

First report on zooplankton abundance and composition in 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 a significant 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 considerable number of fishes, crustaceans and mollusks of commercial interest. Hadhramout coast characterized by riches of primary productivity of 685 mg C / m² / day, secondary productivity ranging between 14 - 68 mg C / m² / day [1,2], 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*

35 and yellowfin tuna *Thunnus albacares*. Latter supports coastal surface and pelagic catches of
36 the Gulf of Aden for more than 30000 tons of fish [3,4].

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

40 East of the Gulf of Aden includes the Hadhramout coast considered one of the most global
41 ocean parts by productivity; its average productivity for more than a hundred kilometers from the
42 beach is more than the productivity of other Upwelling areas, like Peru Coast and West Africa
43 [5,6], higher productivity have been observed in this region (more than 1000 mg / m³) around
44 August, at the end of the south-western monsoon; while less productivity (about 400 mg / m³) in
45 January through the northeastern monsoon [7,8].

46 The Gulf of Aden and its Hadhramout coast are located directly under the influence of the sub
47 Somali sea current approaches, in summer (upwelling phenomenon), mainly through corridors
48 of Socotra Archipelago which are rich in phytoplankton [9]. This coastal upwelling brings
49 nutrients to the surface, where the light, creating a fuel to photosynthesis and phytoplankton
50 growth feed to zooplankton and consequently to fishes.

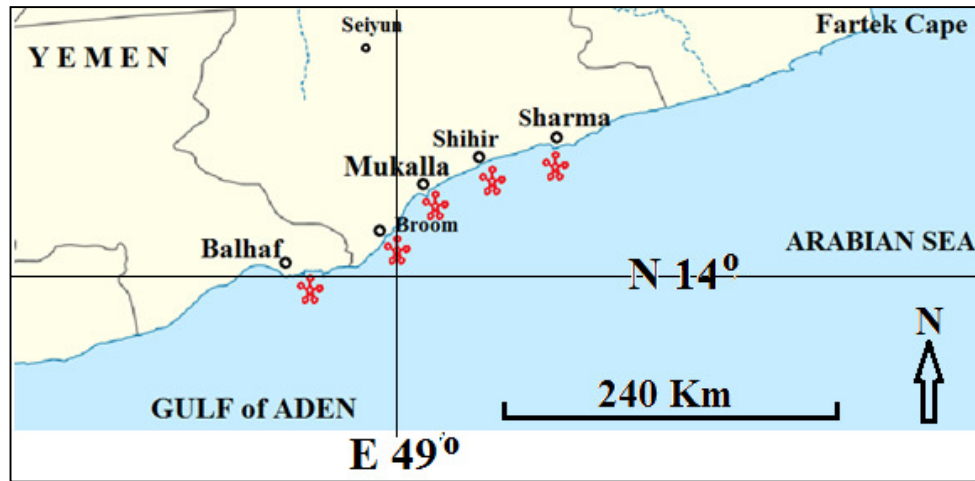
51 It is not new talking about the environmental importance of zooplankton in the marine water
52 bodies, particularly the most abundant component, the Copepods, in pelagic food webs of
53 Global Ocean. These organisms are often considered distinctive component of the zooplankton
54 community in a lot of marine conditions and play a key role in converting nutrients and energy
55 through the trophic levels [10,11]. Quantitative studies of the dynamics of a nearshore
56 zooplankton community along the coast of Gulf of Aden are still fragmentary [12,13,14]. In
57 contrast, the taxonomy and seasonal standing stock of the phytoplankton community in the
58 coastal waters of the Gulf of Aden and Hadhramout area has been investigated but occasionally
59 [15,16,17].

60 There is a big scarcity of knowledge about the spatial and temporal dynamics of zooplankton in
61 the northern coast of the Gulf of Aden, in particular the coast of Hadhramout. In addition there
62 is no information on the zooplankton productivity and diversity on the coast of Hadhramout.
63 Thus, the main objective of our study is to evaluate the possibility of securing biological
64 productivity to support the sustainability and development of the coastal fisheries.

65

66 2. MATERIAL AND METHODS

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



72

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

76

77 Zooplankton samples were carried out in the five stations representing the coast of Hadhramout
 78 monthly during the 2010 (Figure 1). We used for this purpose zooplankton open nets with mouth
 79 diameter of 50 and 80 cm (0.25 and 0.4 m²) with 200 microns mesh. Sample were taken by
 80 vertically open nets from near the bottom - 5 meters above the bottom and up to the surface,
 81 with filtered water volume calculated through the net, which represents the multiplication the net
 82 opening area by distance, which was to contain (the depth of station). In our study, we chose a
 83 depth of 90 meters per station because fading of thermocline in the coastal area in most months
 84 of the year typically can be found at depths greater than 100 meters [18,19].

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

89 Each sample was divided into two parts and after rinsing the splitting apparatus, one half was
 90 returned to the original sample jar, preserved in 100% formalin, and stored in the Faculty
 91 concerned laboratory. The remaining half-sample was flushed in running tap water for five
 92 minutes, drained, and poured into a tared, aluminum foil tray. Samples were dried to constant
 93 weight at 56°C for 18 to 24 hours [21]. Newly removed samples were cooled in desiccators for
 94 10 minutes and then weighed to the nearest milligram on the Mettler 3 F16GN balance.

