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Zooplankton of Oman Coastal Waters

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أنواع العوالق الحيوانية في مياه عمان الساحلية

سيرجي أ بيونتكوفسكي وأصيلة المعولي وورد المنى المنذرية وخالد الهاشمي و إلينا بوبوفا

الخلاصة: قد تم جمع عينات من العوالق الحيوانية خلال الفترة من 2007 الى 2011 من بندر الخيران (23.51°N, 58.72°E) والذي يعتبر أكبر خليج شبه مغلق في الساحل الجنوبي لبحر عمان بمساحة سطحيه قدرها 4 كم مربع مع متوسط عمق قدره 10 أمتار. تكونت العوالق الحيوانية في الخليج من عدة طوائف أهمها: Copepoda (79%) (7%)Oikopleuriddae , (9%)Cladocera, (Decapoda (~2%) Chaetognatha (3%) , متضمنة الجزء الأكبر من مجموع وفرة العوالق الحيوانية. حوت طائفة copepod (مجدافيات الأرجل) على 27 نوعا حيث مثلت ما يقارب 75% من إجمالي وفرتها. لم يكن هناك نمط موسمي واضح للتغيرات في وفرة مجدافيات الأرجل. بينما كانت مضاعفات الذروات في الهيكل ملحوظة في التغيرات الشهرية على مستوى الجنس و كذلك النوع و وفرته .أن ذروة مجدافيات الأرجل كماً و توقيتاً كان تختلف بشكل ملحوظ خلال سنوات البحث.

كلمات مفتاحية: مجدافيات . العوالق الحيوانية بحر العرب

ABSTRACT: Monthly sampling during daytime was carried out in 2007-2011 at Bandar Al-Khyran (23.51°N, 58.72°E) which is the largest semi-enclosed bay on the southern end of the Sea of Oman with about 4 km^2 in surface area and an average depth of 10 m. Zooplankton were represented by *Copepoda* (79%), *Cladocera* (9%), *Oikopleuriddae* (7%), *Chaetognath*a (3%), and *Decapoda* (~2%) comprising the major part of the total zooplankton abundance. Among copepods, 27 species constituted ~75% of total copepod abundance. Changes of copepod abundance have not had a pronounced seasonal pattern. Instead, a multiple peak structure in monthly fluctuations was observed, on the level of genera as well as the abundance of species. Amplitudes and timing of the copepod peak abundance were markedly different during the studied years.

Keywords: Copepods, zooplankton, the Arabian Sea.

Introduction

The necessity to study zooplankton stems from the important role this group of organisms play in the structure and functioning of Omani coastal ecosystems. On one hand, zooplankton species are the consumers of phytoplankton; that means the consumers of the algal blooms as well. At the early stage of algal bloom development, due to intensive grazing, copepods are able to modify the food web structure and shift the phytoplankton species composition (Tan *et al*., 2004). On the other hand, zooplankton organisms contribute to the food spectrum of pelagic predators. Epipelagic and mesopelagic fish are a marked part of fish-kill incidents reported along the Omani coast (Al-Gheilani *et al*., 2005; Tangaraja *et al.,* 1997).

Coordinated zooplankton studies of the north-western part of Arabian Sea began in the 1970s, during the time of the International Indian Ocean Expedition (Panikkar and Rao, 1973). In the 1990s, a series of research cruises with zooplankton sampling were carried out by the Former Soviet Union expeditions (Banse and Piontkovski, 2006), the Netherlands NIOP program (Baars, 1994), the UK ARABESQUE program (Burkill, 1999), the Pakistani NASSER program (Kidwai and Amjad, 2000), and the International JGOFS program (Smith *et al.,* 1998). These studies dealt predominantly with the oceanic and upwelling regions.

The first extended zooplankton sampling in Omani coastal waters was carried out onboard the R/V "Fridtjof

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Nansen", in March to June 1976 (Anonymous, 1975). Materials of these sampling were analyzed later by K.V. Jayalakshmy (2000), who reported the latitudinal variation in the abundance, diversity, dominance, and zonation of the major groups of zooplankton.

In the Sea of Oman, regular (seasonal) sampling of zooplankton in coastal waters was initiated by the Ministry of Fisheries in 1990 and it continues up to the present time. The materials highlighting these sampling are available in the form of annual reports (Thangaraja 1990, 1991). In these studies featuring coastal waters, zooplankton were analyzed to the level of taxonomic groups (*Chaetognaths, Decapods, Copepods, Ostracods,* and etc.) with no detailed studies on species. The species level is important because within a taxonomic group, species could occupy different ecological niches (being the herbivores, carnivores, or omnivores).

With this regard, our goal was to study the taxonomic diversity of zooplankton in the coastal waters of the Sea of Oman, to evaluate dominant species, and to understand seasonal changes of zooplankton abundance.

Methods

Monthly sampling during daytime was carried out in 2007-2011 at Bandar Al-Khyran (23.51°N, 58.72°E) which is the largest semi-enclosed bay on the southern end of the Sea of Oman, with about 4 km^2 in surface area and an average depth of 10 m. The bay has two inlets and is surrounded by steep rocky hills and cliffs of Permian limestones and shales lined with shallow coral communities.

Zooplankton samples were collected using a Bongo net (mouth surface area: 0.125 m^2), with a 150 µm mesh size sieve equipped with a "Hydrobios" digital flowmeter. The net was towed obliquely at a speed of one knot from near the bottom to the surface.

Samples were transferred to 0.5L bottles and preserved in 5% borate-buffered formaldehyde for later analysis. In the laboratory, the organisms encountered were identified to the genus level and if possible to species level and then counted under a stereomicroscope after sub-sampling.

Results

Zooplankton was represented by several taxonomic groups – *Copepoda* (79%), *Cladocera* (9%), *Oikopleuriddae* (7%), *Chaetognath*a (3%), and *Decapoda* (~2%) comprising the major part of the total zooplankton abundance. Copepods were the most abundant group contributing ~ 80%, of which 27 species constituted ~75% of total copepod abundance (Table 1).

