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Original Research Article

First report on zooplankton abundance and composition in the Hadhramout coast, Gulf of Aden

ABSTRACT

Five stations were investigated to represent the Hadhramout coast in the Gulf of Aden. This area, totally or partially, is under the influence of the western Indian Ocean seasonal monsoons. Zooplankton was collected monthly during daytime in 2009 – 2010 with vertical towing of 200 µm mesh plankton nets. The zooplankton community was characterized by its high variability and diversity. 226 taxa of zooplankton were identified in the coast through the different seasons. Zooplankton community was dominated by Copepods during the four seasons, followed by Euphausiids and chaetognatha. The peak of zooplankton abundance was in northeast monsoon. The present results showed that the composition and distribution of zooplankton differed between the monsoon seasons, but little between the stations.

Keywords: Zooplankton, Gulf of Aden, Copepods, Hadhramout coast, coastal upwelling.

1. INTRODUCTION

Zooplankton plays an important role as a key link in any local food chain, nutritional levels, and transporting energy from bacteria and phytoplankton to macroinvertebrates and fish. The structure of plankton communities in any body of coastal waters is also important to commercial fisheries.

Hadhramout coast is well known by a multi species fishery. Its fishing and oceanic properties represents a system of the Upwelling phenomenon in the Gulf of Aden, which occur along most of its regions including a Hadhramout coast during the months of summer monsoon from May to September. The productivity that follows this phenomenon sustains the catches of a significant number of fishes, crustaceans and mollusks of commercial interest. Hadhramout coast characterized by riches of primary productivity of 685 mg C / m^2 / day, secondary productivity ranging between 14 - 68 mg C / m^2 / day [1,2] (Khimitsa, 1968; Savidge and Gilpin, 1999) and contributes by an enormous share of the quantities of fish landing in the whole Yemen - 29% (for 2012). This coast is characterized by abundance of Indian oil sardines *Sardinella longiceps*, Indian mackerel *Rastrelliger kanagurta* and yellowfin tuna *Thunnus albacares*. Latter supports coastal surface and pelagic catches of the Gulf of Aden for more than 30000 tons of fish [3,4](IFAD, 2010; MFW, 2002).

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Crustacean zooplankton is the main organisms in aquatic ecosystems, as they represent an important link in marine food webs. They transport materials and energy from primary phytoplankton production to a higher level of many species of fish and other marine animals.

East of the Gulf of Aden includes the Hadhramout coast considered one of the most global ocean parts by productivity; its average productivity for more than a hundred kilometers from the beach is more than the productivity of other Upwelling areas, like Peru Coast and West Africa [5,6] (Krey and Babenard, 1976; Wooster *et al*, 1967), higher productivity have been observed in this region (more than 1000 mg / m^3) around August, at the end of the south-western monsoon; while less productivity (about 400 mg / m^3) in January through the northeastern monsoon [7,8](Nair, 1980; Madhupratap *et al*., 1981).

The Gulf of Aden and its Hadhramout coast are located directly under the influence of the sub Somali sea current approaches, particular in summer, which enters the Gulf mainly through corridors of Socotra Archipelago and rich in phytoplankton, the output of Upwelling phenomenon [9] (Fratantoni *et al*., 2006). This coastal upwelling brings nutrients to the surface, where the light, creating a fuel to photosynthesis and phytoplankton growth, which in turn feed the zooplankton and fish.

Zooplankton constitutes a sensitive tool for monitoring environmental changes in coastal lagoons.

It is not new talking about the environmental importance of zooplankton in the marine water bodies, particularly the most abundant component, the Copepods, in pelagic food webs of Global Ocean. These organisms are often considered distinctive component of the zooplankton community in a lot of marine conditions and play a key role in converting nutrients and energy through the trophic levels [10,11](Poulet and Williams, 1991; Marcus, 2004)**.** Quantitative studies of the dynamics of a nearshore zooplankton community along the coast of Gulf of Aden are still fragmentary [12,13,14](Vinogradov and Voronina, 1961; Schneider et al., 1994; Wiebinga et al., 1997). In contrast, the taxonomy and seasonal standing stock of the phytoplankton community in the coastal waters of the Gulf of Aden and Hadhramout area in particular has been investigated but occasionally [15,16,17](Savich, 1979; Alkawri and Gamoyo, 2014; Ali and Bazar, 2016).

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2. MATERIAL AND METHODS

A detailed description of the study area and stations sampling for some physical indicators (temperature and salinity) and chemical (dissolved oxygen, nutrients: phosphorus, nitrates, silicate, and chlorophyll a) are presented in Ali and Bazar [17](2016). Analysis of biomarkers samples were taken from all water columns according to the total depth, which ranges between 100 - 90 meters and surface of water.

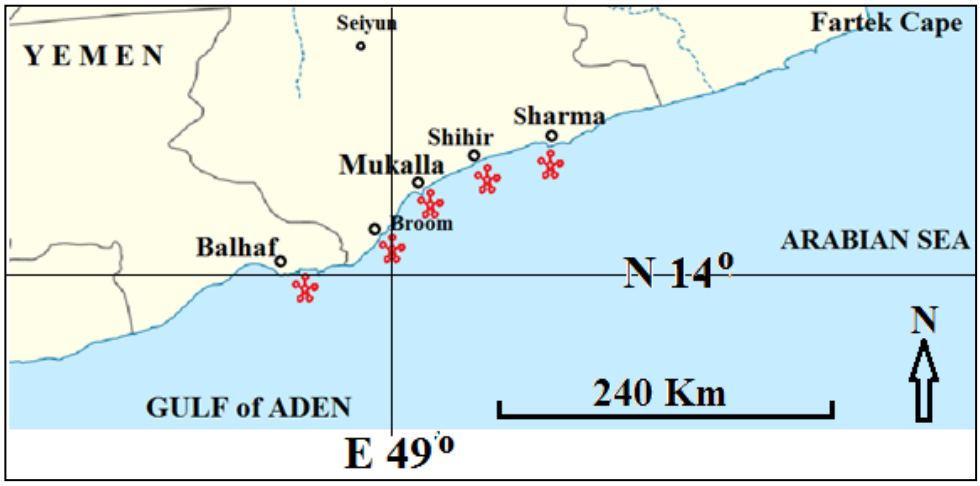

Fig. 1: Study area and sample sites in coast of Hadhramout, geographical locations are as follows: Balhaf (BirAli) (N13° 55′, E48 °26′), Broom (N 14°22′, E49°00′), Mukalla (N14°48′, E50°00′), Sheher (N14 °43′, E49 °40′), Sharma (N14 °48′, E50 °00′)

Zooplankton samples were carried out in the five stations representing the coast of Hadhramout monthly during the 2010 (Figure 1). We used for this purpose zooplankton open nets with mouth diameter of 50 and 80 cm (0.25 and 0.4 m^2) with 200 microns mesh. Sample were taken by vertically open nets from near the bottom - 5 meters above the bottom and up to the surface, with filtered water volume calculated through the net, which represents the multiplication the net opening area by distance, which was to contain (the depth of station). In our study, we chose a depth of 90 meters per station because fading of thermocline in the coastal area in most months of the year typically can be found at depths greater than 100 meters [18,19](Bathafari, 2003; AlSaafani, 2008).