95 Monthly samples of zooplankton were collected early in the morning at 6 – 8 hours; it has been
 96 preserved by adding formalin 4%, the samples have been saved in an icebox for about 2 to 3
 97 hours until reaching to the lab. In the laboratory it has been separated into several
 98 homogeneous parts according to the test program for measuring the mass, a part re-saved in
 99 10% phosphate buffered formalin in sea water for the microscopic study for identifying a
 100 taxonomic belonging. To determining the dry weight, the secondary sample of specified volume
 101 was filtered through filter paper (Whatman GF/C filters, diameter 5.5 cm) to a specified weight
 102 before burning, and wash with the sample with distilled water and then dried under 60 Celsius
 103 for 36-48 hours (till constancy weight) then be calculated weight, and therefore the dry mass of
 104 the Zooplankton was weighted.

105 The Mass (mg Dry wt / m³) is calculated as follows:

106 Biomass (mg/ l) = [zoopl. dry weight (gm) / volume of filtered water (m³)] × 1000,

107 Where the filtered volume of water entering the plankton net, it was calculated as follow:

108 $V = \pi r^2 d$

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

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

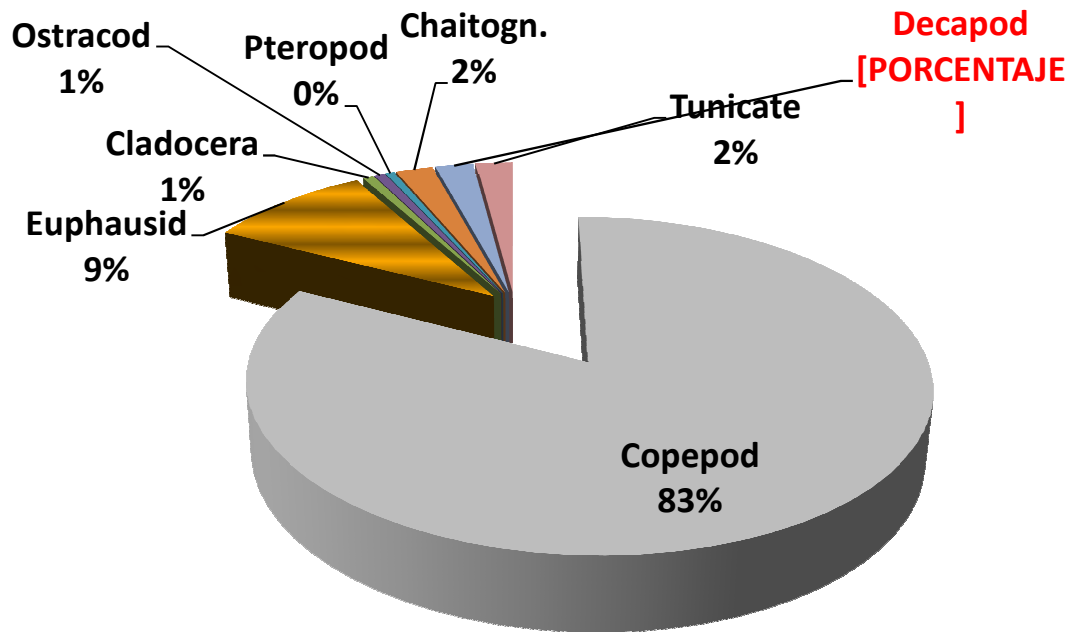
118 planktonic net. For an accurate assessment of the population density we adhere to necessity to
119 do multiple repetitions in the calculation of the organisms in a sub-sample.
120 It has been emphasis in analysis of zooplankton samples, at four-time periods envisaged the
121 inclusion of monsoonal seasons: summer and winter and the in between periods: the months
122 November 2010 represents the period between the summer and winter monsoons, January
123 2010 represented the winter monsoon and May represents a post-winter monsoon and Prior
124 Summer monsoon and August 2010 as representative of the top of Summer monsoon.
125 In all stages of the quantitative and qualitative methods of samples collection and
126 analysis of zooplankton, we follow and guided with what stated in the relevant
127 references, each according to the depth of analysis [24,25]. The taxonomic identification
128 has relied on a lot of special and general keys and guides for zooplankton of the Indian and the
129 Atlantic Oceans, and the Indo-Pacific region [26,27,28]. Despite the lack of studies and
130 references for larval stages of fish and crustaceans in the Gulf of Aden, but it possible to adopt
131 some of which belong to other areas of the Indian Ocean and the Indian Pacific region,
132 including: [29,30].
133 The species richness, Shannon-Weaver Index H' and evenness J' as well as the Bray-Curtis
134 Similarity Index were computed using the multivariate ecological software packages PRIMER
135 program v.6.

136

137 3. RESULTS AND DISCUSSION

138 In this study it was possible to diagnose and counted 226 species of zooplankton which
139 distributed mainly within a basic eight groups; the most common among them were a
140 Copepods, in which prevailed the species belonging to order Calanoida, particularly species of
141 *Acartia*, *Calocalanus* and *Eucalanus* genders. The second order is Poecilostomatoida, which
142 characterized by abundance of species of genus Oncaea. Table (1) shows a picture of the
143 numerical abundance in Hadhramout coast. As it is shown in the table, the 171 species of the
144 copepods are belonging to 20 genera and several families. This kind of numerical abundance of
145 the copepod was recorded in many studies to some areas of the Indian Ocean [31,32,13,33].
146 From the results, it is seen that the most widespread and abundant in Hadhramout coast
147 represent a group of Copepods, which accounted as average of more than 83%, followed by

148 groups Euphausiids that formed 9%; Chaetognath, Decapods and Tunicate formed by 2% each
 149 (Fig. 2).