Seasonal changes of the total copepod abundance exhibited a peak in September in 2007, 2009, and 2010 (Fig. 1). In 2010, the total copepod abundance had a peak in February, which was more pronounced that the peak in September. Zooplankton sampling in 2008 was not regular, however two peaks- in February and June were noticed. In 2011, the fall peak observed in 2007-2010, was shifted to November.

Table 1. Characteriostic species of copepods of the Bandar Al-Khyran Bay.

Copepod Species	Abundance (ind m^{-3})	Total Copepod Abundance (%)
Oithona brevicornis	1511184	9.7
Oithona spp.	1483726	9.5
Temora turbinata	1394334	9.0
Oncaeidae	1231872	7.9
Oithona nana	1190109	7.6
Parvocalanus elegans	940415	6.0
Oithona simplex	695603	4.5
Microsetella spp.	575797	3.7
Euterpina acutifrons	506760	3.3
Acrocalanus spp.	309102	2.0
Acartia amboinensis	200816	1.3
Corycaeus spp.	199764	1.3
Paracalanus indicus	168841	1.1
Acartia spp.	163440	1.0
Paracalanus spp.	150059	1.0
Centropages orsinii	121376	0.8
Paracalanus denudatus	101083	0.6
Oncaea clevei	100686	0.6
Temora spp.	94177	0.6
Parvocalanus spp.	86924	0.6
Oithona plumifera	82915	0.5
Paracalanus aculeatus	82593	0.5
Subeucalanus pileatus	80147	0.5
Parvocalanus crassirostris	69346	0.4
Acrocalanus longicornis	67667	0.4
Centropages spp.	47410	0.3
Paracalanus tropicus	41230	0.3

In analyzing monthly changes of copepod abundance to the level of genera and species, a multiple peak dynamic was noticed (Figs. 2 and 3). For *Oncaeidae* for instance, over the 5 years of zooplankton sampling, peaks were pronounced in September, and November in 2007. The situation was different in 2008, when a major peak was observed in June. In 2009, only one peak was observed in September. In 2010, only one peak was recorded in February.

Oithona sp. (♀)

Oithona plumifera (♀)

Acartia sp. (♂)

Oncaea sp. (♀)

Acartia sp. (♀)

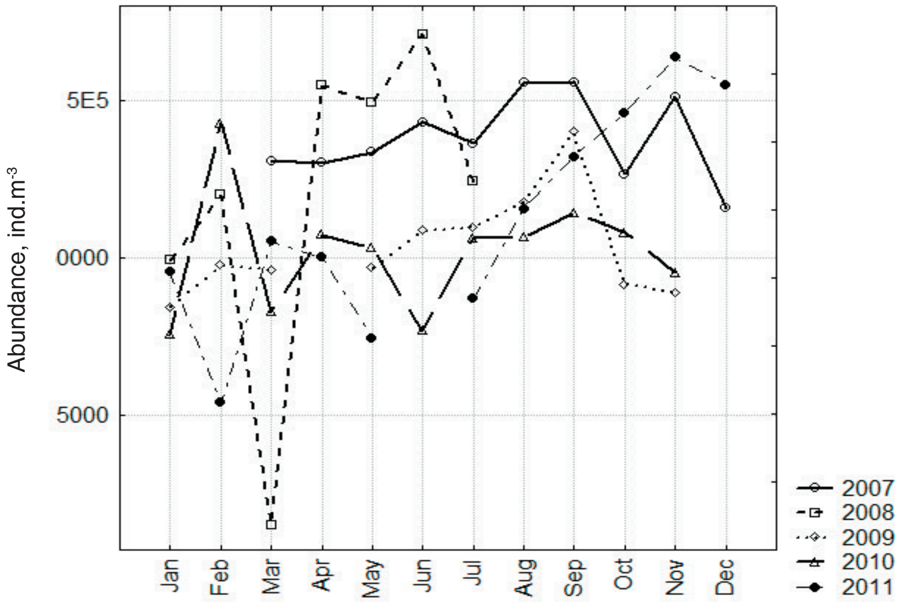

Figure 1. Photographs of some copepod species identified in samples and seasonal changes of the total copepod abundance over years. The Y-axis has the logarithmic scale.

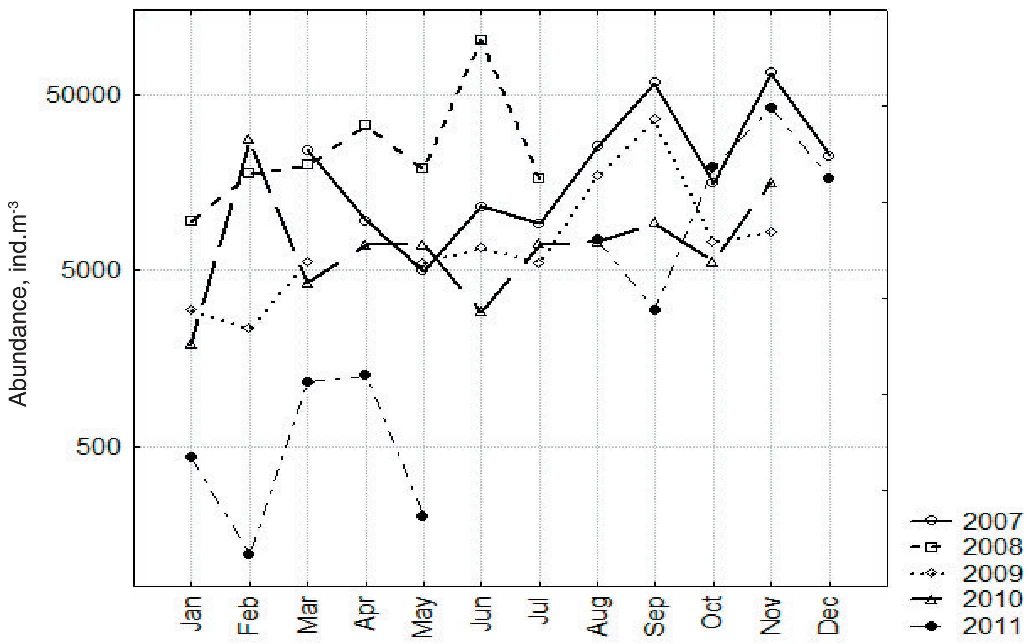

Figure 2. Seasonal changes of the total abundance of *Oncaeida*e species.