Dry weight analyses were performed on preserved zooplankton samples to examine temporal variability in biomass. The procedure, involved dividing the samples into halves using a modified sand splitter [20] (Cooney, 1971). Large scyphozoan medusae and juvenile fishes were not considered in dry weight measurements.

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Each sample was divided into two parts and after rinsing the splitting apparatus, one half was returned to the original sample jar, preserved in 100% formalin, and stored in the Faculty concerned laboratory. The remaining half-sample was flushed in running tap water for 5 minutes, drained, and poured into a tared, aluminum foil tray. Samples were dried to constant weight at 56°C for 18 to 24 hours [21](Lovegrove, 1966). Newly removed samples were cooled in desiccators for 10 minutes and then weighed to the nearest milligram on the Mettler 3 F16GN balance.

Monthly samples of zooplankton were collected early in the morning at 6 - 8; it has been preserved by adding formalin 4%, the samples has been saved in an icebox for about 2 to 3 hours until reaching to the lab. In the laboratory it has been separated into several homogeneous parts according to the test program for measuring the mass, a part re-saved in 10% phosphate buffered formalin in sea water for the microscopic study for identifying a taxonomic belonging. In order to determining the dry weight the secondary sample of specified volume was filtered through filter paper (Whatman GF/C filters, diameter 5.5 cm) to a specified weight before burning, and wash with the sample with distilled water and then dried under 60 Celsius for 36-48 hours (till constancy weight) then be calculated weight, and therefore the dry mass of the Zooplankton was weighted.

The Mass (mg Dry wt / m^3) is calculated as follows:

Biomass (mg/ l) = [zoopl. dry weight (gm) / volume of filtered water (m^3)] × 1000,

Where the filtered volume of water entering the plankton net calculated as follow:

$$\mathbf{V = \eth\, r^2\, d}$$

In the formula, **V** is the volume of water filtered by net, **r** is the radius of the hoop of the net and **d** is the length of the water column transverse by the net [22](Goswami, 2004).

The samples were examined to study the abundance and belonging zooplankton by taking several secondary samples by 5 ml of the sample which well mixed by using a stempel pipette (piston pipette) and Bogarov chamber [23](Omori and Ikeda, 1984) to examine the samples to count and diagnosis by anatomical microscope under magnification ranged between 40 and 200 times. Counting has been for each slide cells (Bogarov chamber); a diagnosis of zooplankton to species or genus despite the difficulty of diagnosis. The abundance of some groups and for the zooplankton as a whole are calculated by re-calculation to cubic meter, depending on the

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volume of water drawn by used planktonic net. For an accurate assessment of the population density we adhere to necessity to do multiple repetitions in the calculation of the organisms in a sub-sample.

It has been emphasis in analysis of zooplankton samples, at four time periods envisaged the inclusion of monsoonal seasons: summer and winter and the in between periods: the months November 2010 represents the period between the summer and winter monsoons, January 2010 represented the winter monsoon and May represents a post-winter monsoon and Prior Summer monsoon and August 2010 as representative of the top of Summer monsoon.

In all the parts of quantitative and qualitative method of samples collection and analysis of zooplankton we adopted and guided with what stated in the relevant sources, each according to the degree of in-depth analysis [24,25](Madhupratap, 1983; Gowsami and Padmavathi, 1996). The taxonomic identification has relied on a lot of special and general keys and guides for zooplankton of the Indian and the Atlantic Oceans, and the Indo-Pacific region [26,27,28] (Silas and Srinivasan 1970; Bradford, 1988; Conway *et al*, 2003;). Despite the lack of studies and references for larval stages of fish and crustaceans in the Gulf of Aden, but it possible to adopt some of which belong to other areas of the Indian Ocean and the Indian Pacific region, including: [29,30] (Leis and Carson-Ewart 2003; Leis and Trnski, 1989).

The species richness, Shannon-Weaver index H′ and evenness J′ as well as the Bray-Curtis Similarity Index were computed using the multivariate ecological software packages PRIMER program v.6.

3. RESULTS AND DISCUSSION

In this study it was possible to diagnose and counted 226 species of zooplankton which distributed mainly within a basic eight groups; the most common among them were a Copepods, in which prevailed the species belonging to order Calanoida, particularly species of the genera Acartia, Calocalanus and Eucalanus. The second order is Poecilostomatoida, which characterized by abundance of species of genus Oncaea. Table (1) shows a picture of the numerical abundance in Hadhramout coast. As it is shown in the table, the 171 species of the copepods are belonging to 20 genera and several families. This kind of numerical abundance of

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the copepod was recorded in many studies to some areas of the Indian Ocean [31,32,13,33] (Gowsami, 1985; Van Couwelaar, 1997; Schneider, *et al*., 1994; Piontkovski *et al.,* 2013).

From the results, it is seen that the most widespread and abundant in Hadhramout coast represent a group of Copepods, which accounted as average of more than 83%, followed by groups Euphausiids that formed 9%; Chaetognath, Decapods and Tunicate formed by 2% each (Fig. 2).

