



## Copepods from Shore and Offshore Waters of Pakistan

Quddusi B. Kazmi

Marine Reference Collection and Resource Centre, University of Karachi, Karachi-75270, Pakistan.,  
gbkazmi@mrcrc.ku.edu.pk

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# COPEPODS FROM SHORE AND OFFSHORE WATERS OF PAKISTAN

Quddusi B. Kazmi

Key words: copepods, checklist, Arabian Sea, Pakistan.

## ABSTRACT

This report is a history of copepodology based on the review of previously recorded species of copepods from Pakistan (Arabian Sea) by Pakistani workers and other contemporary surveys. The plankton samples studied are the epipelagic copepods collected during the Northern Arabian Sea Ecological and Environmental Research (NASEER) Cruise I (January 7-22, 1992) and Cruise IV (May 10-21, 1994). Some planktonic and phytal species obtained from a U.S. Office of Naval Research (ONR) project (1993-1995) on living resources in nearshore waters, and interstitial species obtained during a preliminary survey ONR (1998-2000) of the interstitial copepods carried out for the first time in Karachi intertidal regions (Bulleji and Sandspit) are also included.

Almost all the major copepod groups are represented in the above mentioned collections. In all 61 genera and 109 species have been reported. Out of these, 27 genera and 39 species have been collected from NASEER Cruises, some of them already reported (see Kazmi and Muniza, 1997-98) in the checklist only the species from stations located on Pakistan shelf are included. *Acartia hamata* Mori, 1937, *Porcellidium viride* (Philippi, 1890), *Laophonte cornuta* Philippi 1890 and *Copilia mirabilis* Dana, 1852 are recorded for the first time from the northern Arabian Sea. Abundance of species at all NASEER stations is also calculated. One phytal species *Porcellidium viride* (Philippi, 1840) is also a new record. The first investigation revealed that at least adults, subadults and larval stages of 12 families and 15 species are present in the interstitial copepod fauna. An attempt has been made to relate the diversity of species to the nature of the sand grains at Sandspit site.

## INTRODUCTION

Bordering on the northern Arabian Sea, Pakistan has a sizeable maritime zone, influenced by atmospheric force of reversing monsoons. These result in the strong seasonal variability in its oceanographic conditions and thus the Arabian Sea appears to be an ideal place to understand link between climatic oscillations and community structure of zooplankton and biodiversity. A

multidisciplinary research theme, pertaining to biodiversity of the area, has been engaged by a number of international research activities in the Indian Ocean especially in the Arabian Sea. The Arabian Sea zooplankton is primarily comprised of copepods. However, studies on copepod abundance and distributions in the Indian Ocean have been based on total copepods found in zooplanktons (Kasturirangan *et al.*, 1973) not individual species (with few exceptions) collections. The following presentation is an attempt to evaluate the existing knowledge of richness or scarcity of species in inshore and offshore waters of Pakistan.

## MATERIALS AND METHODS

### 1. Plankton samples

The Northern Arabian Sea Ecological and Environmental Research (NASEER) programme was co-sponsored by the National Institute of Oceanography, Pakistan (Karachi) and Oceanic Biological Programme of the US Office of Naval Research (ONR) programme.

The present NASEER plankton materials were assigned by the NIO to Marine Reference Collection & Resource Centre (MRC), University of Karachi for study. The sampling procedure as communicated by the NIO tells that these samples were collected in horizontal zooplankton tows in the upper 5 m using a Bongo net of 60 cm diameter and 300 micron mesh size, the towing time was 10 minutes, towing direction was circular, the path horizontal and towing speed of net was 2-3 knot. A digital flowmeter was also used; however, it's reading was found to be unreliable on several occasions by NIO. The cruise was undertaken in the northern Arabian Sea (22°51' to 24°58'N and 60°05' to 65°59'E) during January 7-22, 1992 and again in May 10-21, 1994 (Map 1). The cruise track totaled 1,200 nautical miles, included 62 ocean observation stations and 24 hrs time series stations (Sts. 8, 27, 33, 45, and 57).

The samples from NASEER 1 (Sts. 4, 8B, 8C, 8D, 12, 15, 18, 21, 24, 27A, 27B, 27C, 27D, 30, 33A, 33B, 33C, 33D, 45A, 45B, 45C, 45D, 49, 53, 57A, 57B, 57C,

57D, 60, and 62) of January were available for study. NASEER IV covered the same cruise track. Seven samples from Sts. 18, 27A, 27B, 33B, 33C, 33D, and 37 were available for analysis.

The samples were preserved in 5% buffered formalin, each sample measured 600 mL. A subsample of 30 mL (5% of the whole) was separated for study.

Thirty-nine plankton samples were collected from Manora Channel (24°48'N and 66°59'E) for Office of the Naval Research project during the years 1993-1995, using a Bongo net of 300 micron mesh size with horizontally attached flowmeter and a tow time of 10 minutes. These samples were collected twice a month, four samples from each station (Map 2, St. A and St. B). The surface and subsurface (10-12 m) samples were designated as: AI (surface sample), AII (subsurface sample), BI (subsurface sample), BII (surface sample). The samples were preserved in 5% formalin and housed in the Marine Reference Collection and Resource Centre.

## 2. Sampling and extracting meiofauna

Forty sand samples for meiofauna were collected at low and high intertidal areas of two stations 7.5 km apart i.e. from Sandspit near Kakka village (24°50'24"N, 66°54'24"E) and Buleji (24°50'12"N, 66°49'12"E) (Map 3). To collect the sand sample a Yabi pump was used as

a piston corer (dia 5 cm). Sampling was done randomly over an area of 1 square meter quadrat; divided into 16 squares. Each portion of core was kept in a separate plastic bottle, filtered sea water was added to each bottle just above the sand level. The samples were brought to the MRC shore laboratory and preserved in 4% formaldehyde coloured with Rose Bengal.