For the other groups and species, the multiple peak structure was pronounced as well; peaks varied by timing and amplitudes (Fig. 3).

In terms of interannual changes, it was noticed that the year 2008 was quite different compared to the other three years of sampling. This was the year of maximal amplitudes for almost all the species and genera. Also, a gradual shift in taxonomic structure of the plankton community was reported; coastal waters were invaded by the dinoflagellate *Cochlodinium polykrikoides* which was the dominant species of phytoplankton, and caused a huge bloom and massive fish kills in Omani coastal waters (Matsuoka *et al*., 2011; Richlen *et al.,* 2010).

Interannual changes as well as seasonal patterns might be markedly different even for the species of the same genus. We exemplified that fact by the seasonal cycles of 6 species from genus *Oithona* (Fig. 4). This genus is believed to be one of the most important and dominant in the World's Ocean (Gallienne and Robins, 2001). Obviously, timing and amplitudes of abundance are quite variable over the four sampled years and they are far from being similar from species to species.

What unites all these species however is an extremely high variability ranging from a few individuals per cubic meter to hundred thousands of individuals of the same species per cubic meter a few months later.

In comparison to the other taxonomic groups, *Copepoda* is not only the most dominant in terms of contribution to the total zooplankton abundance, but the most variable as well. During the seasonal cycle, many species (like *Oithona brevicornis* and *Temora turbinata*) could reach a concentration of millions of individuals per cubic meter but exhibit a gradual reduction (up to hundreds of individuals) a couple of months later. The other species (like *Subeucalanus pileatus and Paracalanus tropicus)* whose concentration reaches thousands of individuals per cubic meter, could disappear from the community completely in a few months.

In order to understand the role the species play in the formation of the total variance of the copepod community, Principal Component Analysis was carried out (Table 2). In the analysis, the Varimax normalized correlation matrix was employed.

The factor loadings implied that Factors 1, 2, and 3 explain 36%, 30%, and 14% of the total variance correspondently. The cumulative variance explained by these 3 factors was 80%. In table 2, values with a statistically significant contribution to a factor loading are given in bold. Obviously, species tend to form a certain group mostly contributing to the variance. In Factor 1, the components (species) of such a group are quite diverse, whereas in Factor 2, the dominant group is formed mostly by the *Oithona* species.

As for the seasonal changes of the other taxonomic groups, the later ones exhibit a multiple of peaks, shifting over years. For instance in the dynamics of *Chaetognatha*, all five years are different by amplitudes and timing (Fig. 5).

The same goes for the monthly fluctuations of the *Decapoda* larvae (Fig. 6). All five years might be named the years of markedly different fluctuations of abundance exhibiting multiple peaks. Some of them are matched by timing (in May and September), while the others are not.