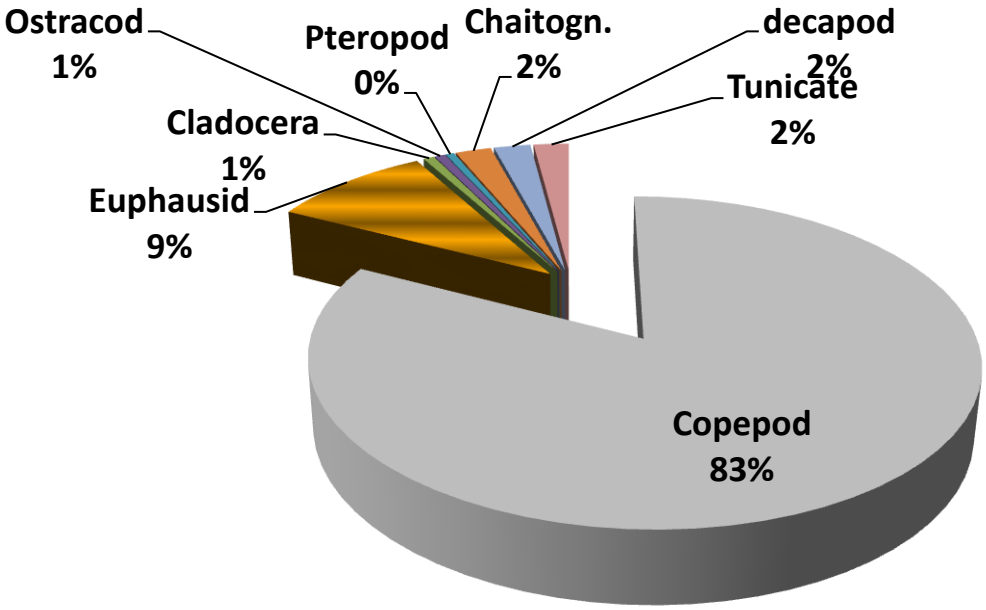

Fig. 2: Relative abundance (%) of different zooplankton groups in Hadhramout coast

The Cyclopods represented basically by the genus *Oithona* spp. Zoea of the Decapods observes throughout the year with maximum abundance as much as 11% of the total zooplankton in March-April, during the intraseason after the winter monsoon; it was represented mainly by the families Portunidae, and Xanthidae and others. The Chaetognatha was found throughout the year, mainly represented by the species of the genus *Sagitta* spp. through the end of winter monsoon and the Intermonsoon season beyond. Fish eggs and larvae found during the spring and summer months and autumn with higher density during the spring and early summer monsoon.

The Copepods, as are other groups found in all stations with analogous density with distinguishing the stations of Bir Ali, Broom and Sheher (Table 1, Fig.3). Zoea and megalops of the true craps (Brachyura) were also spread out with distinction at Sheher and Sharma stations, while the larvae of mollusks have prevailed in the stations of Bir Ali and Sheher compared to

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other stations. All coastal stations are equal by relative abundance of the fish larvae. However, Sheher and Sharma stations were distinguish in terms of the larvae of family Scombridae and Carangidae during August and September.

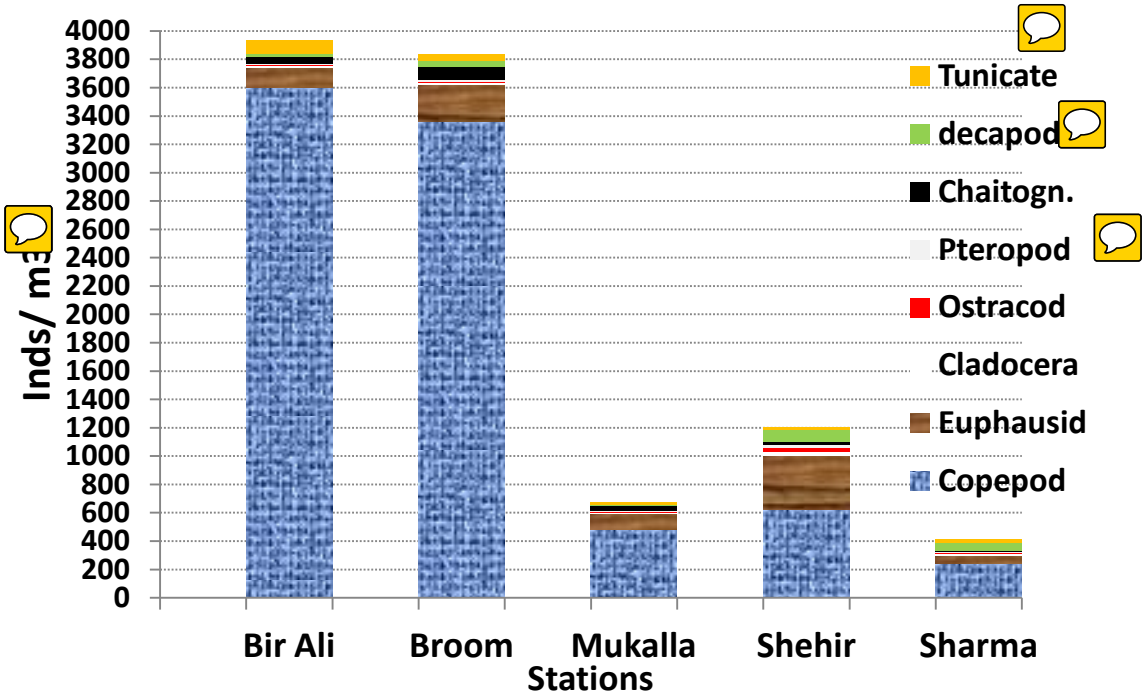

Fig. 3: Zooplankton density and the contribution of the Copepods related to the other groups, in the Hadhramout coast stations.

The Copepod group prevailed during the four seasons achieving an average: 82.6% (3125 individuals / m^3 during the winter northeastern monsoon, 2660 individuals / m^3 during southwest monsoon, 1643 individuals / m^3 during post southwest monsoon, and 1071 individuals/m^3 in the post northeastern monsoon (Table 2 and Figures 4). Abundance of Copepod clearly increased during the winter monsoon, as compared with other seasons. There are distinct spatial differences during the summer monsoon, the post monsoon, and northeastern monsoon, that appears from the analyzing of both tables (1 and 2) in figure 3.