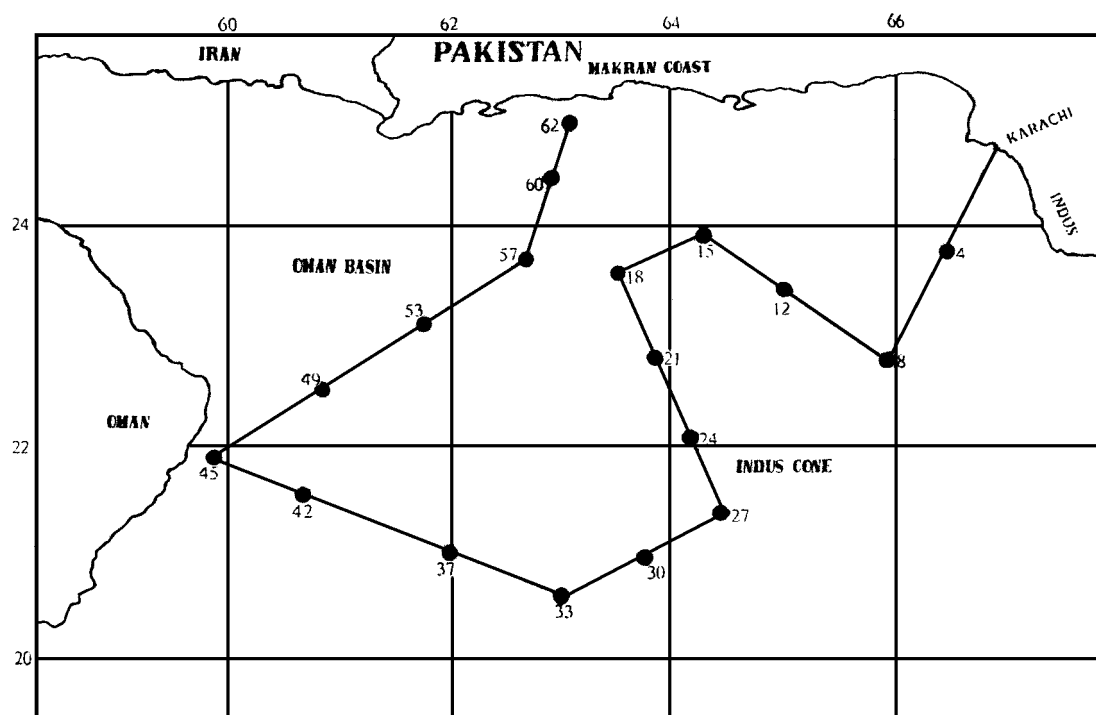
## 3. Sampling of phytal species

The weeds were collected from the coast during years 1993-1995 and also eight samples (June to October, 1999) from the mudflats of upper tidal region of the mangroves, brought to the laboratory in polythene bags. There they were washed in tap water and filtered through a sieve (mesh size 1 mm).

References to authorities of taxa are not included in the listed References of this paper.

## HISTORY OF PREVIOUS WORK

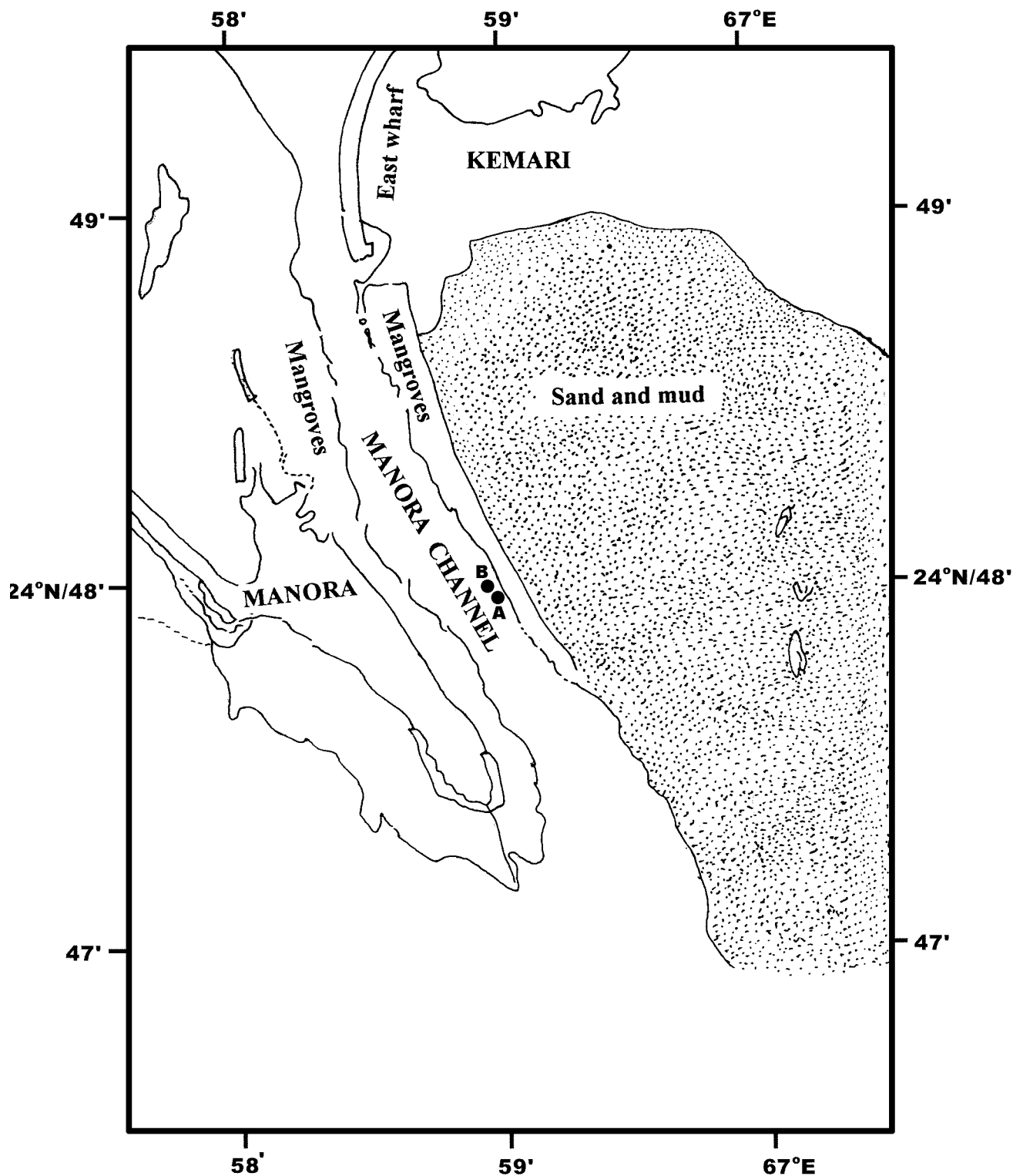
The scientific papers on distribution and taxonomy of the extant copepods occurring in the western Indian Ocean (WIO) have increased tremendously, since the first work of Giesbrecht of 1889 on this group, particularly in the Arabian Sea, which is understood to possess many qualities that make it unique among the world



Map 1. Cruise track and stations (solid circles) of the Northern Arabian Sea Ecological and Environmental Research (NASEER) Programme (modified from Amjad *et al.*, 1995). Solid circles and number show sampling stations.

oceans (Ahmed *et al.*, 1993). Some of the important works on copepods distribution and taxonomy in the WIO are: Pillai (1967, 1978), De Decker and Mombeck (1965), Grice and Hulsemann (1967), Kasturirangan

*et al.* (1973), Fleminger and Hulsemann (1973), Stephen *et al.* (1992), Lawson (1977), Rajaram and Krishnaswamy (1980), Gajbhiye *et al.* (1991), Gopalakrishnan and Balachandran (1992), NIOP (1992-93), ARA-