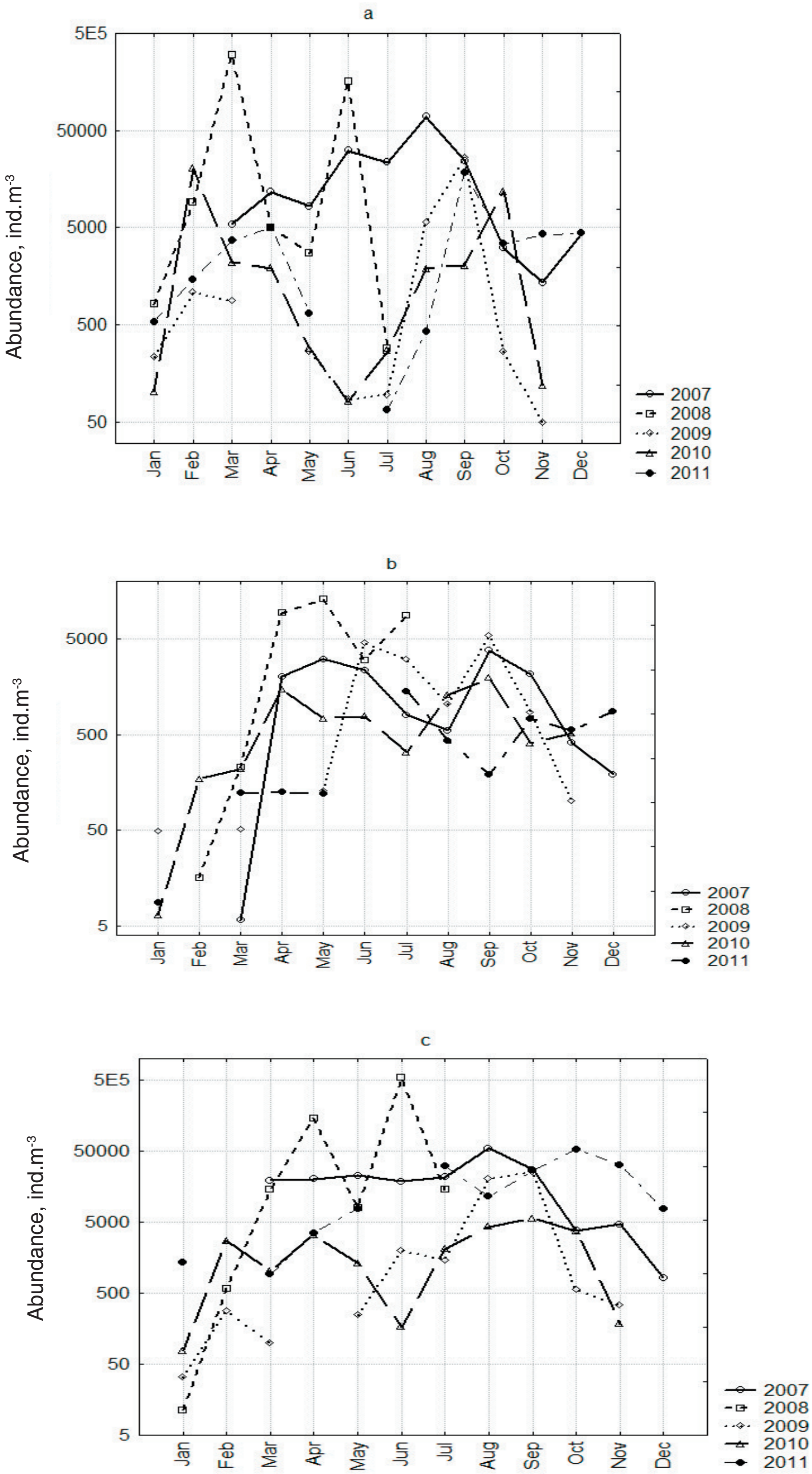

Figure 3. Seasonal changes of the abundance of some typical species (a) *Temora turbinata*, (b) *Centropages orsinii*, and (c) *Penilia avirostris.*

Table 2. Results of the Principal Component Analysis. Factor loadings for the copepod community.

Species	Factor 1	Factor 2	Factor 3
Oithona brevicornis	0.10	0.86	0.32
Oithona spp.	0.29	0.88	0.18
Temora turbinata	0.27	0.84	0.20
Oncaidae	0.76	0.35	0.40
Oithona nana	0.47	0.69	0.39
Parvocalanus elegans	0.29	0.66	0.31
Oithona simplex	0.44	0.78	0.10
Euterpina acutifrons	0.62	0.58	0.21
Acrocalanus spp.	0.82	0.38	0.00
Acartia amboinensis	0.27	0.32	0.84
Corycaeus spp.	0.67	0.49	0.30
Paracalanus indicus	0.69	0.44	0.28
Paracalanus spp.	0.68	0.48	0.13
Centropages orsinii	0.00	0.48	0.78
Oncaea clevei	0.79	-0.16	0.45
Parvocalanus spp.	0.53	0.69	0.09
Oithona plumifera	0.82	0.39	0.19
Paracalanus aculeatus	0.90	0.22	0.20
Subeucalanus pileatus	0.62	0.48	0.17
Parvocalanus crassirostris	0.66	0.31	-0.17
Acrocalanus longicornis	0.66	0.13	0.61
Paracalanus tropicus	0.66	0.51	0.45

In terms of trophic interactions, a multiple peak structure in the dynamics of zooplankton abundance *a priori* sets up the situation when, 1) zooplankton abundance will be synchronized with monthly changes of food objects (the abundance of phytoplankton organisms); 2) zooplankton and phytoplankton abundance exhibit contra-phased fluctuations; and 3) zooplankton and phytoplankton abundance exhibit lagged-in time (but related) fluctuations.

In order to compare fluctuations of zooplankton and phytoplankton, we analyzed monthly changes of the abundance of two major groups - diatoms and dinoflagellates (Fig. 7).

In this plot, monthly time series of abundance were subjected to logarithmic transformations and represented in the form of deviations from the mean. Seasonal changes of phytoplankton abundance have demonstrated (more clearly than zooplankton groups) a certain relationship with the monsoon seasons. Overall, 69% of the diatom peaks (positive deviations from the mean) and 64% of the dinoflagellate peaks both matched the time of summer or winter monsoons. Diatoms formed peaks predominantly during winter, whereas the dinoflagellate peaks were most frequent during summer time. A detailed description of the phytoplankton seasonal changes might be found in Al-Hashmi *et al*. (2012).

As for interannual changes, the duration of time series allowed us to analyze this issue in general terms only. For instance in 2010, peaks of diatoms and dinoflagellates were less pronounced and the mean abundance was low compared to the previous three years. Hopefully, a posterior sampling will allow us to resemble interannual trends with a sufficient accuracy.

Phytoplankton and zooplankton organisms are supposed to be actively consumed by epipelagic fish populations. In Omani coastal waters for instance, sardines (comprising about 50% of annual fish landing) are planktivorous species. In the Sea of Oman, the sardine fishery has not been changing much, in the sense of fishing gear used and fishing boats involved (Fishery Statistics Book, 2011). In following Longhurst and Wooster (1990) and George *et al*. (2012), we hypothesized that in those kinds of situations, the sardine landings are representative of stock abundance. In this regard, sardine landings and data on zooplankton abundance both might be interpreted in the light of predator-prey interactions.

The monitoring of sardine landings along the Omani coast, carried out by the Ministry of Agriculture and Fisheries, from 1970s through the present time, has resulted in historical data with the most detailed data available for the Muscat region (Fig. 8) (Fisheries Statistics Book, 20011). We selected the data covering years of zooplankton sampling (from 2007 to 2011). Monthly time series demonstrated peaks of landings of which 63% corresponded to the time of the winter monsoon. In zooplankton dynamics, December and January were the months of low abundance of copepods, as well as some other zooplankton groups (Figs. 1, 5, and 6).

Discussion

An interesting geographical feature of the Omani coast is the difference in modes of ocean-atmosphere interaction. The Sea of Oman is mainly affected by the Northeast (winter) Monsoon, whereas the coast overlooking the Arabian Sea (in particular, the southern part of this coast) is mediated by the Northeast and Southwest Monsoons. The result is markedly different seasonal cycles of plankton communities inhabiting coastal waters of these regions.

In the surface waters of the Arabian Sea, inhabited by about 50 species of copepods, approximately 11 species dominate throughout the annual cycle (Madhupratap *et al*., 1992; Timonin, 1971). In the Sea of Oman, the total number of species was higher and the dominant group of species was wider. Out of 140 species encountered, 27 species comprised 75 % to the total copepod abundance.

