species were collected throughout a year of sampling on a bi-monthly basis. Generally, Chaetognatha was decidedly abundant in the colder months of the year from December to April with a peak in April where 37767 individuals/L were collected followed by December with 20432 individuals/L. Chaetognatha was less abundant in the warmer times of the year from June to October. The lowest abundance was recorded in June where only 750 individuals/L were collected (Fig.10).

Statistically significant differences in the average of chaetognatha were found between months ($F=13.3$, $P<0.05$). On the other hand, abundance was insignificantly different between sites ($F= 0.97$, $P>0.05$).

Regarding the spatial variations of abundance, chaetognatha were abundant in most of the sites. Magawish transect harbored the highest number of chaetognatha with 22344 individuals/L followed by Sheraton transect (22200 individuals/L). Arabia transect had the lowest number of individuals where 15088 individuals/L were caught (Fig. 11).

Chaetognatha abundance peaked in in MGW2 where 10144 individuals/L were collected followed by SHR3 and MGW3 with 9700 and 9111 individuals/L, respectively. The lowest abundance was recorded in MAR1 (2911 individuals/L) (Fig. 11**).**

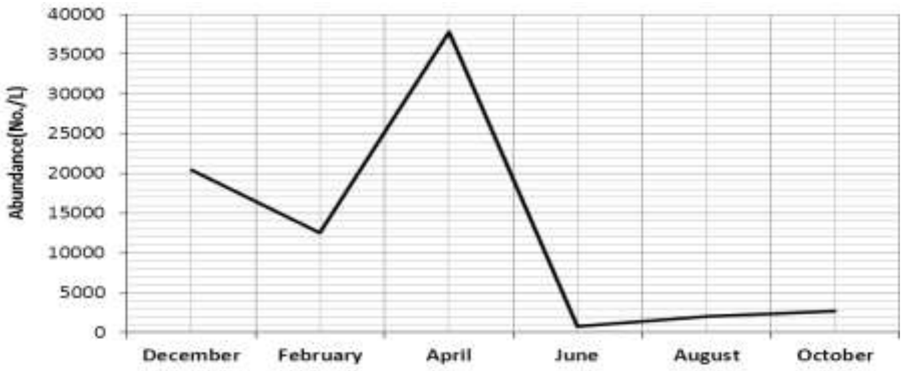

Fig. 10: Abundance of chaetognatha at different seasons

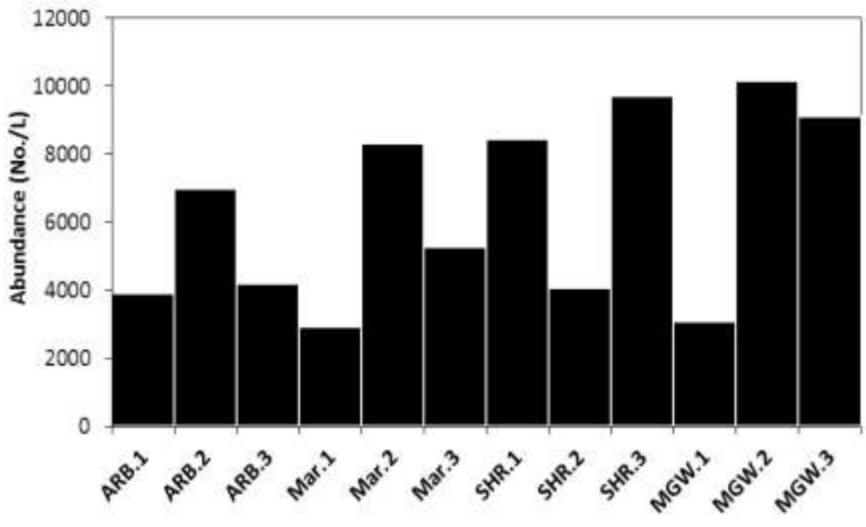

Fig. 11: Abundance of chaetognatha at different sites

Hydromedusae

A total of 24 species belonging to 23 genera and 2 phyla, Cnidarian and Ctenophore, were recorded during the present survey of which 21 were belonging to Cnidarian. A total of 18 species were belonging to Hydrozoa and 3 species belong to Scyphozoans.

Zooplankton-environmental parameters link

There was a significant negative relationship between Chaetognatha and Temperature ($P<0.05$) (Fig.١٥) whereas the relation was in the positive between chetognatha and both pH and O_2 ($P<0.05$). On the other hand, fish larvae has a strong positive relationship with temperature (Fig. 12)

Zooplankton-zooplankton link

Chaetognatha had a positive correlation with copepods and hydromedusae but a negative relationship with fish larvae. On the other hand, fish larvae have a positive relationship with copepods (Fig.13).