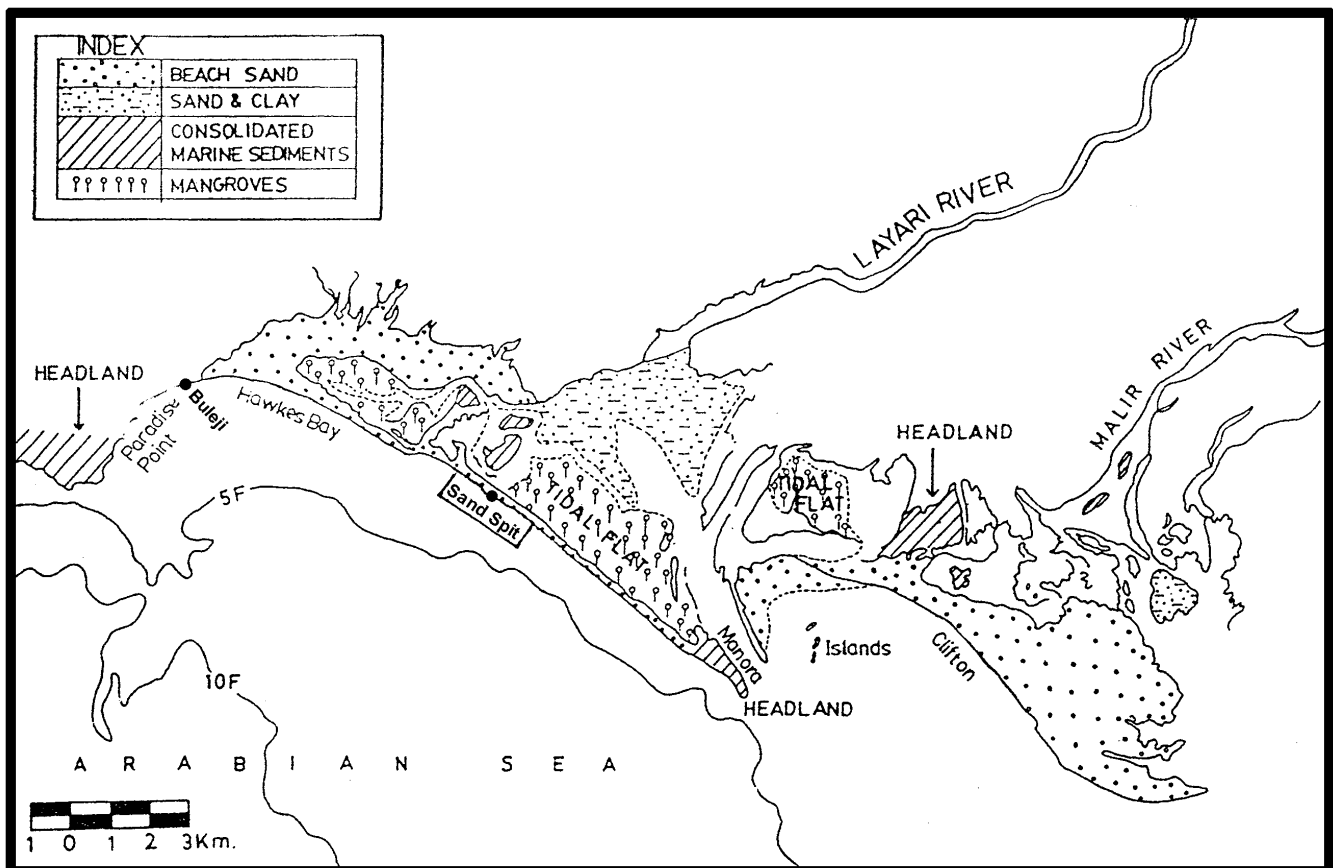


Map 2. Collection sites at Manora Channel.

BESQUE (1994), Goswami (1994), Al-Yamani *et al.* (1995), and Razouls (1993, 1995, 1996, 1998). The history of the copepod taxonomic investigations in Pakistani waters (N. Arabian Sea) dates back to Bindra (1924). The area was then under the control of the British Government. Bindra's work was followed by the excellent contributions made by Sewell (1947, 1948) in the Indian Seas. His work of on John Murray Expedition and Investigator materials is an important reference for Pakistani copepodologists. British India was partitioned into Pakistan and India in 1947. After the political disturbance was over, work was resumed in Pakistan and reports on fresh water and marine copepods were published. The present paper summarises briefly the results of investigations into the marine copepod fauna of Pakistan as following. The early reports on zooplankton of Karachi coast published by the Marine Fisheries Department, Govt. of Pakistan and the Zoology Department of the Karachi University were by Ahmed (1951) and Ali and Arshad (1966) and then Haq (1968) published a paper on the variations in *Undinula vulgaris* (Dana, 1849). Gololobov and Grobov (1970) worked out the biomass, distribution and quantitative zooplank-

ton composition in the Arabian Sea. Fazal-ur-Rehman (1973a) and Haq and Fazal-ur-Rehman (1973) contributed two new species: *Pontella karachien-sis* Fazal-ur-Rehman, 1973 and *Centropages karachien-sis* Haq and Fazal-ur-Rehman, 1973. Fazal-ur-Rehman (1973b) also worked on variation in *Tortanus forcipatus* (Giesbrecht, 1889) and redescribed (1974) *Pontella investigatoris* (Sewell, 1912). Khan (1976) and Khan and Kamran (1975) erected two new species of monstrol-oids, *Cymbasoma williamsoni* Khan, 1976 and *Cymbasoma tirmizii* Khan and Kamran, 1975. The occurrence of another species of *Cymbasoma* (*C. rigidum* Thompson, 1888) was reported by Khan *et al.* (1988). Khan worked on seasonal abundance of zooplankton (1974) and reported in 1977 a poecilostomatoid (*Conchylurus maximus* Reddiah, 1960). The major contributions to the systematics of Pakistani calanoids were by Ali Khan and Ali Khan from 1992-1998. The sources of their material were samples from the International Indian Ocean Expedition (IIOE) during its four cruises and the Cruise 1 of Dr. Fridtjof Nansen in the Arabian Sea.

The Zoological Survey of Pakistan also took part in publishing on copepods where the families



Map 3. Collection sites: Bulleji and Sandspit.

Centropagidae (*Centropages dorsispinatus* Thompson and Scott, 1903, *C. tenuiremis* Thompson and Scott, 1903 and *Isias tropica* Sewell, 1932) and Temoridae (*Temora dubia* (Lubbock, 1856), *Temora turbinata* Dana, 1849) were dealt with by Ahmed *et al.* (1972); *Pontella andersoni* Sewell, 1912, *P. investigatoris* Sewell, 1912 and *Tortanus forcipatus* by Masihuzzaman (1973) whereas Niazi and Ahmed (1973a, b) worked on Siphonostomatoida, reporting *Caligus diaphanous* Nordman, 1832, *Caligus robustus* Bassett-Smith, 1898 (Caligidae) on *Pampus argenteus* and *Larnaeenicus hemirhamphi* (Pennelliidae) on *Hemirhamphus xanthopterus*. The zooplankton of mangrove areas was studied (Huda, 1993).

From NASEER samples analysis at MRC labs the results was the first report on the harpacticoids *Miracia efferata* Dana, 1852 (Miracidae) and *Clytemnestra scutellata* Dana, 1848 (Clymnestridae) from Pakistan (Kazmi and Muniza, 1994), a general survey on NASEER zooplankton by Kazmi *et al.* (1995), a paper on distribution of eucalanids (Muniza and Kazmi, 1995), another on abundance of poecilostomatoids (Kazmi and Muniza, 1995), another report on harpacticoids (Kazmi and Muniza, 1997a), and a broad overall summary of all the copepods of NASEER I and IV (Kazmi and Muniza, 1997b). Muniza was awarded M. Phil degree on her dissertation on NASEER copepods (1998). On the parasitic copepods Ali (1995) and Ghani and Ali (1996a, b) have worked.

The ONR research project (1993-95) in MRC on biodiversity also contributed to our knowledge on Pakistani nearshore copepods. The new record of the family Diossaccidae represented by *Metamphiascopsis hirsutus* (Thompson and Scott, 1903) from seaweeds and *Caligus*

*punctatus* from near shore plankton were published by Sadiq (1995, 1996).

The results of meiobenthic studies (1998-2000) of intertidal sand were very encouraging, as the work was the first of its kind in Pakistan. Meiobenthic species have been reported by Naushaba and Kazmi (1998), Naushaba *et al.* (1998), Kazmi and Naushaba (2000), and Qureshi *et al.* (1999). The weed fauna was also reported upon by Ghani and Nawaz (2000).