The dominance of small-sized copepods of genus *Oithona, Temora, Oncaea, Parvocalanus, Paracalanus, Microsetella, Acartia* and some others was a typical

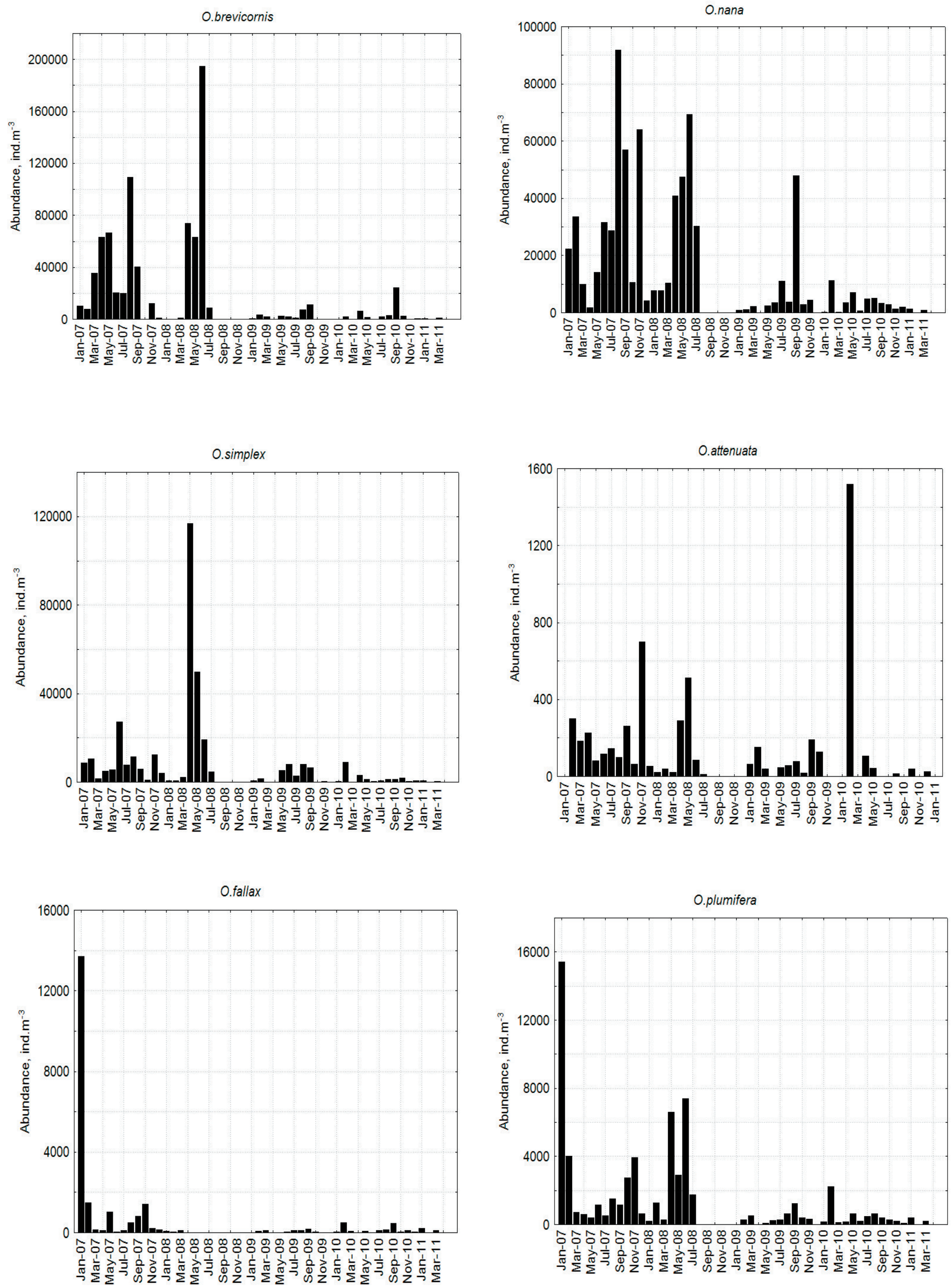

Figure 4. Seasonal changes of species abundance: genus *Oithona.*

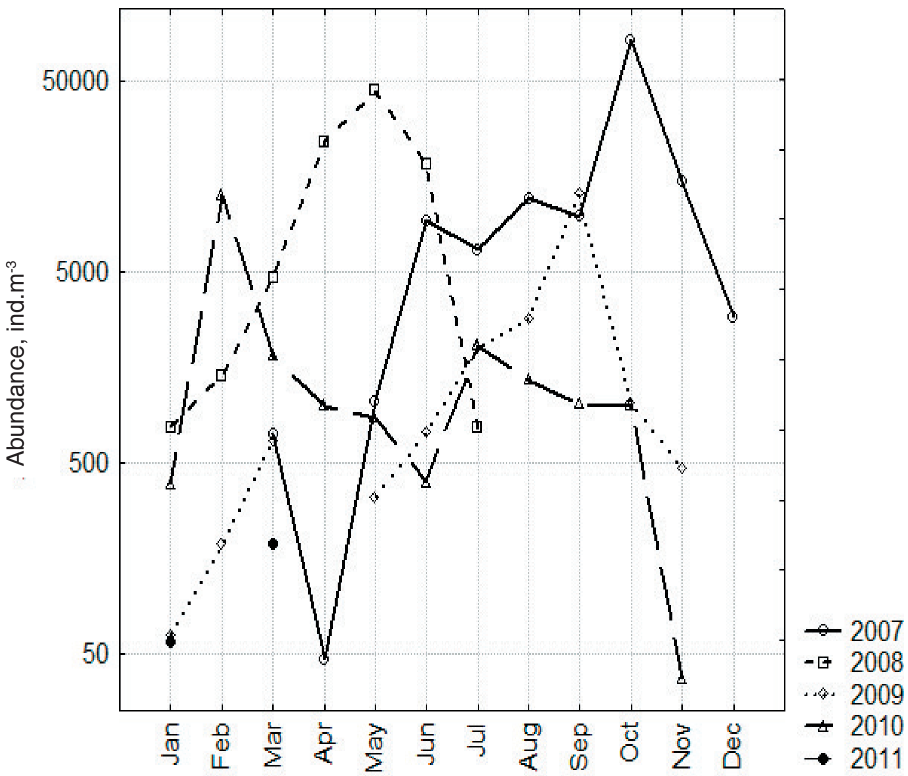

Figure 5. Seasonal changes of the *Chaetognatha* abundance.