150
 151 **Fig. 2: Relative abundance (%) of different zooplankton groups in Hadhramout coast**
 152

153 The Cyclopods were represented by *Oithona* spp. genus. Decapod zoeas were observed at
 154 winter monsoon intraseason (March-April) as much as 11% represented, principally, by the
 155 families Portunidae, and Xanthidae. The Chaetognatha group was found throughout the year,
 156 mainly represented by the genus *Sagitta* spp. through the end of winter monsoon and the
 157 Intermonsoon season beyond. Fish eggs and larvae found during the spring and summer
 158 months and autumn with higher density during the spring and early summer monsoon.

159 The abundance of zooplankton was show in Table 1 and Fig. 3. Copepods group was
 160 the most abundant, principally in Bir Ali and Sheher stations. Zoea and megalops of
 161 the true craps (*Brachyura*) were also spread out with distinction at Sheher and Sharma
 162 stations, while the larvae of mollusks have prevailed in the stations of Bir Ali and Sheher
 163 compared to other stations. All coastal stations are equal by relative abundance of the fish
 164 larvae. However, Sheher and Sharma stations were distinguished in terms of the larvae of
 165 family Scombridae and Carangidae during August and September.

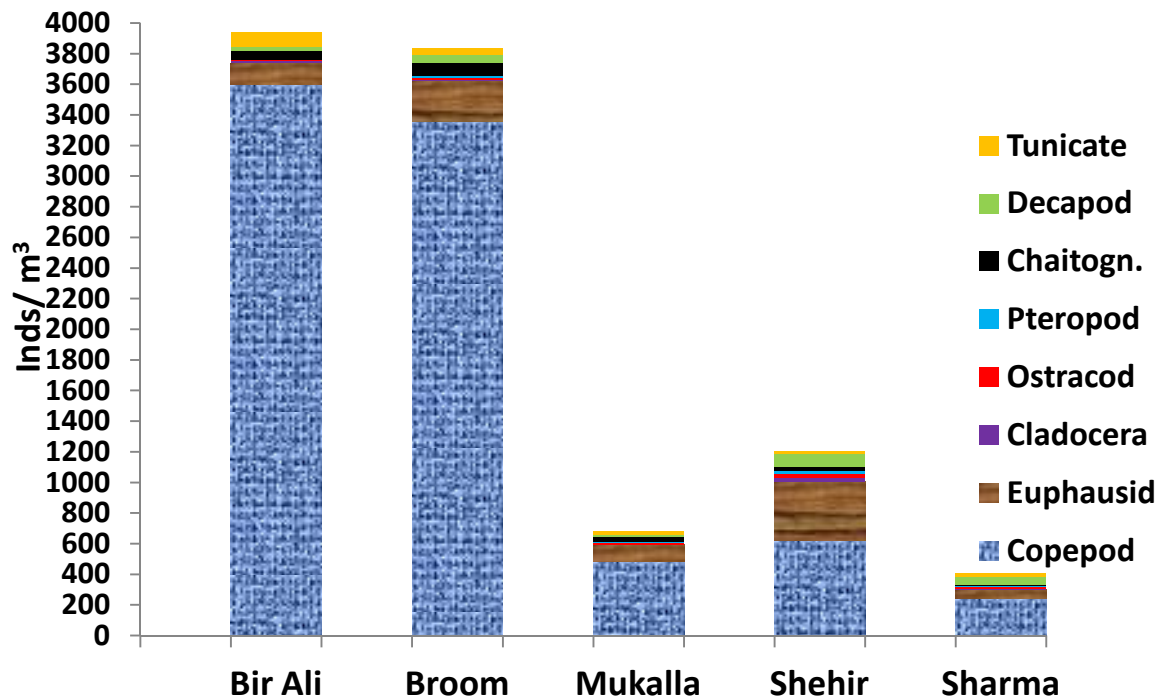


Fig. 3: Zooplankton density and the contribution of the Copepods related to the other groups, in the Hadhramout coast stations.

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; 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) and figure 3.

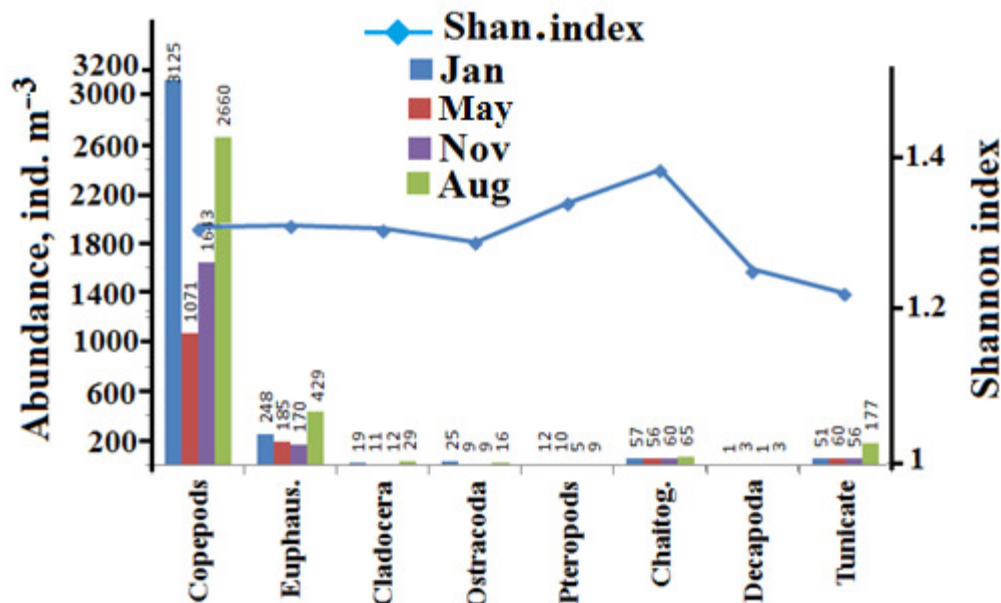


Fig. 4: Relative abundance of zooplankton groups and diversity profile according to seasons in Hadhramout coast.