### CHECK LIST

Utilizing these reports and records, a checklist of Pakistani copepods has been prepared and is presented here. Ali Khan's 1998's list is included in its entirety although she gave it as a list of FAO Area 51, with no differentiation of shore and offshore species of the Pakistani coast and did not include all the IIOE R/V *Anton Bruun* bathypelagic species given by Grice and Hulsemann (1967). From NASEER samples, species only from station 62 on the leg nearer to our coast are included. The scheme of classification is that of Razouls (1993) and Martin and Davis (2001). Some 109 species from 61 genera and 39 families have now been recorded and this is obviously not the total picture. Preliminary identifications of other species are in preparation. Some old names are replaced by new names since some species listed in the earlier literature have been re-identified or identifications have been corrected.

The species listed have particular habitat preferences. Some show a degree of versatility and appear in several different habitat types. The habitats may be nearshore, offshore, psammonic, phytal, parasitic, detrital or associated with invertebrates.

### CHECKLIST OF MARINE COPEPODA OF PAKISTAN

	Source	Habitat
Infraclass Neocopepoda Huys and Boxshall, 1991 Superorder Gymnoplea Giesbrecht, 1882 Order Calanoida Sars, 1903 Family Augaptilidae Sars, 1905 Genus <i>Augaptilus</i> Giesbrecht, 1899 <i>Augaptilus longicaudatus</i> (Claus, 1863) Genus <i>Euaugaptilus</i> Sars, 1920 <i>Euaugaptilus hecticus</i> (Giesbrecht, 1892) <i>Euaugaptilus latifrons</i> (Sars, 1907) <i>Euaugaptilus nodifrons</i> (Sars, 1905) Genus <i>Haloptilus</i> Giesbrecht, 1898 <i>Haloptilus longicornis</i> (Claus, 1863) <i>Haloptilus paralongicirrus</i> Park, 1970 Genus <i>Pachyptilus</i> Sars, 1920 <i>Pachyptilus pacificus</i> Johnson, 1936 Family Heterorhabdidae Sars, 1902 Genus <i>Heterostylites</i> Sars, 1920	Ali Khan and Ali Khan, 1984  Ali Khan and Ali Khan, 1984 Ali Khan and Ali Khan, 1984 Grice and Hulsemann, 1967  Grice and Hulsemann, 1967 Saraladevi, 1977  Ali Khan and Ali Khan, 1984	Pelagic, offshore  Offshore Offshore Offshore, bathypelagic  Offshore, bathypelagic Offshore  Offshore, bathypelagic

<i>Heterostylites longicornis</i> (Giesbrecht, 1893)	Ali Khan, 1993b	Offshore, deep sea
Genus <i>Mesorhabdus</i> Sars, 1905		
<i>Mesorhabdus angustus</i> Sars, 1907	Ali Khan, 1993b	Offshore, deep sea
Family Lucicutiidae Sars, 1902		
Genus <i>Lucicutia</i> Giesbrecht, 1889		
<i>Lucicutia clausi</i> (Giesbrecht, 1889)	Ali Khan and Ali Khan, 1982	Bathypelagic
<i>Lucicutia curta</i> Farran, 1905	Grice and Hulsemann, 1967	Bathypelagic
<i>Lucicutia flavicornis</i> (Claus, 1863)	Gololobov and Grobov, 1970	Bathypelagic, inshore shallow water
<i>Lucicutia gausssae</i> Grice, 1963	Ali Khan and Ali Khan, 1982	Bathypelagic, inshore shallow water
<i>Lucicutia grandis</i> (Giesbrecht, 1895)	Grice and Hulsemann, 1967	Bathypelagic, inshore shallow water
<i>Lucicutia longicornis</i> (Giesbrecht, 1889)	Grice and Hulsemann, 1967	Bathypelagic, inshore shallow water
<i>Lucicutia polaris</i> Brodsky, 1950	Ali Khan and Ali Khan, 1982	Bathypelagic, inshore shallow water
Family Metridinidae Sars, 1902 emend.		
Dunn and Hulsemann, 1979		
Genus <i>Pleuromamma</i> Giesbrecht, 1898		
<i>Pleuromamma indica</i> Wolfenden, 1905	Grice and Hulsemann, 1967, Kazmi and Muniza, 1998	Epi-benthopelagic, nearshore–Oceanic
Genus <i>Gaussia</i> Wolfenden, 1905		
<i>Gaussia swelli</i> Saraswathy, 1973	Saraswathy, 1973	Upper 200 m
Family Nullosetigeridae Soh <i>et al.</i> , 1999		
Genus <i>Phyllopus</i> Brady, 1883		
<i>Phyllopus impar</i> Farran, 1908	Ali Khan, 1998	Offshore
= <i>Nullosetigera bidentata</i> (Brady, 1883)		
Family Acartiidae Sars, 1900		
Genus <i>Acartia</i> Dana, 1846		
<i>Acartia amboinensis</i> Carl, 1907	Haq <i>et al.</i> , 1973	Nearshore, shelf epipelagic
<i>Acartia hamata</i> Mori, 1937	Muniza, 1998 (unpublished thesis). New record	Offshore
Family Candaciidae Giesbrecht, 1893		
Genus <i>Candacia</i> Dana, 1846		
<i>Candacia turberculata</i> Wolfenden, 1905	Ali Khan, 1995	Offshore
<i>Candacia curta</i> (Dana, 1849)	Ali Khan, 1995	Offshore
Genus <i>Paracandacia</i> Grice, 1963		
<i>Paracandacia truncata</i> (Dana, 1849)	Ali Khan, 1995	Offshore
Family Centropagidae Giesbrecht, 1893		
Genus <i>Centropages</i> Kroyer, 1848		
<i>Centropages dorsispinatus</i> Thompson and Scott, 1903	Ahmed <i>et al.</i> , 1972	Nearshore, creeks
<i>Centropages furcatus</i> (Dana, 1849)	Ali Khan, 1998	Offshore, shallow waters
<i>Centropages orsinii</i> Giesbrecht, 1892	Ali Khan, 1998	Nearshore, offshore
<i>Centropages kroeyeri</i> Giesbrecht, 1892	Ali Khan, 1998	Epipelagic
<i>Centropages tenuiremis</i> Thompson and Scott, 1903	Ahmed <i>et al.</i> , 1972	Nearshore, creeks
<i>Centropages karachiensis</i> Haq and Fazal-ur-Rehman, 1973	Haq and Fazal-ur-Rehman, 1973	Nearshore
Genus <i>Isias</i> Boeck, 1864		
<i>Isias tropica</i> Sewell, 1932	Ahmed <i>et al.</i> , 1972	Nearshore
Family Pontellidae Dana, 1852		
Genus <i>Calanopia</i> Dana, 1852		
<i>Calanopia elleptica</i> (Dana, 1849)	Ali Khan, 1998	Coastal
<i>Calanopia minor</i> A. Scott, 1902	Ali Khan, 1998	Coastal and oceanic
Genus <i>Labidocera</i> Lubbock, 1853		
<i>Labidocera acuta</i> Dana, 1849	Ali Khan, 1998	Offshore
<i>Labidocera pectinata</i> Thompson and Scott, 1903	Masihuzzaman, 1973	Nearshore
<i>Labidocera minuta</i> Giesbrecht, 1893	Ali Khan, 1998	Inshore, coastal
Genus <i>Pontella</i> Dana, 1846		
<i>Pontella andersoni</i> Sewell, 1912	Masihuzzaman, 1973	Nearshore
<i>Pontella investigatoris</i> Sewell, 1912	Masihuzzaman, 1973	Inshore, nearshore