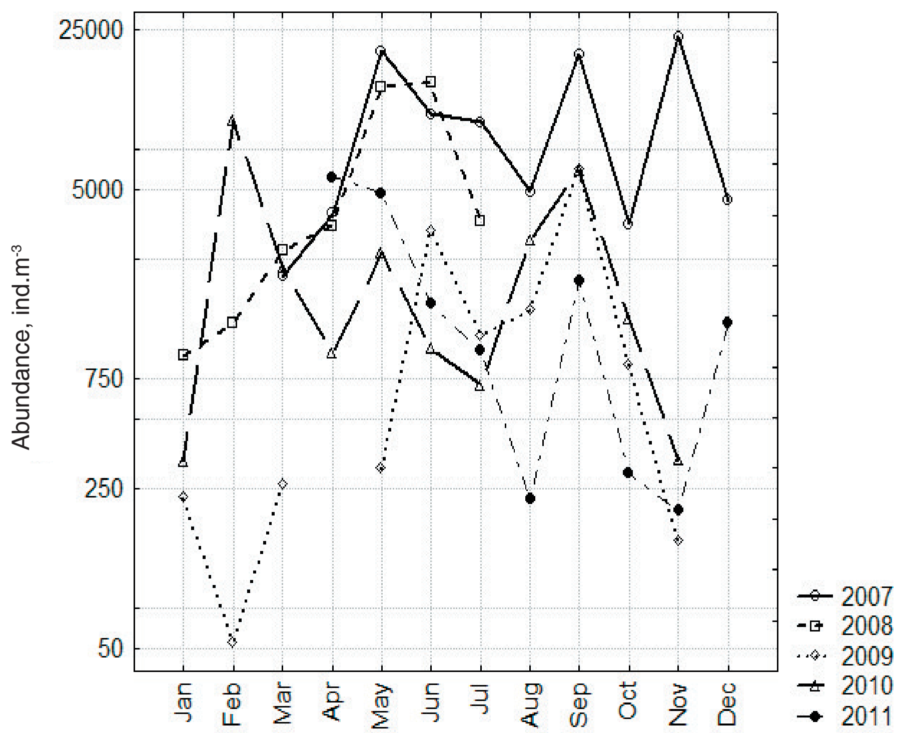

Figure 6. Seasonal changes of the *Decapoda* abundance.

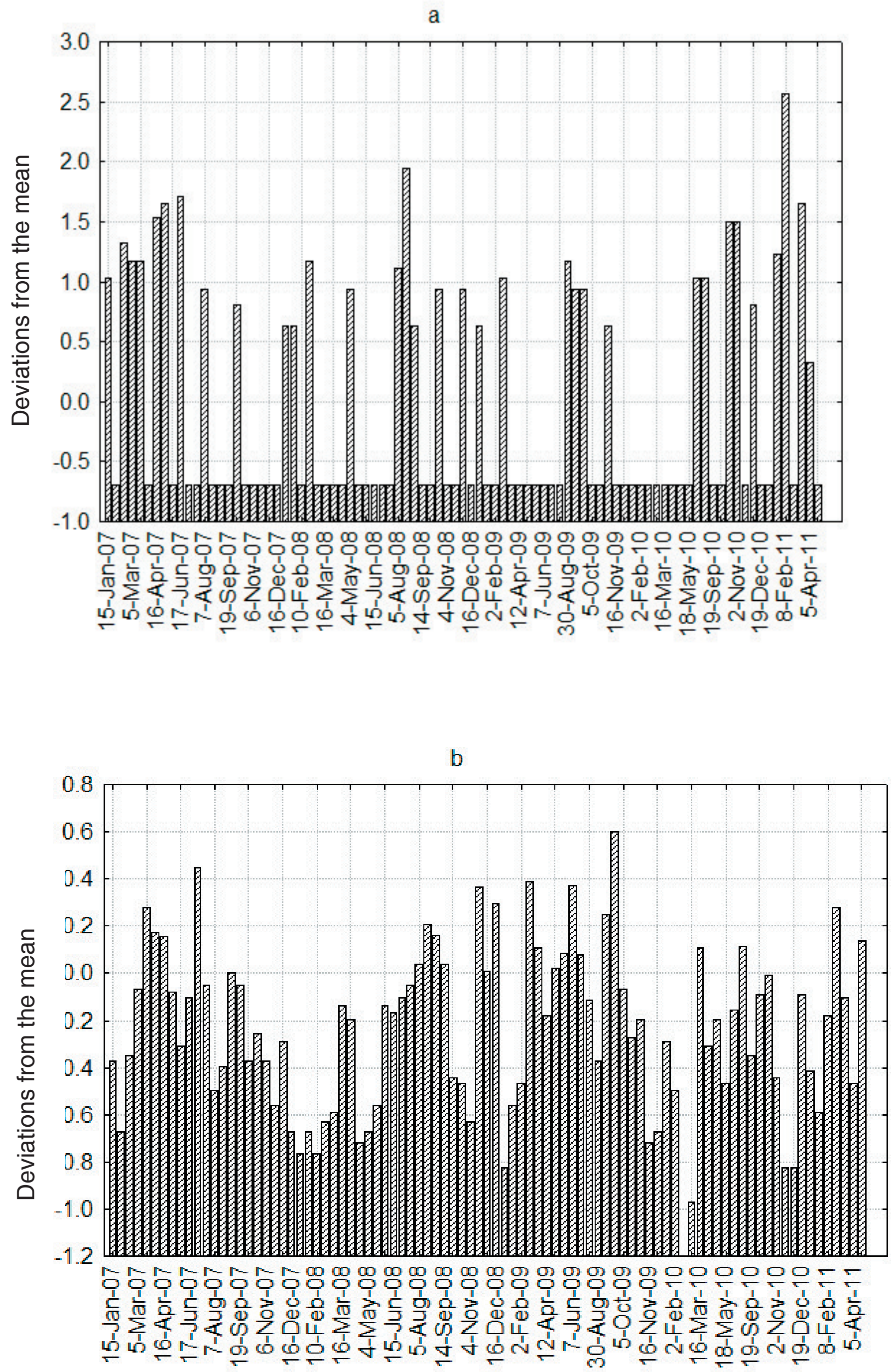

Figure 7. Monthly changes (deviations from the mean) of (a) diatom abundance and (b) dinoflagellate abundance.

