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## Introduction

Western arm of the Arabian Sea, meeting the Red Sea at the strait Babu l-Mandeb.

The gulf runs in west-east direction, between Yemen and Somalia, meeting Djibouti at the western end. It is about 900 km long, and 500 km wide at the eastern end, between Ra's Asir of Somalia and the city of al-Mukalla of Yemen.

Among the strongest atmospheric forcing of the upper water column observable anywhere in the world ocean, recurs in the Arabian Sea. Seasonally reversing monsoonal winds drive strong currents, produce complex eddy fields, deepen the mixed layer and induce both coastal and open ocean upwelling. These physical changes directly affect primary production processes but also may be expected to influence the abundance, distribution and diversity of the animals dependent upon that production. Many planned studies in the Arabian Sea provided GLOBEC investigators a chance to study zooplankton in an exhaustively detailed physical, chemical and biological way.

The purpose of this source guide, is to highlight some of the research done, and practice related to zooplankton in Arabian Sea ,Gulf of Aden, and Gulf of Oman .The information provided is mainly bibliographic information, retrieved from different resources for the period1996-2002, including articles and research reports performed at KISR. Also included an article with background information on the topic. A list of some interesting sites on the Web related to zooplankton in Arabian Sea ,Gulf of Aden, and Gulf of Oman is provided at the end of this source.

## Bibliography Articles

The following is a list of bibliographic citations related to zooplankton and Gulf of Aden, Oman and Red Sea are arranged alphabetically by author. Abstracts are provided Information was retrieved from ASFA Database.

**Ali-Khan-J; Relation of fish larvae and zooplankton biomass in the Gulf of Aden. Mar-Biol 1974 vol. 28, no. 4, pp. 311-316**

This study is based on zooplankton samples collected in the upper 50 m by the F.R.V. 'Manihine' in the Gulf of Aden during Oct-Nov 1966 and Feb- March, 1967. Generally, the displacement vol of zooplankton varied between 20 and 67 ml/m Super(2). Some higher values, up to 100 ml/m Super(2), were also observed. The number of larval fish in positive hauls ranged from 2 to 282 larvae/m Super(2). An inverse relationship between the number of larval fish and the accompanying vol of zooplankton was noted. This relationship is discussed. It is hypothesized that larval mortality due to predation in the Gulf of Aden during the northeast monsoon (Nov, Feb and March) was very high.

**Ali-Khan,-J.Relative abundance of fish larvae in the Gulf of Aden (Arabian Sea) PROCEEDINGS-OF-PAKISTAN-CONGRESS-OF-ZOOLOGY.-VOL.-13,-1993. Ahmad,-M.;Shakoori,-A.R.-eds. LAHORE-PAKISTAN ZOOLOGICAL-SOCIETY-OF-PAKISTAN 1994 vol. 13 pp. 541-554**

The present study is based on 186 zooplankton samples collected during the five cruises undertaken by "F.R.V. Manihine" in October/November 1966 and February/March 1967. All hauls were made vertically (50-0 m) employing a Hensen egg-net (73 cm phi , 330 mu ). The composition, abundance and seasonal differences of the fish larvae found in the Gulf of Aden are described. Out of 2166 larval fish, 92% were classified into 50 families. Forty four genera and 11 species could be identified. The percentage contribution of the families, genera and species has been given in detail. The differences in various seasons and months have been noted. Myctophids were represented by 14 genera and were found dominated (34.6%). These results are compared with those published by Ahlstrom (1971) and Nellen (1973).

**Ali-Khan,-J.Occurrence and distribution of fish larvae in Gulf of Aden during October-November 1966 and February-March 1967. INDIAN-J.-FISH. 1985. vol. 32, no. 2, pp. 198-**

A total of 2166 larval fishes were collected from 186 zooplankton samples taken vertically by a Hansen egg-net from the upper 50-m layer of Gulf of Aden during five cruises undertaken by P.R.V. Manihine . Of these larvae, 1991 were sorted into 51 known families. 44 genera and 11 species could be identified. Larvae belonging to the families Myctophidae, Gobiidae, Gonostomateidae, Engraulidae, Synodontidae and Serranidae together constituted 70% of the collection. The larvae of the other 45 identified families were stray, but included some commercially important taxa. The frequency of occurrence and distribution of the taxa of all the 51 families are given.

**Auras-Schudnagies Distributional pattern of planktonic foraminifers and pteropods in surface waters and top core sediments of the Red Sea, and adjacent areas controlled by the monsoonal regime and other ecological factors. DEEP-SEA-RES.-A-OCEANOGR.-RES.-PAP.. 1989. vol. 36, no. 10, pp. 1515-1533**

Living planktonic foraminiferal and pteropod distribution patterns in the western Arabian Sea, Gulf of Aden and Red Sea, collected during two summer cruises (1984, 1985), reflect the hydrographical system that is mainly controlled by a combination of monsoonal winds and evaporation rates. Spinose species constitute the majority of the planktonic foraminiferal assemblages in the Red Sea during both monsoonal seasons. Trends in the foraminiferal distribution in surface waters compare well with those of the sea floor, as far as larger specimens ( $> 250 \mu\text{m}$ ) are concerned, but differ for the small ones. The distribution pattern of living pteropods in the Red Sea is closely related to distinct water masses and corresponds to the distribution in top core sediments. Pteropods are absent in the sediments of the Gulf of Aden and the western Arabian Sea due to dissolution. Peak abundances of various pteropods and foraminifers indicate the presence of local upwelling processes in the Bab el Mandeb area.