<i>Pontella securifer</i> Brady, 1883	Fazal-ur-Rehman, 1974	Inshore, offshore
<i>Pontella karachiensis</i> Fazal-ur-Rehman, 1973	Ali Khan, 1998	Nearshore
Genus <i>Pontellopsis</i> Brady, 1883	Fazal-ur-Rehman, 1973a	
<i>Pontellopsis</i> sp.	Huda, 1993	Coastal
Family Pseudodiaptomidae Sars, 1902		
Genus <i>Pseudodiaptomus</i> Herrick, 1884		
<i>Pseudodiaptomus serricaudatus</i> J. Scott, 1894	Ali Khan, 1998	Coastal, brackish
Family Temoridae Giesbrecht, 1893		
Genus <i>Temora</i> Baird, 1850		
<i>Temora discaudata</i> Giesbrecht, 1889	Flemingere Hulsmann, 1973	Nearshore-off shore
<i>Temora turbinata</i> (Dana, 1849)	Ahmed <i>et al.</i> , 1972	Nearshore, shelf, epipelagic
	Ahmed <i>et al.</i> , 1972	Nearshore
<i>Temora dubia</i> (Lubbock, 1856)		
Genus <i>Temoropia</i> J. Scott, 1894		
<i>Temoropia mayumbaensis</i> J. Scott, 1894	Ali Khan, 1998	Offshore
Family Tortanidae Sars, 1902		
Genus <i>Tortanus</i> Giesbrecht, 1898		
<i>Tortanus (Tortanus) forcipatus</i> (Giesbrecht, 1889)	Masihuzzaman, 1973	Inshore, nearshore
Family Clausocalanidae Giesbrecht, 1893		
Genus <i>Clausocalanus</i> Giesbrecht, 1888		
<i>Clausocalanus minor</i> Sewell, 1929	Golobov and Grobov, 1970	Offshore
<i>Clausocalanus furcatus</i> (Brady, 1883)	Grice and Hulsemann, 1967	Offshore, bathypelagic
<i>Clausocalanus arcuicornis</i> (Dana, 1849)	Haq <i>et al.</i> , 1973	Shelf, epipelagic
<i>Clausocalanus farrani</i> Sewell, 1929	Haq <i>et al.</i> , 1973	Shelf
Family Euchaetidae Giesbrecht, 1893		
Genus <i>Euchaeta</i> Phillipi, 1843		
<i>Euchaeta rimana</i> Bradford, 1974	Ali Khan, 1998	Offshore
<i>Euchaeta concinna</i> Dana, 1849	Haq <i>et al.</i> , 1973	Offshore, epipelagic
<i>Enchaeta murrayi</i> , Sewell, 1948	Sewell, 1948	Epipelagic to mesopelagic
		Offshore
<i>Euchaeta marina</i> (Prestandarea, 1833)	Haq <i>et al.</i> , 1973	Nearshore, offshore
<i>Euchaeta wolfendeni</i> A. Scott, 1909	Haq <i>et al.</i> , 1973	
Family Scolecitrichidae Giesbrecht, 1893		
Genus <i>Pseudoamallothrix</i> Sars, 1925		
<i>Pseudoamallothrix longispina</i> (Schulz, 1991)	Ali Khan, 1998	Bathypelagic
Genus <i>Scaphocalanus</i> Sars, 1900		
<i>Scaphocalanus magnus</i> (Scott, 1894)	Grice and Hulsemann, 1967	Offshore, bathypelagic
<i>Scaphocalanus longifurca</i> (Giesbrecht, 1888)	Ali Khan, 1998	Bathypelagic
Genus <i>Scolecithricella</i> Sars, 1902		
<i>Scolecithricella paramarginata</i> Schulz, 1991	Ali Khan, 1998	Offshore
Genus <i>Scolecithrix</i> Brady, 1883		
<i>Scolecithrix nicobarica</i> Sewell, 1929	Grice and Hulsemann, 1967	Bathypelagic
<i>Scolecithrix ctenopus</i> (Giesbrecht, 1888)	Ali Khan, 1998	Offshore
Genus <i>Scottocalanus</i> Sars, 1905		
<i>Scottocalanus sedatus</i> Farran, 1936		
Family Eucalanidae Giesbrecht, 1893		
Genus <i>Subeucalanus</i> Geletin, 1976		
<i>Subeucalanus crassus</i> (Giesbrecht, 1888)	Ali Khan, 1998	Offshore
<i>Subeucalanus pileatus</i> (Giesbrecht, 1888)	Haq <i>et al.</i> , 1973	Coastal shelf, epipelagic
<i>Subeucalanus subcrassus</i> (Giesbrecht, 1888)	Haq <i>et al.</i> , 1973	Coastal shelf, epipelagic
<i>Subeucalanus subtenuis</i> (Giesbrecht, 1888)	Ali Khan, 1992	Coastal, bathypelagic
	Golobov and Grobov, 1970	Coastal, shelf, epibathypelagic
<i>Subeucalanus mucronatus</i> (Giesbrecht, 1888)	Haq <i>et al.</i> , 1973	Oceanic
Genus <i>Pareucalanus</i> Geletin, 1976		
<i>Pareucalanus attenuatus</i> (Dana, 1849)		
Genus <i>Rhincalanus</i> Dana, 1853		
<i>Rhincalanus nasutus</i> Giesbrecht, 1888	Ali Khan, 1992	Bathypelagic
<i>Rhincalanus cornutus</i> (Dana, 1849)	Haq <i>et al.</i> , 1973, Muniza and Kazmi, 1995	Epi-bathypelagic, oceanic
Family Calanidae Dana, 1846	Sewell, 1947	Bathypelagic