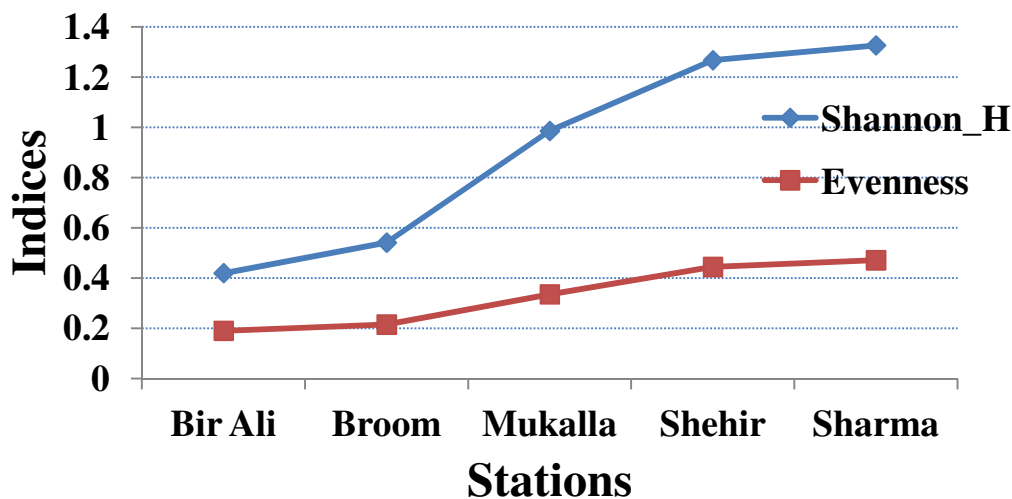
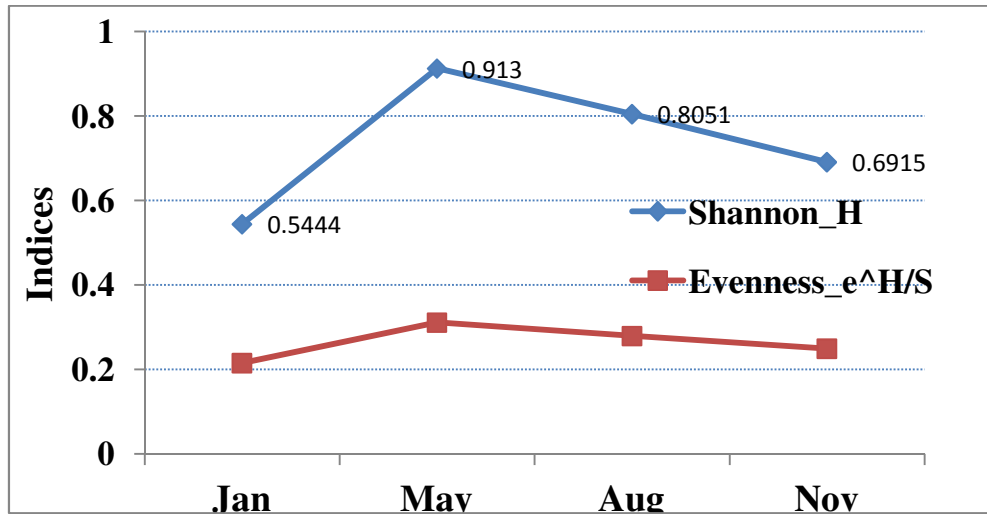


Fig. 5: Variations of different species diversity indices (Shannon-Weaver diversity and evenness) of zooplankton present in the Hadhramout coast stations.

Even though, 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. Shehir 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 diversity

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



197
 198
 199 **Fig. 6: Seasonal variations of different species diversity indices (Shannon-Weaver**
 200 **diversity and evenness) of zooplankton present in the Hadhramout coast.**
 201

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

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

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

233 The study reveals that the biomass of zooplankton in the whole Hadhramout coast
 234 characterized by high-value, which ranged on average between 113.6 and 214.5 mg / m³ dry
 235 weight with an average of 128.28 mg / m³ (ranging between 214.5 mg / m³ of Sharma station in
 236 May and 113.6 mg / m³ for station of Broom, which characterized by low zooplankton indicators
 237 during all months). As for spatial distribution of the abundance zooplankton mass has shown
 238 heterogeneity clearly between stations (Table 2), the highest value for dry mass reached 222.6
 239 mg / m³ registered in Sharma station, while the minimum value was in Sheher station, reaching
 240 38.5 mg / m³ (Fig. 7). As of a statistical standpoint, the mass of zooplankton is subject to
 241 significant variation between different stations ($p < 0.05$).