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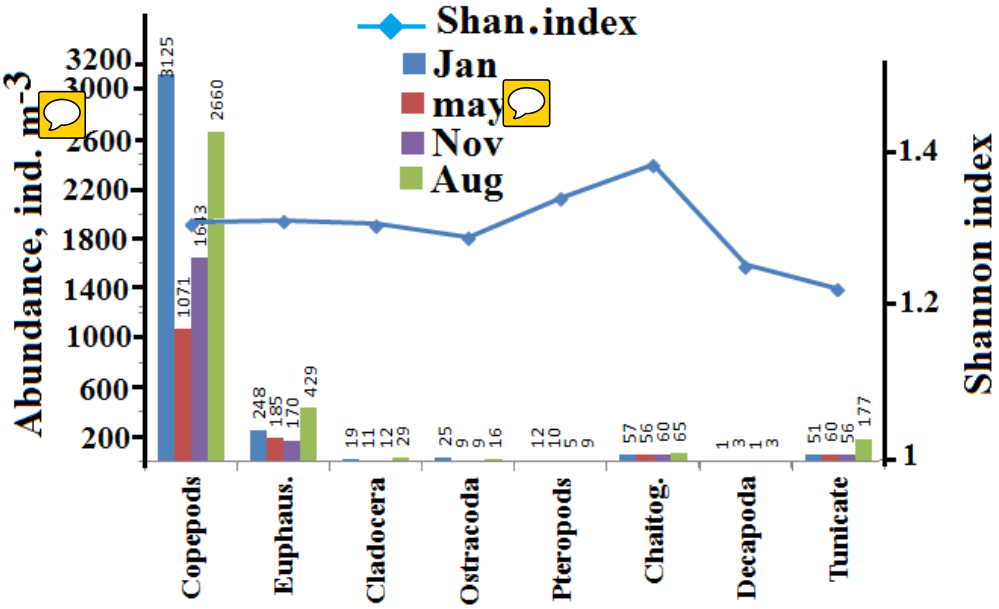

Fig. 4: Relative abundance of zooplankton groups and diversity profile according to seasons in Hadhramout coast.

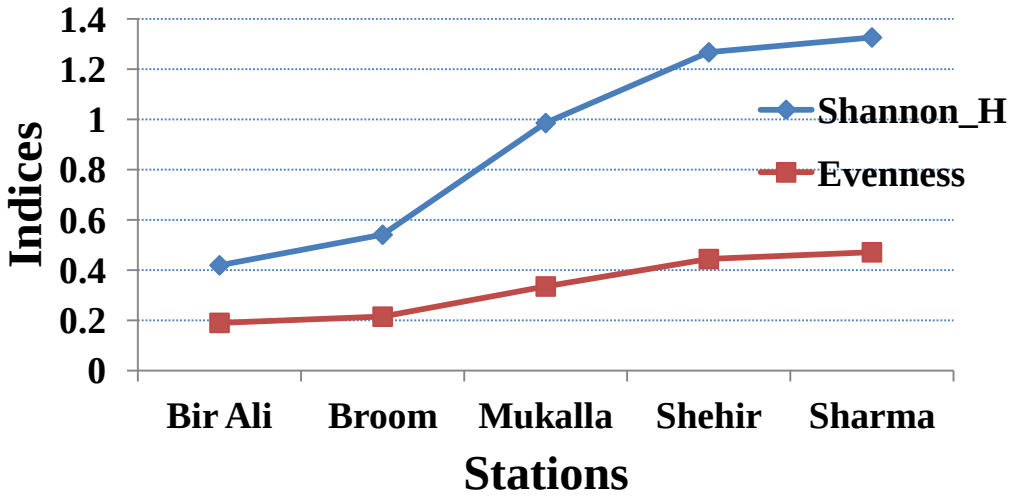

Fig. 5: Variations of different species diversity indices (Shannon-Weaver diversity and evenness) of zooplankton present in the Hadhramout coast stations.

Despite the fact that the predominance of the copepod group in all stations is observed, the coefficient of zooplankton diversity in these stations has a marked tendency to vary - from 0.42 in Bir Ali station to 1.33 in Sharma, the same trend was Evenness index (Figure 4 and 5); but there were no significant differences between density and Shannon's index temporally and spatially ($p>0.05$). Here we notice that south Hadhramout coast (i.e. Sheher and Sharma) exhibited higher zooplankton diversity than west coast. Mean H ranged from 0.42 to 1.27 in south coast while it ranged between 0.42 and 0.99 in west coast - Bir Ali and Mukalla. Species

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diversity varied significantly between seasons ($p < 0.05$). Mean zooplankton diversity was higher in May (H = 0.9) and Aug. (H = 0.8) than in Jan (H = 0.54) (Figure 6).

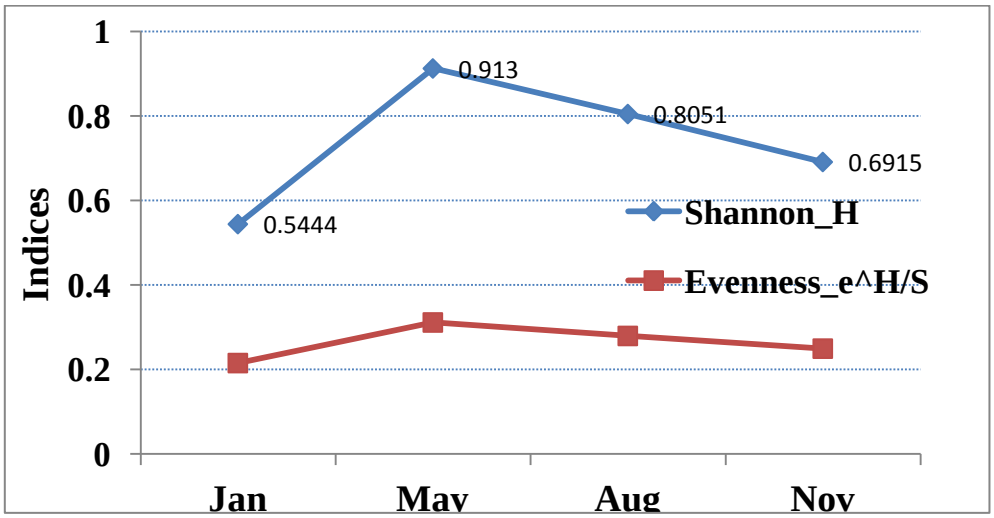

Fig. 6: Seasonal variations of different species diversity indices (Shannon-Weaver diversity and evenness) of zooplankton present in the Hadhramout coast.