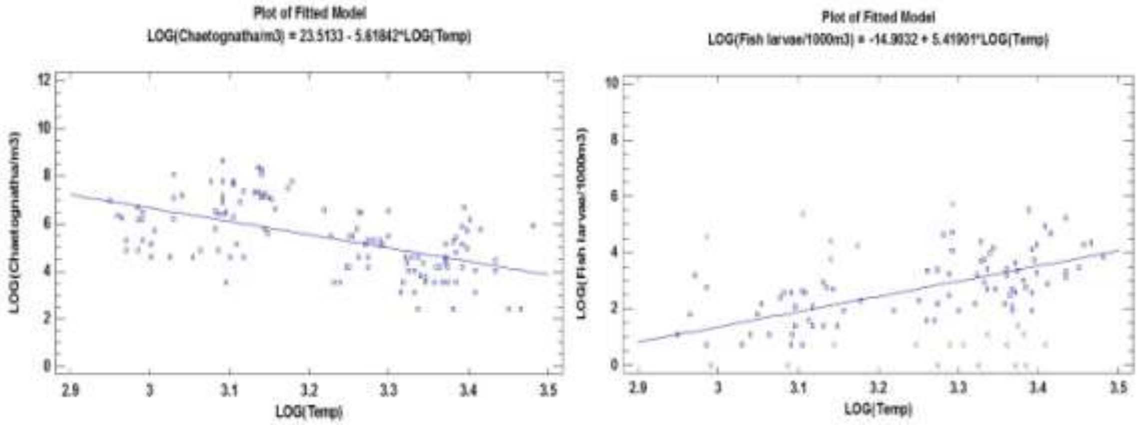

Fig. 12: Linear regression between temperature and abundance of chaetognatha and fish larvae at Hurghada area

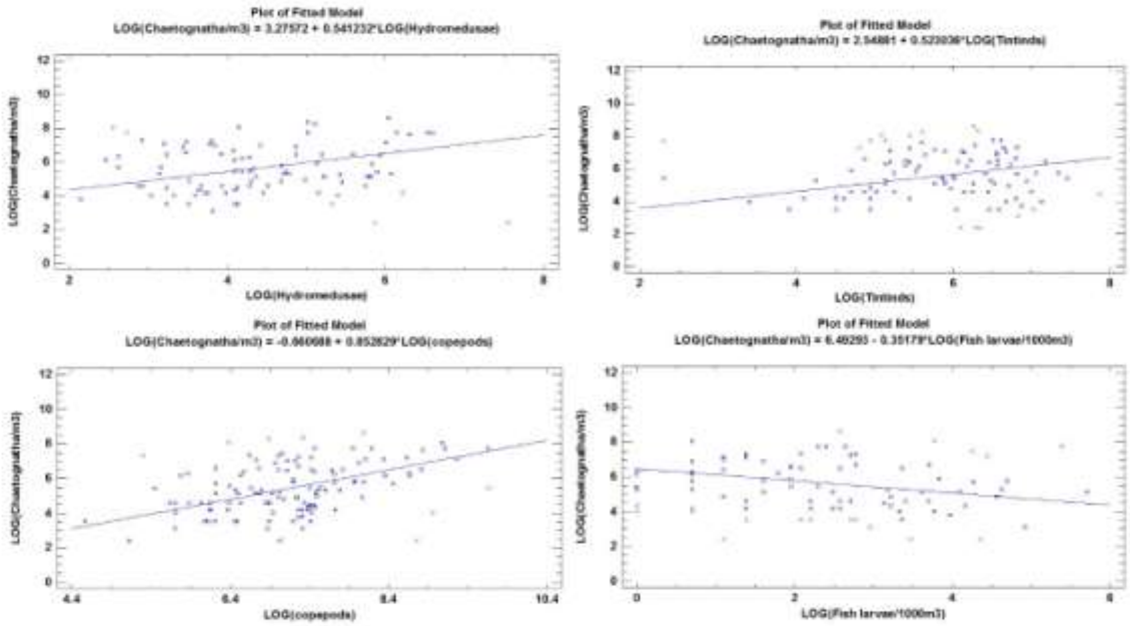

Fig. 13: Linear regression between different zooplankton groups at Hurghada area

DISCUSSION

This study was carried out in Hurghada in order to explore the composition of zooplankton community in the area and the community is influenced by both physical factors such as temperature and salinity and biological factors. The trophic relationship is well-known among different zooplankton groups (Koppelmann *et al*., 2009). The Red Sea has a very high diversity of zooplankton as indicated by the presence of most zooplankton groups in the collection. The community was dominated by copepods that contributed 53% of all zooplankton collected. This percentages seems very low compared to that recorded in previous studies in the Red

Sea (Abdel-Rahman 1993; Dorgham *et al*., 2012) and Gulf region (Michel *et al*. 1986, Dorgham & Hussein 1997) where copepods formed 78-92% of all zooplankton collected in the surface layer up to 50m. Aboul Ezz *et al.,* (2014) found that copepods constituted about 72% of the total zooplankton collected from Matrouh beaches of the Mediterranean Sea. Similarly, copepods dominated zooplankton communities in other regions as in Arctic regions (Greenland Sea, White Sea, Icelandic waters, Beaufort Sea, Kara Sea, Arctic Ocean) during summer seasons (Mumm 1991, Richter 1994, Auel & Hagen 2002, Fetzer et al. 2002, Walkusz et al. 2009; Dvoretsky & Dvoretsky, 2013) whereas the peak of copepods was in winter season.