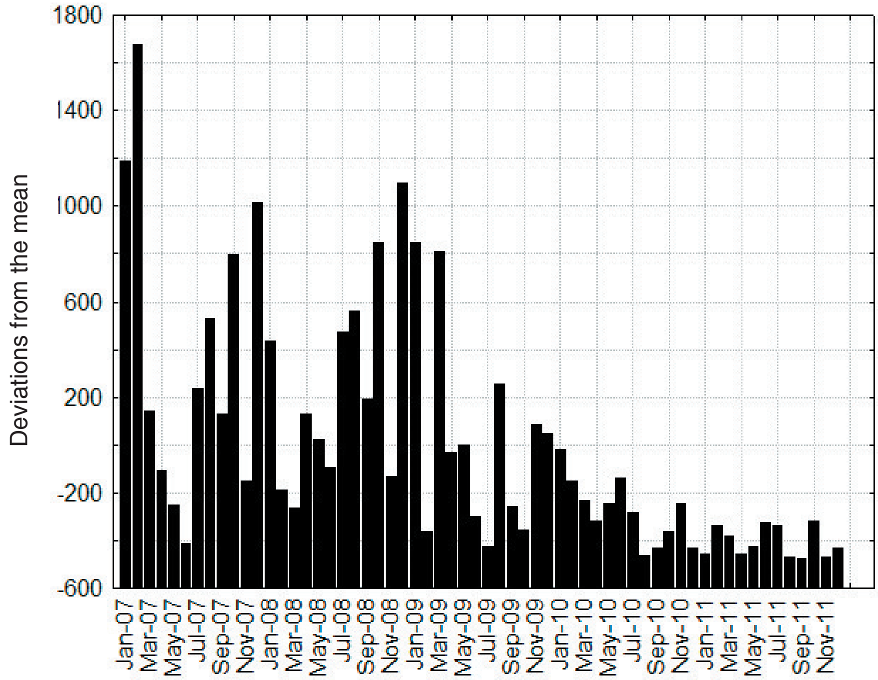

Figure 8. Seasonal changes of sardine landings (Muscat region).

feature of the plankton community inhabiting coastal waters of the Sea of Oman. Moreover, similar genera (*Oncaea, Paracalanus,* and *Acartia*) were reported far to the south down the coast- in Ras Madrakah and Ras Marbat regions, in which sampling off the coast was carried out by the US GLOBEC expedition (Hitchcock *et al.,* 2002). For instance, at Ras Marbat, the dominant taxa were small-bodied *Acartia spp*., *Corycaeus spp*., *Oncaea spp*. and *Paracalanus spp*. in both daytime and night-time tows. At Ras Fartak (which is about 200km to the south), copepods were dominated by *Paracalanus spp*.

If we expanded our comparison towards the waters of the Arabian Gulf, a similar tendency would be noticed there as well. The dominant copepod genera are: *Oithona, Oncaea*, and *Paracalanus* (Al-Khabbaz and Fahmi, 1998; Al-Yamani *et al*., 1998). Consequently, small-sized copepod species dominate coastal waters of the western Arabian Sea and the Gulf. In oceanic waters of the Arabian Sea, zooplankton biomass is dominated by large-sized copepods >2mm (Roman *et al*., 2000).

Interestingly, studies similar to ours were conducted on the northern (Iranian) coast of the Sea of Oman, across the Muscat region, from August to November 2007 and from February to May 2008 (Fazeli *et al*., 2010). The authors identified 75 copepod species and demonstrated that *Copepoda* was the dominant group throughout the seasons and that zooplankton abundance in the region follows a cycle related to the monsoonal winds. Along with that, their study revealed a correlation between copepod abundance, chlorophyll-*a*, and concentration of phosphates. A time lag between copepod abundance and chlorophyll was noticed.

A multiple peak structure of the abundance reported for species and genera (Figures 1-4), reflects the adaptation of zooplankton populations to availability of food on one hand and to the press of predators (carnivorous zooplankton and mesopelagic fish) on the other. Multiple peaks do also imply that there is no well-pronounced seasonal pattern. Lack of seasonality in copepod abundance has been reported before, for the central and eastern Arabian Sea (Mahupratap *et al*., 1996).

Nonetheless, it was demonstrated that the Northeast Monsoon season "is always characterized by an increase in the abundance of the cyclopoid copepods, particularly *Oithona* species, regardless of location in the Arabian Sea" (Smith and Madhupratap, 2005). We tested this concept's applicably to the coastal community of Omani waters. It was found that the *Oithona* species did not exhibit this pattern (Figure 4). All 6 abundant species have had different seasonal changes over the years and the majority of the peaks observed did not match the time of the Northeast Monsoon.

Smith *et al.* (1998b) have reported that in the western Arabian Sea, the most abundant copepod species of the upper 25 m in the upwelling area during the Southwest Monsoon were the small-bodied *Paracalanus aculeatus*, *Paracalanus denudatus* and *Parvocalanus dubia* (Smith *et al.,* 1998b). Four species of copepod (*P. denudatus, P. dubia, P. aculeatus* and *Acartia longicornis*) account for 36% of the total numbers in the upper 25 m during the Southwest Monsoon. With two other species added (*Subeucalanus crassus* and *Calanoides carinatus*), the group will account for 37% of total abundance (Smith and Madhupratap, 2005).

In our case, the group accounting for 37% of total abundance was different (Table 1). Overall, this means that species composition of abundant species in the Sea of Oman versus the western Arabian Sea is different, and seasonal cycles of species inhabiting shallow coastal waters of the Sea of Oman might not match seasonal cycles of the same species or genera inhabiting shelf and oceanic waters of the western Arabian Sea.