It is obvious that *Calanoides carinatus* is the most abundant in the community of the Copepod during the upwelling season in Hadhramout coast; this is in agreement with the nature of its abundance in the Somali and Omani Upwelling areas [34](Stephen *et al*., 1992), as well the findings reveal that this species in great abundance at the stations Bir Ali , Broom and Al Mukalla during the summer season (southwest monsoon), this means that this species is predominant in the Upwelling seasons; and its life cycle here seems to be depend largely on the physical conditions of the coastal Upwelling [35](Madhupratap *et al*., 1992). This is also reflected on the species of the group of Euphausiids, such as *Pseudeuphausia latifrons*, *Euphausia distinguenda*, and *E. diomediae*, which also prevail in the Hadhramout coast partly in the southwestern monsoon, and decreases in the northeastern monsoon. Although it known for the group of Euphausiids their coexistence at higher depths, especially in daylight time, but the fact that the plankton samples taken mostly at the early morning, so the presence in the samples was distinct in terms of quality and quantity, sometimes *E. diomedeae* has been present more in Bear Ali and Broom and was not found of them just a few individuals in the Sharma station. These Euphausiids also present in Red Sea, thought Ponomareva [36](1975) discusses that 10 species of this group known from Red Sea being immigrants from Gulf of Aden.

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The species *C. carinatus* is of great importance in biological configuration of water mass as all, being a subject in a relatively short life to climate impacts which controls the seasonal cycle of upwelling. Angel [37] (1984) was found that it can build a large gathering where there are stable hydrocyclones systems in open offshore upwelling zone. Smith [38](1982) found such qualities for these groups in such deep eddy in the east of the Gulf of Aden and the coast of Oman at the end of upwelling seasons.

Although the marine Cladocera have limited diversity and abundance in most seas [39,40] (Onbe, 1977; Tang *et al*., 1995), but being unique by ways of asexual reproduction and what resulting from, prosperity of their groupings in the marine coasts during certain seasons of the year, being an adequate and typical prey for fishes that feeding on plankton their early stages. Cladocera presence in zooplankton samples of Hadhramout coast was little in terms of diversity and quantities that varied at the sites as they are in the seasons; as appears from the tables 1 and 2, the presence of species of this group of mezozooplankton was a little more in the eastern stations of the coast in most of the seasons; at the same time their abundance is noticeable at the end of the southwest monsoon period and beyond - August and September.

The study reveals that the biomass of zooplankton in the whole Hadhramout coast characterized by high-value, which ranged on average between 113.6 and 214.5 mg / m^3 dry weight with an average of 128.28 mg / m^3 (ranging between 214.5 mg / m^3 of Sharma station in May and 113.6 mg / m^3 for station of Broom, which characterized by low zooplankton indicators during all months). As for spatial distribution of the abundance zooplankton mass has shown heterogeneity clearly between stations (Table 2), the highest value for dry mass reached 222.6 mg / m3 registered in Sharma station, while the minimum value was in Sheher station, reaching 38.5 mg / m3(Fig. 7). As of a statistical standpoint, the mass of zooplankton are subject to significant variation between different stations ($P < 0.05$).

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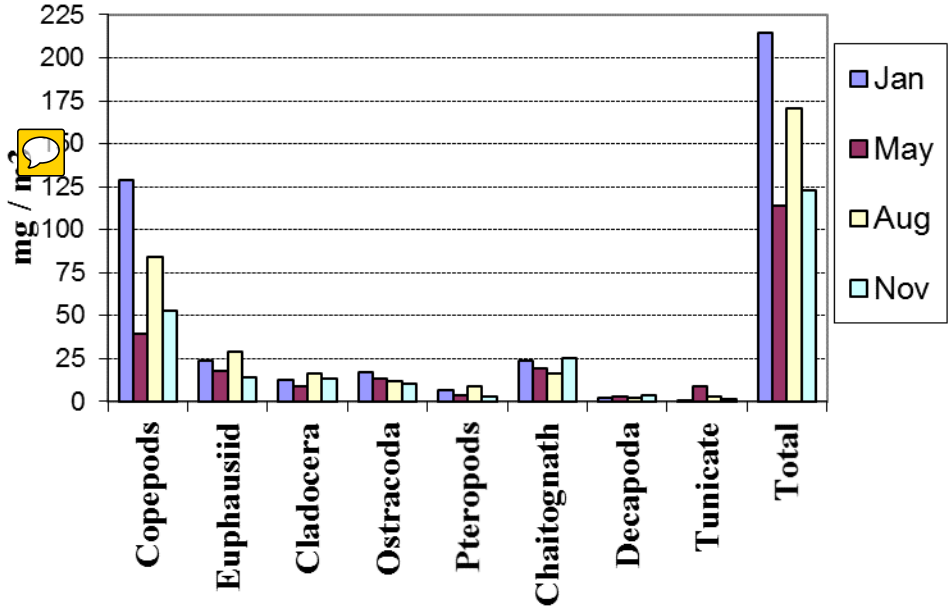

Fig. 7: The quarterly Mean variation of zooplankton groups' abundance in Hadhramout coast

It is obvious that these preliminary results of community of zooplankton of Hadhramout coast not differ significantly from the situation observed in most of the northern Arabian Sea regions [41,42] (Jyothinayagam, 1998; El-Serehy, 1999); but it much more than what recorded in the Indian Ocean mission during southwestern monsoon [43](GLOBEC. 1991). Also, a result of this study characterized by a diagnosis of species combination of Copepods, the traditional coastal and oceanic surface illuminated areas of northwest and east of the Indian Ocean. What was found of them a total of 171 element here is much more than recorded in the inner continental shelf of western India [44](Goswamy *et al*., 2000) and for the Bay of Bengal [45] (Rakhesh *et al*., 2005); but it less than what is found in the Somali eastern coast, the traditional Upwelling area [32](Van Couwelaar, 1997). Although this differences is illustrate distinction of Hadhramout coast by relative bio richness, however, it might due to the differences in zooplankton net meshes that used in the different studies. It was found by Bathafari [18](2003) in a previous study that there are more than 13 taxonomic units of zooplankton in the waters of the northern Gulf of Aden, from which the richest representatives of the copepod represented then by only about 163 species consisting until 69% of zooplankton mass in period of winter northeast monsoon (January). During the summer monsoon (July), the role of the Copepods was largest

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and has reached more than 79% of the total mass. In the transitional period from summer monsoon to winter northeast monsoon (Sept.) for the same period, the role of copepods in composition of zooplankton has not declined but dropped relatively little bit to 58% in the total mass of zooplankton.