Genus <i>Canthocalanus</i> A. Scott, 1909 <i>Canthocalanus pauper</i> Giesbrecht, 1888	Grice and Hulsemann, 1967, Haq <i>et al.</i> , 1973	Bathypelagic, offshore, epipelagic
Genus <i>Undinula</i> A. Scott, 1909 <i>Undinula vulgaris</i> (Dana, 1849)	Haq, 1968	Nearshore, shallow water
Family Paracalanidae Giesbrecht, 1893 Genus <i>Acrocalanus</i> Giesbrecht, 1888 <i>Acrocalanus longicornis</i> Giesbrecht, 1888 <i>Acrocalanus monachus</i> Giesbrecht, 1888 <i>Acrocalanus gracilis</i> Giesbrecht, 1888 Genus <i>Paracalanus</i> Boeck, 1864 <i>Paracalanus aculeatus</i> Giesbrecht, 1888 Genus <i>Calocalanus</i> Giesbrecht, 1888 <i>Calocalanus pavo</i> (Dana, 1849) Order Harpacticoida Sars, 1903 Family Canuellidae Lang, 1944 Genus <i>Scottolana</i> Por, 1984 <i>Scottolana longipes</i> (Thompson and Scott, 1903) Family Ectinosomatidae Sars, 1903 Genus <i>Microsetella</i> Brady and Robertson, 1873 <i>Microsetella norvegica</i> (Boeck, 1865) Family Clytemnestridae A. Scott, 1909 Genus <i>Clytemnestra</i> Dana, 1847 <i>Clytemnestra scutellata</i> Dana, 1848 Family Porcellidiidae Boeck, 1865 Genus <i>Porcellidium</i> Sars, 1904 <i>Porcellidium viride</i> (Philippi, 1840) Family Tisbidae Stebbing, 1910 Genus <i>Sacodiscus</i> Wilson, 1926 Genus <i>Sacodiscus littoralis</i> (Sars, 1904) Family Tegastidae Sars, 1904 Genus <i>Parategastes</i> Sars, 1904 <i>Parategastes</i> sp. Family Canthocamptidae Sars, 1906 Genus <i>Bryocamptus</i> Westwood, 1836 <i>Bryocamptus</i> sp. (Copepodid II) Family Cylindropsyllidae Sars, 1909 Genus <i>Arenopontia</i> Kunz, 1837 <i>Arenopontia indica</i> Rao, 1967 (stage) Family Diosaccidae Sars, 1906 Genus <i>Metamphiascopsis</i> Thompson and Scott, 1903 <i>Metamphiascopsis hirsutus</i> (Thompson and Scott, 1903) Family Miraciidae Dana, 1846 Genus <i>Miracia</i> Dana, 1846 <i>Miracia efferata</i> Dana, 1852 Genus <i>Macrostellata</i> A. Scott, 1909 <i>Macrostellata gracilis</i> (Dana, 1847) Famils Laophontidae Scott, 1905 Genus <i>Laophonte</i> Philippi, 1840 <i>Laophonte cornuta</i> Philippi, 1840 Order Poecilostomatoida Thorell, 1859 Family Chondracanthidae Milne Edwards, 1840 Genus <i>Protochondracanthus</i> Kirtisinghe, 1950 <i>Protochondracanthus</i> sp. Family Clausidiidae Embleton, 1901 Genus <i>Conchylurus</i> Bocquet and Stock, 1957 <i>Conchylurus maximus</i> Reddiah, 1960 Family Corycaeidae Dana, 1852 Genus <i>Corycaeus</i> Dana, 1845 <i>Corycaeus crassiusculus</i> Dana, 1891	Ali Khan, 1998 Ali Khan, 1998 Gololobov and Grobov, 1970  Gololobov and Grobov, 1970  Ali Khan, 1998  Kazmi and Naushaba, 2000  Kazmi and Naushaba, 2000  Kazmi and Muniza, 1994  New record Tirmizi and Sadiq, 1995  Kazmi and Naushaba, 2000  Kazmi and Naushaba, 2000  Kazmi and Naushaba, 2000  Sadiq, 1996  Kazmi and Muniza, 1994  Sewell, 1948  New record  Ghani and Ali, 1996b  Khan, 1977  Haq <i>et al.</i> , 1973	Oceanic, surface Offshore Shelf  Shelf, epipelagic  Offshore, coastal  Psammonic  Offshore  Offshore, inshore, sand  Phytal Phytal  Phytal  Psammonic  Psammonic  Phytal  Offshore, inshore  Coastal  Phytal  Parasitic  Parasitic  Shelf, epipelagic

<i>Corycaeus flaccus</i> Giesbrecht, 1892 Family Oncaeidae Giesbrecht, 1893 Genus <i>Oncaea</i> Philippi, 1943 <i>Oncaea media</i> Giesbrecht, 1891 <i>Oncaea conifera</i> Giesbrecht, 1891 <i>Oncaea vanusta</i> Philippi, 1843 Family Sapphirinidae Thorell, 1860 Genus <i>Copilia</i> Dana, 1849 <i>Copilia mirabilis</i> Dana, 1852 Genus <i>Sapphirina</i> Thompson, 1829 <i>Sapphirina gemma</i> Dana, 1849 Order Siphonostomatoidea Thorell, 1859 Family Caligidae Burmeister, 1834 Genus <i>Caligus</i> Muller, 1785 <i>Caligus punctatus</i> Shiino, 1955 <i>Caligus diaphanus</i> Nordman, 1832 <i>Caligus robustus</i> Bassett. Smith, 1898 Genus <i>Paralebion</i> Wilson, 1911 <i>Paralebion elongatus</i> Wilson, 1911 Family Pennelliidae Burmeister, 1834 Genus <i>Lernaenicus</i> Le Sueur, 1824 <i>Lernaenicus hemirhamphi</i> Kirtisinghe, 1933  Order Monstrilloidea Sars, 1901 Family Monstrillidae Dana, 1849 Genus <i>Cymbasoma</i> Thompson, 1888 <i>Cymbasoma williamsoni</i> Khan, 1976  <i>Cymbasoma tirmizii</i> Khan and Kamran, 1975  <i>Cymbasoma rigidum</i> Thompson, 1888  Superorder Podoplea Giesbrecht, 1882 Order Misophrioida Gurney, 1933 Family Misophriidae Brady, 1878 Genus <i>Benthomisophria</i> Sars, 1909 <i>Benthomisophria palliata</i> Sars, 1909 Order Cyclopoida Burmeister, 1834 Family Oithonidae Dana, 1852 Genus <i>Oithona</i> Baird, 1843 <i>Oithona plumifera</i> Baird, 1843	Haq <i>et al.</i> , 1973  Kazmi and Naushaba, 2000 Haq <i>et al.</i> , 1973 Sewell, 1948  New record  Muniza, 1988 (unpublished thesis)  Sadiq, 1995 Niazi and Ahmed, 1973a Niazi and Ahmed, 1973a  Ali, 1995  Niazi and Ahmed, 1973b, Ghani and Ali, 1996a  Khan, 1976 Khan and Kamran, 1975 Khan <i>et al.</i> , 1988  Ali Khan, 1993c  Haq <i>et al.</i> , 1973	Shelf, epipelagic  Planktonic, associated Epipelagic Epiplagic-bathypelagic  Inshore  Coastal, inshore  Parasitic Parasitic Parasitic  Parasitic  Parasitic  Endoparasitic naupliar and planktonic adult Endoparasitic naupliar and planktonic adult Endoparasitic naupliar and planktonic adult  Offshore, bathypelagic  Shelf, epipelagic
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## GENERAL FEATURES OF MATERIALS DISCUSSED

### 1. Shelf species

In the northwestern sector where high productivity was recorded (Gololobov and Grobov, 1970) the predominant organisms were the Calanidae, having different generic compositions from the previous check lists.

### 2. NASEER samples

Numerically, copepods were by far the most dominant group in the NASEER samples in the northeast

monsoon cruise ranging from 12,290-58,214/10 m<sup>2</sup> and in the southwest monsoon (cruise 1), copepods were the second most abundant, ranging between 8,600 and 52,474/10 m<sup>2</sup> (Amjad *et al.*, 1995).

In all 27 genera and 39 species were identified. Percentages of copepods among all zooplankters was calculated for all of NASEER (I) 32 samples, which was on average 75.30%. The highest value (93.79%) was at station 57B between the coast of Makran (Pakistan) and Oman coast and the lowest value (38.45%) was very near the Oman coast. The four copepod groups showed different distributional patterns. The calanoids were numerically highest (92.09%) in the central Arabian Sea station (St. 24) during the day and lowest (47.61%) at station (St. 49)

opposite to Oman coast. In contrast, the percentage of harpacticoids was highest (0.70%) at St. 60 opposite the Makran coast and lowest (0.02%) in the central Arabian Sea station (33C) during the day. The cyclopoids were most abundant (15.16%) at St. 37 and lowest (0.04%) near the Makran coast. The poecilostomatoids occurred in their highest percentage (46.78%) at station 57A (D) and lowest (7.76%) in the central Arabian Sea. The cyclopoids highest percentage (15.16%) was at St. 37(N) and lowest at St. 62 (0.04%). A total of 17 families, identified and arranged in order of frequency of occurrence at all stations occupied during NASEER I, are: Paracalanidae, Calanidae, Corycaeidae, Euchaetidae, Oncaeidae, Eucalanidae, Metridinidae, Oithonidae, Pontellidae, Sapphirinidae, Candaciidae, Centropagidae, Acartiidae, Clymnestridae, Ectinosomatidae, Miraciidae, and Temoridae.