As far as the grazing patterns are concerned, the small-sized copepods inhabiting coastal waters are the herbivores, omnivores, and carnivores so the feeding strategy of many of them is quite diverse. Depending on food availability, one and the same species could switch feeding behavior from herbivores to omnivores or carnivores. For instance, both phytoplankton and zooplankton remains were frequently found in the guts of *Oncaea* species (Pasternak 1984; Turner, 1986; Hopkins 1987). In the oligotrophic Red Sea, this species actively consume appendicularian houses (Ohtsuka *et al.,* 1996). Lampitt *et al.* (1993) reported *Oncaea conifera* consuming amorphous marine snow. In experiments, *Temora longicornis* actively consumed diatoms (Yule and Crisp, 1983), as well as ciliates (Jakobsen, 2005), and fecal pellets (Poulsen and Kiørboe, 2005).

In the sub-arctic waters of the White Sea, three species of copepods (*Acartia spp., Centropages hamatus* and *Temora longicornis*) consume up to 85% of phytoplankton standing stock (in terms of chlorophyll-*a*), and play a significant role in the transformation of particulate organic matter (Martynova *et al*., 2011).

The cyclopoid family *Oithonida* is one of the most abundant groups inhabiting coastal waters worldwide (Paffenhöfer 1993, Gallienne and Robins, 2001). This group combines a feeding strategy that includes consumption of herbivores, carnivores, and omnivores (Drits and Semenova, 1984; Nishibe *et al.,* 2010; Uchima and Hirano, 1986).

Feeding of the *Oncaea* species is poorly understood. In coastal waters, they were found attached to large zooplankton organisms such as *Salpa* spp, *Sagitta* spp., and *Oikopleura* spp (Go *et al.*, 1996). Copepod nauplii, copepodits, diatoms, and appendicularia houses were found in the guts of large-sized species and rarely in small-sized onesof less than 0.7mm in length (Ohtsuka *et al*., 1996).

Gut contents of 3 copepods including *Oncaea venusta*, *O. mediterranea*, and *O. conifera*, of the southern Taiwan Strait were picked out using a fine needle under a stereomicroscope and then examined with scanning electron microscopy. Study of the gut content showed that the major components of their diets were the diatoms *Chaetoceros* sp. and *Thalassiothrix* sp. Along with that, radiolarian, microzooplanktonic, and copepod debris was also found in the gut contents (Wu *et al.,* 2004).

Among the other groups markedly contributing to the total zooplankton abundance of Omani coastal waters, *Penilia avirostris* (Cladocera) was noticed. This species is a typical inhabitant of neritic waters reported all over the globe. The diet of *Penilia* is flexible, ranging from small diatoms and bacterivorous microflagellates (Turner *et al.,* 1988) to prymnesiophyceans (Paffenhöfer and Orcutt 1986) and bacteria (Lipej *et al.,* 1997). Katechakis and Stibor (2004) reported significant grazing on elongated diatoms (*Nitzschia elongata* and *Rhizosolenia* spp) or long-chain diatoms (*Skeletonema costatum* and *Thalassiosira* spp.) up to 135 μm long.

Recent studies in the Gulf of Trieste (Adriatic Sea) showed that in summer-2000, *P. avirostri*s was preferentially consuming diatoms, and particularly the elongated cells of *Proboscia (Rhizosoleni*a*) alat*a (2.5-13 μm). In summer- 2002, this species fed upon autotrophic nanoplankton*. P. avirostr*is grazed also on microzooplankton- mostly small ciliates and heterotrophic dinoflagellates. (Fonda-Uman*i et al*., 2005).

The above comparisons imply that all the discussed species or genera of zooplankton reported for the Omani coastal waters possess a flexible feeding strategy and might be active consumers of algal blooms. The percentage of the phytoplankton standing stock ingested is yet to be estimated however. The assessment carried out for the other geographical regions implies a marked variety- from non-significant effects not exceeding a few percent (Calbe*t et al*., 2009; Dam*e et al.,* 1993) to a gradual elimination of up to 100% of the phytoplankton standing stock (Lopez and Anadon, 2008).

The flexibility and switches in feeding strategy of copepods in coastal subtropical communities also means that coupling in the abundance of phytoplankton and herbivorous zooplankton might occur temporarily, during a certain period of time, the duration of which is unknown. As for the whole time series covering the range from 2007 to 2011, a comparison of the total copepod and the phytoplankton group abundance enabled us to denote no general concordance in timing of the abundance peaks. In 64% of cases, the copepod peaks were lagging the diatom or dinoflagellate peaks, by one or two months.

There are a number of other ecologically important factors mediating monthly changes of copepod populations. For instance, algal toxic blooms could suppress the abundance and occurrence of coastal copepod species (Leste*r et al*., 2008). In our case, the harmful algal bloom of dinoflagellat*e Cochlodinium polykrikoid*es in 2008 was not fully covered by zooplankton sampling.

In the Arabian Sea, sardines are consumers of phyto- and zooplankton (Prasad, 1953; Sekharan, 1966). We speculated that, through the trophic press in particular in the upper layers, sardines and the other small pelagic species impact zooplankton, making the multiple peak structure of zooplankton abundance more pronounced. However, the data represented by figures 1-7 and 8 enabled us to assume that monthly changes of the total copepod abundance (as well as some typical species) were less related to changes of sardine landings in comparison to the seasonality of phytoplankton (especially diatoms) which had better matched the seasonal pattern of sardines in the Muscat region. The gut content analysis of the sardines caught along the coast of the Sea of Oman (in the Muscat and Sohar regions) has indicated that about 62-68% is contributed by phytoplankton (Haleem *et al*., 2011).

Conclusion

Zooplankton communities of the shallow coastal waters of Oman are diverse by taxa. However, *Copepoda* are the most numerous zooplankton organisms. Within copepods, no dominant species were found; instead, a group of 15 species comprised about 80% of the total zooplankton abundance. Changes of copepod abundance do not have a pronounced seasonal pattern. On the level of genera and the abundant species, a multiple peak structure in monthly fluctuations was observed. Amplitudes and timing of the copepod peak abundance were markedly different during the studied years (2007-2011).

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