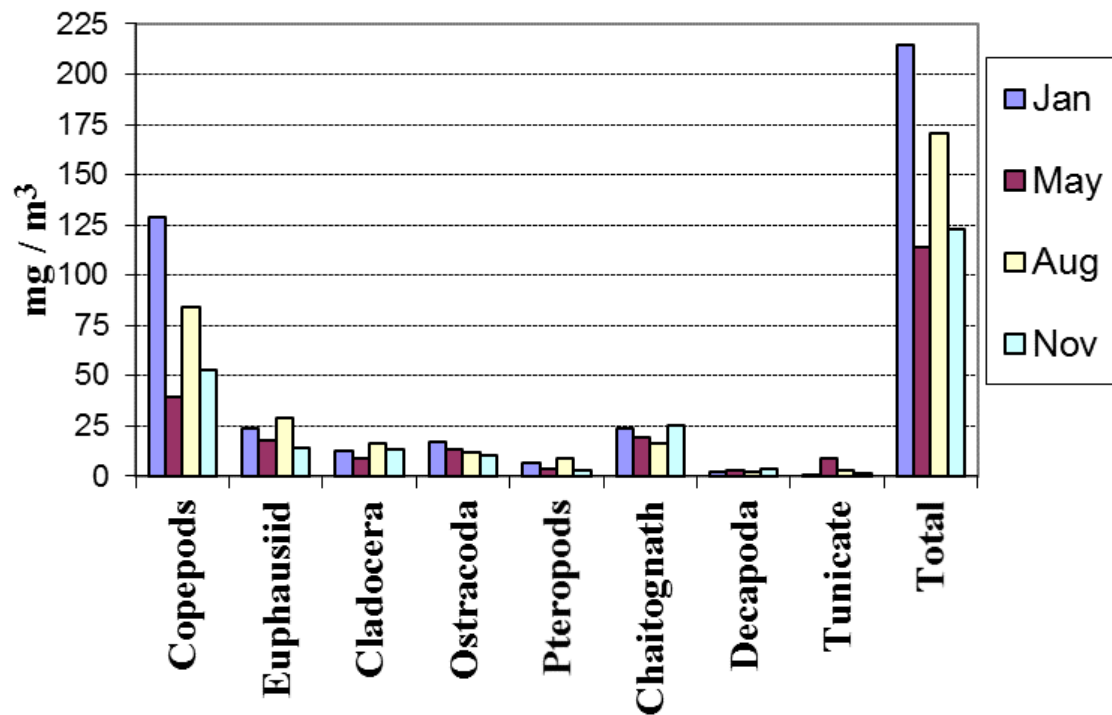


Fig. 7: The quarterly Mean variation of zooplankton groups' abundance in Hadhramout coast

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]; but it much more than what recorded in the Indian Ocean mission during southwestern monsoon [43]. 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 elements here is much more than recorded in the inner continental shelf of western India [44] and for the Bay of Bengal [45]; but it less than what is found in the Somali eastern coast, the traditional Upwelling area [32]. Although, this difference 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] 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 and has reached more than 79% of the total mass. In the transitional period from summer monsoon to winter northeast monsoon (Sept.)

262 for the same period, the role of copepods in composition of zooplankton has not declined but
263 dropped relatively little bit to 58% in the total mass of zooplankton.

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

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

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

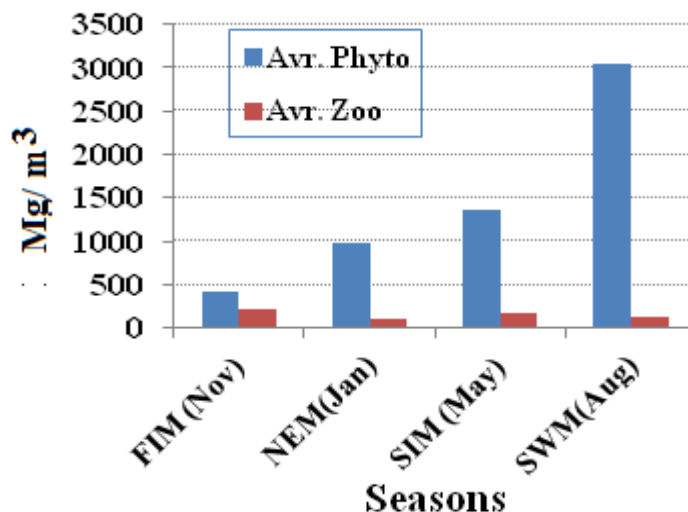


Fig 8: Time lag between the phytoplankton bloom and the increase of zooplankton abundance

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

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].

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.

CONCLUSION

This study is the first report on distribution of zooplankton from the coastal waters of Gulf of Aden, Yemen. In the present study, a total of 226 species belonging to eight taxa such as copepod, medusae, ctenophores, Chaetognaths, Appendicularians, Tunicate, Siphonophores and developmental stages of different taxa was identified. A variation in species composition between stations was recorded. This study indicates that Bir Ali and Broom stations had a

306 higher abundance of zooplankton than that of other stations, and their abundance and
 307 successful diversity is governed by geographical features of locality. It is obvious that
 308 *Calanoides carinatus* is the most abundant in the community of the Copepod during the
 309 upwelling season in Hadhramout coast. The study reveals that the biomass of zooplankton in
 310 the whole Hadhramout coast characterized by relatively high-value.

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443

444

445 **Table 1. Zooplankton species found according to stations:**
446 **(+++ Abundant (more than 500 cells / m³), ++ Frequent (more than 150) and + Present (less than 50), - absent.**

Groups, genus and the species	BirAli	Broom	Mukalla	Sheher	Sharma
Copepods:2800 ind/ m³ 171 taxa					
Order Calanoida					
<i>Acartia danae</i>	++	+	++	+	+
<i>A. (Acanthacartia) dweepi</i>	+	+	+	+	+
<i>A. (Acanthacartia) tropica</i>	++	++	+	+	++
<i>A. (Acanthacartia) fossae</i>	+	+	+	+	+
<i>A. (Acartia) negligens</i>	++	++	+++	+++	++
<i>A. (Acartiura) clausi</i>	+	+	+	+	+
<i>A. (Acartiura) longiremis</i>	+	+	+	+	+
<i>A. (Odontacartia) centrura</i>	+	-	-	-	-
<i>A. (Odontacartia) erythraea</i>	++	++	+++	+	+++