There is no appropriate information or data for this coast regarding the zooplankton, as they are for other indicators, nevertheless, the present results showed that the coast of Hadhramout is rich by zooplankton and includes at least main groups with large food important for most marine organisms as mollusks, crustaceans and fish. Despite the lack of the studies, but that carried of them for the Gulf of Aden found that the zooplankton mass during the autumn intern period (October to January) was the highest in the Hadhramout coast, particularly the east of Mukalla, and during August in the west of Mukalla - Ras El Kalb (Mayfa'a Hajar) [46,47](Ali Khan and Hempel, 1974; Druzhini, 1973).

Through the role of this species by its optional feeding on large diatoms and Dinoflagellates, and because these species, as we noted, prevail in mass and quality of phytoplankton of Hadhramout coast in particular and gulf of Aden at all [17](Ali and Bazar, 2016), the observer simply can see the extent of securing and ensuring the food resources and feeding base in primary and secondary production. This is what mentioned by Smith [48](1984) through studying food and primary production relationships of Somali current, where Copepods group dominated within the zooplankton, especially in the Upwelling center and the regions, which fueled by this current.

Fertility of zooplankton apparently follows, in Hadhramout coast, the quarterly monsoonal cycle of the wind and the nutrient-rich, an essential element regulator temporal variation in zooplankton (often Copepods) in coastal conditions [49](Garcia and Lopez, 1989). Although the phytoplankton is a source of nutrition of herbivorous copepod, but we did not find a clear correlation between the concentration of chlorophyll and the abundance of copepod, but there was found a time lag between the phytoplankton bloom and the increase of zooplankton abundance (Figure 8).

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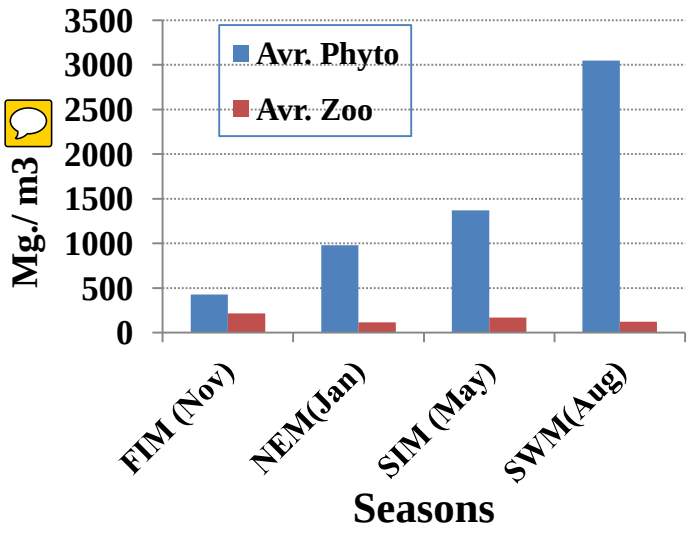

Fig 8: Time lag between the phytoplankton bloom and the increase of zooplankton abundance

The zooplankton plays, along with phytoplankton, in the Arabian coast of the Gulf of Aden, a major role in feeding and food for small pelagic fish, for example, the elements of Euphausidia, Decapoda and Stomatoids (Squilids) occupies about 50% of stomach content of chub mackerel *Scomber japonicus* [18](Badhafary, 2003). Phyto and zooplankton are considered having a special valuable in the food of Scombrid and Carangids fishes [50](Morote *et al*., 2008).

We believe that the high density of zooplankton in the waters of the coast due to the favorable environmental conditions during the year, such as salinity and temperature that ideal for good productivity of the phytoplankton, existing and prevailing in the region [17](Ali and Bazar, 2016).

In this study it had been getting larvae of different crustaceans and fish that formed between 2 and 12% of the zooplankton mass during the study period, even though it not included in the accounts of the quantity of zooplankton, and was isolated according to traditional methods to study them independently of the zooplankton.

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Table 1. Zooplankton species found according to stations: (+++ Abundant (more than 500 cells / m^3), ++ Frequent (more than 150) and + Present (less than 50), - absent.

Groups, genus and the species	BirAli	Broom	Mukalla	Sheher	Sharma
Copepods:2800 ind/ m^3 171 taxa					
Order Calanoida					
Acartia danae	++	+	++	+	+
A. (Acanthacartia) dweepi	+	+	+	+	+
A. (Acanthacartia) tropica	++	++	+	+	++
A. (Acanthacartia) fossae	+	+	+	+	+
A. (Acartia) negligens	++	++	+++	+++	++
A. (Acartiura) clausi	+	+	+	+	+
A. (Acartiura) longiremis	+	+	+	+	+
A. (Odontacartia) centrura	+	-	-	-	-
A. (Odontacartia) erythraea	++	++	+++	+	+++
A. eremeevi	+	+	+	+	+
A. spinicuda Mukalla + beer	+++	++	+++	+	+
Acrocalanus gracilis	++	+++	+	+	+++
Acrocalanus longicornis	+++	+++	++	+	++
Bestiolina arabica	+++	++	+	+	+
Bestiolina similis	+++	++	+	+	+
Calanus finmarchicus	+++	+++	+++	+	++
Calanoides carinatus	+	+	++	+++	+++
Calanoides carinatus dominant	+++	+++	+++	+++	+++
Calanopia minor	++	+++	++	++	+++
Calanopia elliptica	+	+	+	+	++
Calanopia media	++	++	++	++	++
Candacia pachydactyla	+	+	++	++	++
Candacia bispinosa	+	+	++	+	+
Candacia longimana	++	++	++	++	++
C.curta	+++	+++	++	+	++
C.tenuimana very rare (Sharm)	+	+	+	+	-
C. bipinnata very rare (Sharm)	+	+	+	+	-
C.cheirura	+	+	+	+	+
C.discaudata	+	+	+	+	+