#### DISTRIBUTION OF DIFFERENT SPECIES

*Pleuromamma indica* is not uniformly distributed in NASEER samples, maximum at St. 42(D) near Oman coast missing from Sts. 24, 27B, 27C and 53. Goswami *et al.* (1992) found this species with high densities in the northern Arabian Sea, highest near the India–Pakistan border at Kutch, whereas Razouls (1998) indicated a high density throughout much of the northern Arabian Sea. Saraswathy (1986) suggested that *P. indica* was tolerant of low oxygen concentration (as low as 0.1 ml L<sup>-1</sup>) in the northern Arabian Sea and made up 21–95% of myctophid diet (Saraswathy, 1986; Goswami *et al.*, 1992).

*Gaussia swelli* is endemic to the northern Indian Ocean particularly in the Arabian Sea and Bay of Bengal (Saraswathy, 1973).

*Acartia amboinensis* is said to be the most dominant copepod in shelf and slope regions of Pakistan (Haq *et al.*, 1973), a conclusion supported by the processing of the NASEER samples. *Acartia hamata* was collected for the first time from the northern Arabian Sea (Indian Ocean). This is an extension of range record. The present distribution of *Acartia hamata* is the Pacific Ocean.

*Pontella karachiensis* Fazal-ur-Rehman, 1973 is no longer considered endemic to Karachi. Its range now extends to India (Patel, 1975).

*Candacia samassae* was not encountered in NASEER samples, although it is considered endemic in all waters north of 10°N in the Arabian Sea (Razouls, 1998). Pillai (1967) had already pointed out its rarity in the area.

The paracalanid e.g. *Paracalanus parvus*, is the most abundant species in NASEER samples i.e. 93% of all the copepods.

The calocalanid *Calocalanus pavo* was numerically maximum at St. 37. *Rhincalanus cornutus* is very poorly represented in NASEER samples. This species is equatorial, known from the Atlantic Ocean on one hand and from the Indian and Pacific Oceans on the other. It has been reported that *R. cornutus* is geographically polytypic and actually consists of 2 populations, one restricted to the Atlantic Ocean and the other ranging through the Indian and Pacific Oceans (Fleminger and Hulsemann, 1973). The prevalence of females dominated males in *Rhincalanus* and *Subeucalanus*.

The calanids are second highest (31.47%) among the calanoids but the diversity is low. *Undinula vulgaris*, present in the samples, is a species of upwelling waters (Razouls, 1998). Different Pakistani genera reacted in different ways to the variation of the oxygen. Species that reacted worst to oxygen deficiencies in the upper layer were *Calanus minor*, *Calanus brevicornis*, *Acrocalanus gracilis*, *Lacicutia flavicornis*, and *Subeucalanus subtenius* (Gololobov and Grobov, 1970). The numbers of individuals of the predator genera *Oncaea* and *Oithona* and the phytophagous genera (*Paracalanus*, *Acrocalanus* and *Clausocalanus*) were uneven at the nearest-situated stations depending upon the predominance of upwelling (Gololobov and Grobov, 1970).

Species of *Oncaea*, *Corycaeus*, *Farranula*, *Copilia* and *Sapphirina* are not common in ONR inshore samples as already noted for the northern Arabian Sea inshore waters of Bombay (Gajbhiye *et al.*, 1991), but some of them like *Corycaeus* spp. and *Oncaea conifera* are most common epipelagic species from Pakistan offshore waters (Haq *et al.*, 1973). *Oncaea* and *Farranula* in NASEER samples were in breeding stages, either as copulated females with spermatophores or with attached egg cases. *Oncaea venusta*, although free living and pelagic, has been found on fish gills (Kazatchenko and Adeev, 1977) or in a sponge (Ho, 1984) and now from the sand (Kazmi and Naushaba, 2000).

Although six species of *Copilia* are present in the northern Arabian Sea (Sewell, 1948), only *Copilia mirabilis* was encountered in NASEER I samples with both morphs present. Sapphirinidae is the least abundant family with maximum numbers at St.33D and minimum near the Makran coast (St. 62). Five species of *Sapphirina* are reported by Sewell (1947) but NASEER I samples had only *S. gemma*, and another species has yet to be determined.

*Oithona plumifera*, sole species representing the cyclopoids, had its highest number observed in a night sample at St. 37, which is away from the Pakistan coast. *Oithona* spp. were dominant (397 individuals/m<sup>3</sup>) in shelf area (Gololobov and Grobov, 1970).

*Centropages furcatus* is present in a patchy pattern in NASEER I samples, with St. 18 having the highest numbers while nearby station (St. 15) had the lowest number. Two temorids were encountered in NASEER samples, one is still unidentified. The genus *Temora* is found in maximum numbers in the central part of the Arabian Sea. The euchaetids are the third highest in the NASEER samples, a finding that concurs with Razouls' report (1998) for the Arabian Sea. Euchaetids' maximum numbers were obtained at a station located in the Indus Cone area.

The eucalanids are present in all samples, though the density pattern is not uniform.

The Ectinosomatidae was most abundant near the Makran coast in night samples (St. 60) and the second highest (21.71%) among the harpacticoids in NASEER samples. *Clytemnestra scutellata* was the most copious (62.99%) among the harpacticoids, with the highest number at an off shore station (St. 60) in a night sample. *Miracia efferata* and *Macrosetella gracilis* are the least abundant harpacticoids.

It can be concluded that in the NASEER samples the maximum numbers of copepods were present at St. 33D. The calanoids and poecilostomatoids are present in all the samples. When comparisons are made for all the four general groups in samples from NASEER I and NASEER IV, at different stations the prevalence of species is variable. Only females represent most of the taxa as generally is the case, and if males are present, they are smaller than the females. Most of the individuals were adults, few immature copepodid stages were observed.

## 1. ONR plankton samples (1993-1995)

The plankton sample analysis revealed that copepods were generally higher in number at the surface than at the subsurface level of Manora Channel waters. In an earlier study from the same area (Nayeem, 1993) two peaks of copepods were reported. The distribution of copepods in the Manora Channel may be influenced by the circulation water, nutrients and contamination of water since this channel receives a large quantity and variety of effluents from Karachi City through the sewage outfall of the River Lyari and from oil waste discharge. The stratification and stability of the seawater does not allow for vertical mixing (Rizvi *et al.*, 1995).

## 2. ONR meiobenthic samples (1998-2000)

A literature survey indicated that no such type of study had been done before in our coastal areas. During recent years, two different projects for meiobenthic

surveys on sandy and backwater mangrove areas respectively, were conducted. The copepod densities in the mangrove area were lower in pre-monsoon and southwest monsoon seasons and were higher with more harpacticoids found in northeast monsoon season (Qureshi and Sultana, 2000).