The abundance and the development of zooplankton are affected by the variations in the environmental factors (Suresh *et al.,* 2011; Paturej *et al.,* 2017).

The peak of zooplankton abundance in the present survey was recorded in spring followed by summer season which is in agreement with other studies in the area (Al-Najjar 2000; Dorgham *et al.*, 2012). However, zooplankton peaked in winter (Echelman & Fishelson 1990, Khalil & Abdel-Rahman 1997) in the Gulf of Aqaba.

Khalil and Abdel-Rahman (1997) collected 62 taxa and species from surface water in the Gulf of Aqaba. At all sites, copepods were predominant in the standing crop with an average of 1945 ind./ m^3 and formed 75.5%, numerically, of the total zooplankton community. In the present study many more taxa and species of zooplankton were taken from Hurghada. This high number of zooplanktonic species from different groups is attributed to the monthly sampling program compared to bi-montly sampling by Khalil & Abdel-Rahman (1997).

Chaetognaths are highly abundant carnivores in marine environments, and feed both on fish larvae and on the same foods as fish larvae. The present study tried to find the link between both Chaetognatha and fish larvae from one side and the two groups and other zooplankton groups from the other side. There was a negative correlation between the abundance of Chaetognatha and that of fish larvae. Number of fish larvae decreased as number of Chaetogntha increased. On the other hand, the relationship between fish larvae and copepods, the main food of fish larvae, was positive. Other paly-maker in the marine environment which has a great role in the pelagic food chain was hydromedusae.

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ARABIC SUMMARY

التركيب والتوزيع المكاني والزماني لمجتمع العوالق الحيوانية في ساحل البحر الأحمر المصري بالغردقة.

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تم إجراء مسح للعوالق الحيوانية بين أغسطس ٢٠١٥ ويوليو ٢٠١٦ على طول ساحل البحر الأحمر المصري بالغردقة لوصف التركيب النوعى والاختلافات المكانية والزمانية لمجتمع العوالق الحيوانية في المنطقة. قسمت منطقة الدراسة إلى أربعة قطاعات عمودية على خط الشاطئ وثلاث

تم إجراء مسح للعوالق الحيوانية بين أغسطس ٢٠١٥ ويوليو ٢٠١٦ على طول ساحل البحر الأحمر المصري بالغردقة لوصف التركيب النوعى والاختلافات المكانية والزمانية لمجتمع العوالق الحيوانية في المنطقة. قسمت منطقة الدراسة إلى أربعة قطاعات عمودية على خط الشاطئ وثلاث مناطق موازية للشاطئ. تم جمع عينات العوالق كل شهر بواسطة شباك بلانكتون فتحات العيون ٣٥٠ µ و ٥٠٠ µ وقطر الشبكة ١٠٠ سم. تم حساب حجم المياه الذى تم ترشيحه في كل سحبة بواسطة مقياس التدفق المضافة إلى شبكة العوالق. تم حساب الكثافة العددية للعوالق الحيوانية بحساب عدد الأفراد التي تم جمعها بالنسبة لحجم المياه التي تم ترشيحها. تمت دراسة العلاقة بين وفرة مجموعات العوالق الحيوانية المختلفة والخصائص البيئية في المنطقة. تم تحديد مؤشرات التنوع باستخدام PRIMER5. تم جمع ما مجموعه ٤١٥٩٣٣ فرد / م^{٣} يمثلون مجموعات مختلفة من العوالق الحيوانية. كانت العوالق الحيوانية أكثر وفرة في محطة مارينا MAR1 وكانت أقل وفرة في MAR3 حيث تم جمع ٢٦٣٣٨ لكل متر مكعب ماء. سادت مجموعة مجدافيات الأرجل حيث شكلت حوالي ٥٣٪ من جميع العوالق الحيوانية التي تم جمعها. كانت العوالق الحيوانية وفيرة خلال الفصول الدافئة من السنة من مايو إلى أغسطس ووصلت الكثافة العددية إلى أعلى مستوى في يوليو وأغسطس حيث تم جمع ٩١٢٦٧ فرد / م^{٣} و ٩٧٤٦٦ فرد لكل متر مكعب ماء على الترتيب. وجدت هناك علاقة معنوية بين درجات الحرارة وكثافة الهائمات الحيوانية وبين مجموعات الهائمات المختلفة.