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C. tuberculata	+	+	-	-	-
C. armata	+	++	++	++	++
C. samassae very in Bir	+++	++	+	+	+
C. bradyi	++	++	++	++	++
C. catula	++	++	++	++	++
C. truncata	++	++	++	++	++
Calocalanus contractus	++	+++	++	++	+++
Calocalanus elegans	+++	+++	++	++	++
Calocalanus indicus	+++	+++	++	++	++
Calocalanus kristalli	+	+	++	++	++
Calocalanus latus	+++	+++	++	++	++
Calocalanus lomonosovi	++	++	++	+++	+++
Calocalanus longifurca	+	+	++	+++	+++
Calocalanus neptunus	+	+	+	+	+
Calocalanus styliremis	+	+	+	+	+
Calocalanus minor	+	+	+	-	-
Calocalanus minutus	-	-	-	+	+
Calocalanus namibiensis	+	-	-	-	-
Calocalanus nanus	+	+	-	-	-
Calocalanus pavo	++	++	+	+++	++
Calocalanus pavoninus	+	+	+	-	-
Calocalanus plumulosus	+	+	+	-	-
Clausocalanus minor	++	+++	++	+++	+++
Clausocalanus arcuicornis	++	++	++	++	++
Clausocalanus furcatus	+++	+++	++	++	++
Canthocalanus pauper	+	+	++	++	++
Cosmocalanus darwini	+	+	+	+	+
Cosmocalanus indica	++	+++	++	++	++
Centropages calaninus	+++	+++	++	++	+++
Centropages dorsispinatus	++	+++	+	+	++
Centropages elongatus	+++	+++	+	+	+
Centropages furcatus	+	+	+	+	++
Centropages kroeyeri	+	+	+	+	+
Centropages gracilis	++	+++	+++	++	+
Centropages orsinii	+	+	-	-	-
Centropages violaceus	-	-	+	+	-
Cymbasoma tropicum	+	+	+	+	+
Cymbasoma spp	+	+	+	-	-
Eucalanus crassus	++	+++	+++	+++	++
Eucalanus subtenuis	++	+	+	+	++
Eucalanus attenuatus	+	+	+	+	+
Eucalanus elongatus	+++	++	++	++	++
Euchaeta marina	++	+	++	+++	+++
Euchaeta rimana	+	+	+	-	-
Gaussia swelli	+	+	+	+	+
Heterostylites longicornis	+	+	+	+	+
Labidocera minuta	+	+	+	+	+
Labidocera acuta	+	+	+	+	+
Lucicutia grandis	+	+	+	+	+
Lucicutia parva	+	+	+	+	+
Macrosetella gracilis	++	+++	++	+	++
Microsetella rosea	+++	+++	++	++	+
Mesocalanus tenuicornis	+	++	+	+	+
Nannocalanus minor 1078/L	++	+++	+++	++	++

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Neocalanus grasilis 10 -20cold water	++	+	+	++	+++
Paracandacia simplex	+++	+++	++	+	+
Paracandacia truncata	++	+	+	+++	++
Paracandacia sp.	+	+	+	+	+
Paracalanus aculeatus	++	++	+	++	+++
Paracalanus aculeatus minor	+	+	++	+++	+++
Paracalanus arabiensis	+++	++	+	+	+++
Paracalanus denudatus	+	++	+	++	++
Paracalanus indicus	+++	+++	++	++	+++
Paracalanus nanus	+	++	+	+	+
Paracalanus parvus	+++	+++	++	++	++
Paracalanus tropicus	++	+	+	+	++
Paracalanus sp.	++	+	+	++	++
Paracartia latisetosa	+	+	+	+	+
Paracartia dubia	++	++	-	-	+
Parvocalanus dubia	+	+	+	++	++
Phaenna spinifera	+	+	+	+	+
Pleuromamma abdominalis	+	+	+	+	+
Pleuromamma indica	+	+	++	++	++
Pontella fera	-	-	-	+	+
Pontella investigatoris	++	++	++	+	+
Pontella securifer	+	+	+	+	+
Pontella karachiensis	+	+	+	+	+
Rhincalanus nasutus	++	++	++	+	+++
Rhincalanus cornutus	-	+	+	+	+
Sapphirina gastrica	+	-	-	-	-
Sapphirina maculosa	+	-	-	-	-
Sapphirina scarlata	+	+	-	-	-
Sapphirina vorax	+	-	-	-	-
Scolecithrix bradyi	++	+	-	-	-
Scolecithrix longipes	++	+	+	+	+
Scolecithricella tropica	+	+	+	+	+
Scolecithricella orientalis	+	+	+	++	++
Scolecithricella minor	+	+	-	-	+
Subeucalanus crassus	++	+	-	-	-
Subeucalanus pileatus	+	+	+	-	-
Subeucalanus subcrassus	+	+	-	-	-
Subeucalanus subtenuis	+	+	-	-	-
Undinula vulgaris	++	+	+	++	+++
Xanthocalanus gigas	+	+	+	+	+
Ord. Cyclopoida					
Acanthocyclops vernalis	++	++	++	++	++
Oithona attenuata	-	-	+	+	+
Oithona brevicornis	++	++	+	+	+
Oithona decipiens	++	+	+	+	+
Oithona fallax	+	+	+	+	+
Oithona nana	+	+	+	+	+
Oithona pacifica	++	++	+	+	+
Oithona plumifera	+	+	+	+	+
Oithona pulla	+	+	+	+	+
Oithona robusta	++	+	+	+	+
Oithona setigera	+	+	+	+	+
Oithona simplex	+	-	-	+	+