<i>A. eremeevi</i>	+	+	+	+	+
<i>A. spinicuda</i> Mukalla + beer	+++	++	+++	+	+
<i>Acrocalanus gracilis</i>	++	+++	+	+	+++
<i>Acrocalanus longicornis</i>	+++	+++	++	+	++
<i>Bestiolina arabica</i>	+++	++	+	+	+
<i>Bestiolina similis</i>	+++	++	+	+	+
<i>Calanus finmarchicus</i>	+++	+++	+++	+	++
<i>Calanoides carinatus</i>	+	+	++	+++	+++
<i>Calanoides carinatus</i> dominant	+++	+++	+++	+++	+++
<i>Calanopia minor</i>	++	+++	++	++	+++
<i>Calanopia elliptica</i>	+	+	+	+	++
<i>Calanopia media</i>	++	++	++	++	++
<i>Candacia pachydactyla</i>	+	+	++	++	++
<i>Candacia bispinosa</i>	+	+	++	+	+
<i>Candacia longimana</i>	++	++	++	++	++
<i>C. curta</i>	+++	+++	++	+	++
<i>C. tenuimana</i> very rare (Sharm)	+	+	+	+	-
<i>C. bipinnata</i> very rare (Sharm)	+	+	+	+	-
<i>C. cheirura</i>	+	+	+	+	+
<i>C. discaudata</i>	+	+	+	+	+
<i>C. tuberculata</i>	+	+	-	-	-
<i>C. armata</i>	+	++	++	++	++
<i>C. samassae</i> very in Bir	+++	++	+	+	+
<i>C. bradyi</i>	++	++	++	++	++
<i>C. catula</i>	++	++	++	++	++
<i>C. truncata</i>	++	++	++	++	++
<i>Calocalanus contractus</i>	++	+++	++	++	+++
<i>Calocalanus elegans</i>	+++	+++	++	++	++
<i>Calocalanus indicus</i>	+++	+++	++	++	++
<i>Calocalanus kristalli</i>	+	+	++	++	++
<i>Calocalanus latus</i>	+++	+++	++	++	++
<i>Calocalanus lomonosovi</i>	++	++	++	+++	+++
<i>Calocalanus longifurca</i>	+	+	++	+++	+++
<i>Calocalanus neptunus</i>	+	+	+	+	+
<i>Calocalanus styliremis</i>	+	+	+	+	+
<i>Calocalanus minor</i>	+	+	+	-	-
<i>Calocalanus minutus</i>	-	-	-	+	+
<i>Calocalanus namibiensis</i>	+	-	-	-	-
<i>Calocalanus nanus</i>	+	+	-	-	-
<i>Calocalanus pavo</i>	++	++	+	+++	++
<i>Calocalanus pavoninus</i>	+	+	+	-	-
<i>Calocalanus plumulosus</i>	+	+	+	-	-
<i>Clausocalanus minor</i>	++	+++	++	+++	+++
<i>Clausocalanus arcuicornis</i>	++	++	++	++	++
<i>Clausocalanus furcatus</i>	+++	+++	++	++	++
<i>Canthocalanus pauper</i>	+	+	++	++	++
<i>Cosmocalanus darwini</i>	+	+	+	+	+
<i>Cosmocalanus indica</i>	++	+++	++	++	++
<i>Centropages calaninus</i>	+++	+++	++	++	+++
<i>Centropages dorsispinatus</i>	++	+++	+	+	++
<i>Centropages elongatus</i>	+++	+++	+	+	+
<i>Centropages furcatus</i>	+	+	+	+	++
<i>Centropages kroeyeri</i>	+	+	+	+	+
<i>Centropages gracilis</i>	++	+++	+++	++	+

<i>Centropages orsinii</i>	+	+	-	-	-
<i>Centropages violaceus</i>	-	-	+	+	-
<i>Cymbasoma tropicum</i>	+	+	+	+	+
<i>Cymbasoma spp</i>	+	+	+	-	-
<i>Eucalanus crassus</i>	++	+++	+++	+++	++
<i>Eucalanus subtenuis</i>	++	+	+	+	++
<i>Eucalanus attenuatus</i>	+	+	+	+	+
<i>Eucalanus elongatus</i>	+++	++	++	++	++
<i>Euchaeta marina</i>	++	+	++	+++	+++
<i>Euchaeta rimana</i>	+	+	+	-	-
<i>Gaussia swelli</i>	+	+	+	+	+
<i>Heterostylites longicornis</i>	+	+	+	+	+
<i>Labidocera minuta</i>	+	+	+	+	+
<i>Labidocera acuta</i>	+	+	+	+	+
<i>Lucicutia grandis</i>	+	+	+	+	+
<i>Lucicutia parva</i>	+	+	+	+	+
<i>Macrosetella gracilis</i>	++	+++	++	+	++
<i>Microsetella rosea</i>	+++	+++	++	++	+
<i>Mesocalanus tenuicornis</i>	+	++	+	+	+
<i>Nannocalanus minor</i> 1078/L	++	+++	+++	++	++
<i>Neocalanus grasilis</i> 10 -20cold water	++	+	+	++	+++
<i>Paracandacia simplex</i>	+++	+++	++	+	+
<i>Paracandacia truncata</i>	++	+	+	+++	++
<i>Paracandacia sp.</i>	+	+	+	+	+
<i>Paracalanus aculeatus</i>	++	++	+	++	+++
<i>Paracalanus aculeatus minor</i>	+	+	++	+++	+++
<i>Paracalanus arabiensis</i>	+++	++	+	+	+++
<i>Paracalanus denudatus</i>	+	++	+	++	++
<i>Paracalanus indicus</i>	+++	+++	++	++	+++
<i>Paracalanus nanus</i>	+	++	+	+	+
<i>Paracalanus parvus</i>	+++	+++	++	++	++
<i>Paracalanus tropicus</i>	++	+	+	+	++
<i>Paracalanus sp.</i>	++	+	+	++	++
<i>Paracartia latisetosa</i>	+	+	+	+	+
<i>Paracartia dubia</i>	++	++	-	-	+
<i>Parvocalanus dubia</i>	+	+	+	++	++
<i>Phaenna spinifera</i>	+	+	+	+	+
<i>Pleuromamma abdominalis</i>	+	+	+	+	+
<i>Pleuromamma indica</i>	+	+	++	++	++
<i>Pontella fera</i>	-	-	-	+	+
<i>Pontella investigatoris</i>	++	++	++	+	+
<i>Pontella securifer</i>	+	+	+	+	+
<i>Pontella karachiensis</i>	+	+	+	+	+
<i>Rhincalanus nasutus</i>	++	++	++	+	+++
<i>Rhincalanus cornutus</i>	-	+	+	+	+
<i>Sapphirina gastrica</i>	+	-	-	-	-
<i>Sapphirina maculosa</i>	+	-	-	-	-
<i>Sapphirina scarlata</i>	+	+	-	-	-
<i>Sapphirina vorax</i>	+	-	-	-	-
<i>Scolecithrix bradyi</i>	++	+	-	-	-
<i>Scolecithrix longipes</i>	++	+	+	+	+
<i>Scolecithricella tropica</i>	+	+	+	+	+
<i>Scolecithricella orientalis</i>	+	+	+	++	++