The difference in the species composition at Buleji and Sandspit area is due to differences in the beach slopes and distribution of grain size (Fig. 1). The Sandspit is a major recreational attraction for the residents of Karachi. Consequently, this collection site for ONR samples at Sandspit was purposely chosen for its location in the vicinity of a large fishing village (Kakka Village) and hence considerable human pressure was expected. The abundance and diversity of copepods (both adult and larvae) in the coming months may be correlated with the changes of size in sand grains at Sandspit in the months of April and May, with a slight increase in the salinity. The harpacticoids usually dominated the populations. Some species, which are either planktonic or seem to be phytal, were trapped in the sediments. The maximum numbers of copepod larvae were observed in July and adults observed were in September (Fig. 2). Nauplii of Diossacidae were dominant in the sand samples in the month of August.

*Parategastes*, a phytal genus which was screened out of the sand samples, was surprisingly not reported from the algae by Ghani and Nawaz (2000).

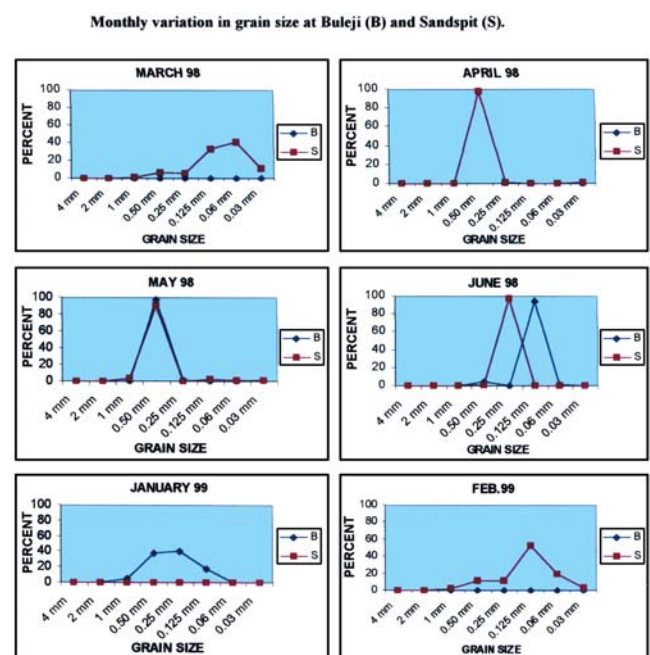


Fig. 1. Monthly variation in grain size at Buleji (B) and Sandspit (S).

### 3. ONR phytal species

The search for phytal species can be divided into two phases, one from 1993-1995 on the coast and the other from 1998-2000 in the mangrove area of Manora Island near Karachi.

During the first phase copepods were found in associations with *Caulerpa racemosa*, *Galaxura* sp., *Ulva fasciata*, *Sargassum swartzii*, *Laurentia* sp., *Corallina*, *Colpomenia*, and *Hypnea maciformis*. The results of 1995 analysis showed that the abundance (%) of epifaunal copepods among the other epifauna was the highest (43.20%) on *Caulerpa racemosa* at Bulleji in April and on *Galaxura* sp. at Korangi Creek in May (47.05%), on *Ulva fasciata* at Pacha (75.80%) and on *Sargassum swartzii* at the same place in November (35.66%). *Sargassum swartzii* at Bulleji in the same month had a more or less similar percentage (37.26%). *Laophonte cornuta* was collected from *Laurentia* at Cape Monze, *Metamphiascopsis hirsutus* from *Corallina* sp., *Laurentia* sp. and *Hypnea maciformis* at Pacha, *Porcellidium fimbriatum* and *Caligus* sp. from *Corallina*, *Sargassum*, *Caulerpa*, *Colpomenia* and *Ulva* from different localities.

During the second phase, *Ulva reticulata* and *Enteromorpha inestinalis* were collected from mangrove area. Copepods were second highest to amphipods in all the samples except those from *Enteromorpha*

in June, 1999 and January 2000 (Ghani and Nawaz, 2000).

### CONCLUSION

A conclusion can not be drawn regarding the species composition that is different in all the available lists (Sewell, 1948; Gololobov and Grobov, 1970; Ali Khan, 1998; NASEER samples and Razouls' 1998 IND 16). In the present checklist, the taxonomy in Sewell's and Ali Khan's lists has been updated to match Razouls' taxa of 1993. Nevertheless, for many reasons the species compositions are not comparable. For example, most of the available older data from the area under investigation primarily cover the large calanoid copepods of the 0-200 m strata, thus under-representing the inshore water planktonic and benthic copepods and smaller species. In addition, Soviet research vessels in the Arabian Sea collected throughout the northern and central Arabian Sea but, except for a few reports, the results are either unpublished or written only in Russian and are generally unavailable. Another reason may be that the Arabian Sea is a distinctive pelagic habitat in some respects and as a result there are distinctive hydrographic subregions, as indicated by the uneven distribution patterns of *Candacia* and *Paracandacia* (Lawson, 1977). Physical forces, monsoon reversal, and low oxygen levels can influence distribution and species composition.

Because enumeration of the Indian Ocean plankton samples of the entire copepods assemblage from samples collected previously within a defined region and season, has not been done before, the earlier reports leave us ill-prepared to specify with any confidence which copepod species are dominant regionally or seasonally. (taken from [www.cbl.umces.edu](http://www.cbl.umces.edu) and usglobe reports).

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These scientists helped in various ways: Dr. Hans-

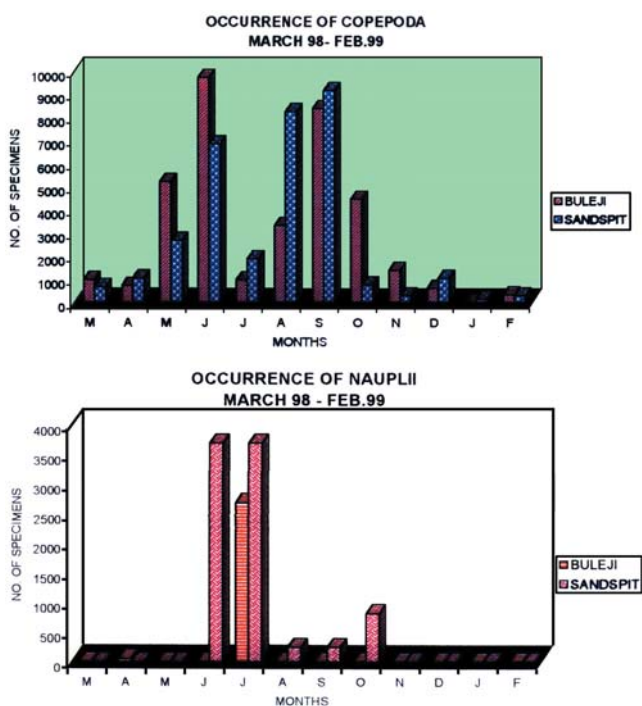


Fig. 2. Occurrence of adult copepods and nauplii collected during March 1988-Feb. 1999 from Buleji and Sandspit.

U-Dahms of Oldenburg, Germany for identification of the genus *Parategastes* and nauplii of Diosaccidae. Drs. Ju-Shey Ho, F.D. Ferrari, S. Vander Spoel, A.D. Mackinnon, C.K. Wong, T.C. Walter, H.B. Michael, G. A. Boxshall, and C. Razouls – who also allowed a free access to websites for confirmation of species, provided necessary literature and valuable suggestions on Muniza's thesis. Razia Naushaba of MRC helped in meiobenthic collection.

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