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Oithona tenuis	+	+	+	-	-
Oithona vivida	-	-	-	+	+
Oithona spinirostris	+	+	+	+	+
Triconia conifera	+	+	-	-	-
Triconia rufa	-	-	-	-	+
Triconia umerus	-	-	+	+	+
Triconia parasimilis	-	-	+	+	+
Ord. Poecilostomatoida					
Amallothrix indica	+	+	+	++	++
Corycaeus (Agetus) limbatus	+	+	+	+	+
Corycaeus typicus	++	+++	+	+	+
Corycaeus speciosus	++	++	++	+	++
Corycaeus asiaticus	+	+	+	+	+
Corycaeus erythraeus	+	+	+	++	++
Corycaeus agilis	+++	+++	+	++	++
Corycaeus latus	+	+	+	+	+
Corycaeus ovalis	+	+	-	-	-
Corycaeus pacificus	+	-	-	-	-
Corycaeus pumilus	+	+	++	++	++
Corycaeus sp.	+	+	+	-	-
Copilia quadrata	-	-	-	+	+
Copilia lata	-	-	-	-	+
Copilia spp.	+	+	+	+	+
Oncaea venella	++	+++	++	++	++
Oncaea mediterranea	++	++	++	+	+
Oncaea paraclevei	+	+	+	+	+
Oncaea ivlevi	+	+	++	++	++
Oncaea vodjanitskii	+	+	+	+	+
Oncaea venusta	+	+	+	-	-
Oncaea media	++	+++	++	+	+
Oncaea longipes	++	++	++	+	+
Oncaea ovalis	++	++	+	+	+
Oncaea cristata	+	+	+	+	+
Oncaea clevei	+	+	+	+	+
Oncaea brodskii	+	+	+	++	++
Oncaea similis	++	++	++	++	++
Oncaea subtilis	+	+	+	+	+
Oncaea tenella	+	+	-	-	-
Oncaea zernovi	+	+	+	++	++
Oncaea bispinosa	+	+	+	+	+
Spinoncaea ivlevi	-	-	-	+	+
Temora stylifera	+	+	+	+	+
Ord. Siphonostomatoida					
Caligus diaphanus	++	++	+++	+	+
Lernaeocera branchialis	+	+	+	+	+
Lernaeenicus hemirhamphi	+	+	++	+++	++
Ord. Harpacticoida					
Clytemnestra scutellata	+	+	+	+	+
Macrosetella gracilis	+	+	+	+++	++
Copepod nauplius	+++	+++	++	++	++
Copepodid stage	++	++	++	++	++
Euphausiid 14 taxa					
Bentheuphausia amblyops	+	+	+	+	+
Euphausia brevis	+	+	+	+	+

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E. sibogae	+	+	+	+	+
E. sibogae Calyptopis C2	+	+	+	+	+
E. sibogae Furcilia 2					
E. sanzoi	+	+	+	+	+
Euphausia diomedia SW abundant	++	++	++	+	++
Euphausia distingüenda?? 96/m3 SW abundant	+	+	+	+	+
E. paragibba	+	+	+	+	+
E. pseudogibba	+	+	+	+	+
E. mutica Calyptopis/ Furcilia F1	+	+	+	+	+
Nematoscelis tenella Larva F2					
Pseudeuphausia latifrons 12/m3 SW abundant	+	+	+	+	++
Stylocheiron abbreviatum Furcilia	++	+	+	+	+
Stylocheiron armatum	+	+	+	+	+
S. carinatum	+	+	+	+	+
Cladocera: 42 ind/ m3 4 taxa					
Evadna nordmanni	+	+	+	+++	+++
E. tergestina	+	+	+	++	++
Penilia avirostris	+	+	+	+	++
Podon intermedius	+	-	-	+	+
Ostracoda: 25 ind/ m3 3 taxa					
Conchoecia sp.	+	+	+	+	+
Cypridina sp.	+	+	+	+	+
Euconchoecia spp.	+	+	+	+	+
Pteropods: 14ind/ m3					
Creseis acicula	+	+	+	+	+
Cavolinia globulosa	-	-	-	+	+
Limacina inflata	+	+	+	+	+
Chaitognatha: 20 taxa					
Eukrohnia sp.	+++	+++	++	++	++
Krohnitta pacifica	++	++	+	+	+
Krohnitta balagopali	+	+	+	+	+
Sagitta adenensis	++	++	++	+	++
Sagitta bipunctata	+	+	+	+	+
Sagitta erythraea	+	+	++	++	++
Sagitta enflata	+	+	+	+	+
Sagitta ferox	+	+	+	+	+
Sagitta hexaptera	++	++	++	+	+
Sagitta lucida	+	+	+	+	+
Sagitta madhupratapi	+	+	+	++	++
Sagitta nagae	+	+	+	+	+
Sagitta neglecta	++	++	++	+	+
Sagitta regularis	++	++	+	+	+
Sagitta robusta	+	+	+	+	+
Sagitta serratodentata	++	+++	+	+	+
Sagitta sibogae	++	++	+++	+++	+++
Sagitta setosa	++	++	++	++	++
Pterosagitta draco	+	+	+	+	+
Pterokrohnia arabica	++	++	++	++	++
Decapoda: 3 ind/m^3 1 taxa					
Lucifer spp.	++	++	++	+++	++
larvae of sergestids	++	++	++	++	++
Penaed nauplius	+++	+++	+	+	++

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Megalopa of crab	+++	++	+++	+++	+++
Decapod zoea	+++	+++	+++	+++	+++
Tunicate: 125 ind/m^3 10 taxa					
Cyclosalpa affinis	+	+	+	+	++
Fritllaria borealis f. sargassi	-	-	-	+	+
Fritllaria formica f. digitata	-	-	-	+	+
Fritllaria tenella	-	-	-	+	+
Oikopleura albicans	+	+	+	-	-
Oikopleura parva	+	+	-	-	-
Oikopleura rufescens	+	+	-	-	-
Stegosoma magnum	-	-	+	+	++
Salpa fusiformis	+	+	+	+	+
Thalia democratica 386/m^3 upwelling time dominant	+	+++	++	+	+
Bivalve viliger	+++	+++	++	++	++
Gastropod veliger	+++	+++	+	+	++
Auricularia - larva of a sea cucumber	+++	+++	+	+	++
TOTAL spp. 226					

Table 2. The numerical abundance and dry weight of the main groups of zooplankton in Hadhramout coast according to the seasons

Groups	January 2010		May 2010		August 2010		Nov. 2010	
	Ind/m^3	mg/m^3	Ind/m^3	mg/m^3	Ind/m^3	mg/m^3	Ind/m^3	mg/m^3
Copepods	3125	128.5	1071	39.7	2660	83.8	1643	52.4
Euphausiids	248	24	185	17.5	429	29.2	170	13.8
Cladocera	19	12.3	11	8.6	29	16.4	12	13.5
Ostracoda	25	17	9	13.3	16	11.6	9	10.2
Pteropods	12	6.6	10	3.7	9	8.5	5	2.8
Chaitognatha	57	23.6	56	19.2	65	16	60	25
Decapoda	1	1.8	3	2.6	3	2.2	1	3.6
Tunicate	51	0.7	60	09	177	2.8	56	**1.5**
Total	**3538**	**214.5**	**1405**	**113.6**	**3388**	**170.5**	**1957**	**122.8**