<i>Scolecithricella minor</i>	+	+	-	-	+
<i>Subeucalanus crassus</i>	++	+	-	-	-
<i>Subeucalanus pileatus</i>	+	+	+	-	-
<i>Subeucalanus subcrassus</i>	+	+	-	-	-
<i>Subeucalanus subtenuis</i>	+	+	-	-	-
<i>Undinula vulgaris</i>	++	+	+	++	+++
<i>Xanthocalanus gigas</i>	+	+	+	+	+
Ord. Cyclopoida					
<i>Acanthocyclops vernalis</i>	++	++	++	++	++
<i>Oithona attenuata</i>	-	-	+	+	+
<i>Oithona brevicornis</i>	++	++	+	+	+
<i>Oithona decipiens</i>	++	+	+	+	+
<i>Oithona fallax</i>	+	+	+	+	+
<i>Oithona nana</i>	+	+	+	+	+
<i>Oithona pacifica</i>	++	++	+	+	+
<i>Oithona plumifera</i>	+	+	+	+	+
<i>Oithona pulla</i>	+	+	+	+	+
<i>Oithona robusta</i>	++	+	+	+	+
<i>Oithona setigera</i>	+	+	+	+	+
<i>Oithona simplex</i>	+	-	-	+	+
<i>Oithona tenuis</i>	+	+	+	-	-
<i>Oithona vivida</i>	-	-	-	+	+
<i>Oithona spinirostris</i>	+	+	+	+	+
<i>Triconia conifera</i>	+	+	-	-	-
<i>Triconia rufa</i>	-	-	-	-	+
<i>Triconia umerus</i>	-	-	+	+	+
<i>Triconia parasimilis</i>	-	-	+	+	+
Ord. Poecilostomatoida					
<i>Amalothrix indica</i>	+	+	+	++	++
<i>Corycaeus (Agetus) limbatus</i>	+	+	+	+	+
<i>Corycaeus typicus</i>	++	+++	+	+	+
<i>Corycaeus speciosus</i>	++	++	++	+	++
<i>Corycaeus asiaticus</i>	+	+	+	+	+
<i>Corycaeus erythraeus</i>	+	+	+	++	++
<i>Corycaeus agilis</i>	+++	+++	+	++	++
<i>Corycaeus latus</i>	+	+	+	+	+
<i>Corycaeus ovalis</i>	+	+	-	-	-
<i>Corycaeus pacificus</i>	+	-	-	-	-
<i>Corycaeus pumilus</i>	+	+	++	++	++
<i>Corycaeus sp.</i>	+	+	+	-	-
<i>Copilia quadrata</i>	-	-	-	+	+
<i>Copilia lata</i>	-	-	-	-	+
<i>Copilia spp.</i>	+	+	+	+	+
<i>Oncaea venella</i>	++	+++	++	++	++
<i>Oncaea mediterranea</i>	++	++	++	+	+
<i>Oncaea paraclevei</i>	+	+	+	+	+
<i>Oncaea ivlevi</i>	+	+	++	++	++
<i>Oncaea vodjanitskii</i>	+	+	+	+	+
<i>Oncaea venusta</i>	+	+	+	-	-
<i>Oncaea media</i>	++	+++	++	+	+
<i>Oncaea longipes</i>	++	++	++	+	+
<i>Oncaea ovalis</i>	++	++	+	+	+
<i>Oncaea cristata</i>	+	+	+	+	+
<i>Oncaea clevei</i>	+	+	+	+	+

<i>Oncaea brodskii</i>	+	+	+	++	++
<i>Oncaea similis</i>	++	++	++	++	++
<i>Oncaea subtilis</i>	+	+	+	+	+
<i>Oncaea tenella</i>	+	+	-	-	-
<i>Oncaea zernovi</i>	+	+	+	++	++
<i>Oncaea bispinosa</i>	+	+	+	+	+
<i>Spinoncaea ivlevi</i>	-	-	-	+	+
<i>Temora stylifera</i>	+	+	+	+	+
Ord. Siphonostomatoida					
<i>Caligus diaphanus</i>	++	++	+++	+	+
<i>Lernaeocera branchialis</i>	+	+	+	+	+
<i>Lernaeenicus hemirhamphi</i>	+	+	++	+++	++
Ord. Harpacticoida					
<i>Clytemnestra scutellata</i>	+	+	+	+	+
<i>Macrosetella gracilis</i>	+	+	+	+++	++
<i>Copepod nauplius</i>	+++	+++	++	++	++
<i>Copepodids stage</i>	++	++	++	++	++
Ord. Euphausiacea: 14 taxa					
<i>Bentheuphausia amblyops</i>	+	+	+	+	+
<i>Euphausia brevis</i>	+	+	+	+	+
<i>E. sibogae</i>	+	+	+	+	+
<i>E. sibogae Calyptopsis C2</i>	+	+	+	+	+
<i>E. sibogae Furcilia 2</i>					
<i>E. sanzoi</i>	+	+	+	+	+
<i>Euphausia diomedea</i> SW abundant	++	++	++	+	++
<i>Euphausia distinguenda</i> ?? 96/m3 SW abundant	+	+	+	+	+
<i>E. paragibba</i>	+	+	+	+	+
<i>E. pseudogibba</i>	+	+	+	+	+
<i>E. mutica Calyptopsis/ Furcilia F1</i>	+	+	+	+	+
<i>Nematoscelis tenella</i> Larva F2					
<i>Pseudeuphausia latifrons</i> 12/m3 SW abundant	+	+	+	+	++
<i>Stylocheiron abbreviatum</i> Furcilia	++	+	+	+	+
<i>Stylocheiron armatum</i>	+	+	+	+	+
<i>S. carinatum</i>	+	+	+	+	+
Ord. Cladocera: 42 ind/ m3 4 taxa					
<i>Evadna nordmanni</i>	+	+	+	+++	+++
<i>E. tergestina</i>	+	+	+	++	++
<i>Penilia avirostris</i>	+	+	+	+	++
<i>Podon intermedius</i>	+	-	-	+	+
Ord. Ostracoda: 25 ind/ m3 3 taxa					
<i>Conchoecia sp.</i>	+	+	+	+	+
<i>Cypridina sp.</i>	+	+	+	+	+
<i>Euconchoecia spp.</i>	+	+	+	+	+
Ord. Pteropods: 14ind/ m3					
<i>Creseis acicula</i>	+	+	+	+	+
<i>Cavolinia globulosa</i>	-	-	-	+	+
<i>Limacina inflata</i>	+	+	+	+	+
Ord. Chaitognatha: 20 taxa					
<i>Eukrohnna sp.</i>	+++	+++	++	++	++
<i>Krohnitta pacifica</i>	++	++	+	+	+

<i>Krohnitta balagopali</i>	+	+	+	+	+
<i>Sagitta adenensis</i>	++	++	++	+	++
<i>Sagitta bipunctata</i>	+	+	+	+	+
<i>Sagitta erythraea</i>	+	+	++	++	++
<i>Sagitta enflata</i>	+	+	+	+	+
<i>Sagitta ferox</i>	+	+	+	+	+
<i>Sagitta hexaptera</i>	++	++	++	+	+
<i>Sagitta lucida</i>	+	+	+	+	+
<i>Sagitta madhupratapi</i>	+	+	+	++	++
<i>Sagitta nagae</i>	+	+	+	+	+
<i>Sagitta neglecta</i>	++	++	++	+	+
<i>Sagitta regularis</i>	++	++	+	+	+
<i>Sagitta robusta</i>	+	+	+	+	+
<i>Sagitta serratodentata</i>	++	+++	+	+	+
<i>Sagitta sibogae</i>	++	++	+++	+++	+++
<i>Sagitta setosa</i>	++	++	++	++	++
<i>Pterosagitta draco</i>	+	+	+	+	+
<i>Pterokrohnia arabica</i>	++	++	++	++	++
Ord. Decapoda: 3 ind/m³ 1 taxa					
<i>Lucifer spp.</i>	++	++	++	+++	++
<i>larvae of sergestids</i>	++	++	++	++	++
<i>Penaed nauplius</i>	+++	+++	+	+	++
<i>Megalopa of crab</i>	+++	++	+++	+++	+++
<i>Decapod zoea</i>	+++	+++	+++	+++	+++
Ord. Tunicate: 125 ind/m³ 10 taxa					
<i>Cyclosalpa affinis</i>	+	+	+	+	++
<i>Fritillaria borealis f. sargassi</i>	-	-	-	+	+
<i>Fritillaria formica f. digitata</i>	-	-	-	+	+
<i>Fritillaria tenella</i>	-	-	-	+	+
<i>Oikopleura albicans</i>	+	+	+	-	-
<i>Oikopleura parva</i>	+	+	-	-	-
<i>Oikopleura rufescens</i>	+	+	-	-	-
<i>Stegosoma magnum</i>	-	-	+	+	++
<i>Salpa fusiformis</i>	+	+	+	+	+
<i>Thalia democratica</i> 386/m ³ upwelling time dominant	+	+++	++	+	+
<i>Bivalve veliger</i>	+++	+++	++	++	++
<i>Gastropod veliger</i>	+++	+++	+	+	++
<i>Auricularia</i> - 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

<i>Pteropods</i>	12	6.6	10	3.7	9	8.5	5	2.8
<i>Chaitognatha</i>	57	23.6	56	19.2	65	16	60	25
<i>Decapoda</i>	1	1.8	3	2.6	3	2.2	1	3.6
<i>Tunicate</i>	51	0.7	60	09	177	2.8	56	1.5
Total	3538	214.5	1405	113.6	3388	170.5	1957	122.8

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