**Baars,-M.A. On the paradox of high mesozooplankton biomass, throughout the year in the western Arabian Sea: Re-analysis of IIOE data and comparison with newer data Indian-J-Mar-Sci 1999 vol. 28, no. 2, pp. 125-137**

The mesozooplankton data from the northwestern Indian Ocean collected during 1962-1965 by the International Indian Ocean Expedition (IIOE; displacement volumes from vertical net catches, 330  $\mu\text{m}$  mesh, upper 200 m) showed highest biomass in the summer upwelling areas of Oman and Somalia but also suggested that zooplankton stocks were relatively large outside the SW monsoon. Catches by 200  $\mu\text{m}$  nets off Oman (1963/64), Yeman (1984/85) and Somalia (1992/93) confirmed that mean biomass during winter is considerably above the level that is found in water with the typical tropical structure. In the Gulf of Aden, the NE monsoon is even the richest zooplankton season. This is due to winter cooling, with entrainment of nutrients into the upper layer, producing phytoplankton blooms. The relatively high zooplankton biomass outside the upwelling season seems less paradoxical since seasonal differences in phytoplankton production and stock are less extreme than previously thought.

On the one hand the early super(14)C data underestimated primary production outside the SW monsoon, and on the other hand the CZCS images exaggerated the chlorophyll concentration during the SW monsoon. The productivity in the strong Somali Current upwelling is below potential due to large advection and mixing, and zooplankton stocks in July are probably much smaller than off Oman. Results from an Arabian Sea model [McCreary et al., Progr. Oceanogr. 37 (1996) 193], including zooplankton biomass and grazing, support the observation that zooplankton development differs between subregions

and that entrainment blooms produce zooplankton peaks during the NE monsoon as well. The IIOE data set seems still useful for comparison with existing and recently collected data from smaller-meshed nets, and for validation of JGOFS Arabian Sea modelling. Displacements from 330 and 230  $\mu\text{m}$  catches were strikingly similar (RV Discovery 1963/64). In catches from hauls with a 50  $\mu\text{m}$  net, the 50-300  $\mu\text{m}$  fraction only added about 25% to the biomass > 300  $\mu\text{m}$  (samples without contamination by phytoplankton, RV Baldrige 1995).

**Baars,-M.A.; Zooplankton biomass in the upper 200 m in and outside the seasonal upwelling areas of the Western Arabian Sea Pelagic-Biogeography-ICoPB-II- Proceedings-of-the-2nd-International-Conference-Final-report-of-SCOR; IOC- Working-Group-93-'-Pelagic-Biogeography'--Noordwijkerhout,-The-Netherlands,-9-July-14-July-1995 Pierrot-Bults,-A.C.-(ed.); Spoel,-S.-van-der-(ed.) Paris-France UNESCO 1998 no. 142, pp. 36-49**

The seasonal variation of productivity in the northwestern Indian Ocean is among the largest of oceans on the planet. The typical tropical structure predominates only part of the year, especially during the spring intermonsoon. During the southwest monsoon (June-September), upwelling occurs in almost the entire western Arabian Sea, giving high primary productivity and vast diatom blooms, especially off Oman. During the autumn intermonsoon, oligotrophic conditions slowly return, but during the northeast monsoon (December-March) winter cooling may imply the entrainment of new nutrients into the upper layer during windy periods, resulting in blooms of phytoplankton >3  $\mu\text{m}$  in the northern Arabian Sea and in the Gulf of Aden. The winter monsoon seems a much more productive season than indicated by primary production data from IIOE 1959-1965 and INDEX 1979, probably due to the fact that these early measurements were before the introduction of clean techniques. The relatively rich winter conditions may partly explain the 'Arabian Sea Paradox': the high zooplankton abundance outside the upwelling season. Collections in the upper 200 m by 330  $\mu\text{m}$  nets during IIOE, INDEX and NIOP 1992-1993 surprisingly showed no significant difference in mesozooplankton biomass between the SW and NE monsoons. However, good data sets for winter-summer comparisons are only available for the Somali Current area, showing interannual variation. It is suggested that off Somalia during summer, phytoplankton development in the upwelled waters is often below potential maximum, due to the high current speed and mixing velocities. On the other hand, the mesh size used could have led to underestimates of zooplankton biomass. Nets of 200  $\mu\text{m}$ , the mesh size recommended by JGOFS, were used both during INDEX and NIOP, in addition to the 330  $\mu\text{m}$  nets. Taxonomic analysis of these 200  $\mu\text{m}$  catches off Somalia revealed little difference of the numbers of calanoid and cyclopoid copepods between March and July 1979. A much larger change was noted July 1992-January 1993, with calanoids dropping from over 1000 to 200/m<sup>3</sup> and cyclopoids from 500 to 100/m<sup>3</sup>. In the Gulf of Aden a reversed seasonal pattern occurred, with higher numbers during winter. Re-analysis of data from 200  $\mu\text{m}$  catches off Yemen during 1984 also showed that zooplankton biomass in the Gulf of Aden is generally large during winter. Published IIOE data (330  $\mu\text{m}$ ) for the upwelling areas off Oman are virtually limited to the period June-November. New collections (by 150 and 200  $\mu\text{m}$  nets) during the JGOFS Arabian Sea Process Study (1994-1996) should complete the

annual pattern off Oman. Interestingly, results from a four-component model for the western Arabian Sea (McCreary, in press), including zooplankton biomass and grazing, support the surmise that the zooplankton development is different in different subareas and that winter entrainment blooms produce zooplankton peaks during the NE monsoon. Off Somalia stocks remain below potential during the upwelling season and the model generates a much larger zooplankton stock off Oman during July/August. Accordingly, preliminary data from 300  $\mu$ m catches from a GLOBEC Arabian Sea cruise during August 1995, showed a much larger zooplankton biomass off Oman than off Somalia.

**Baars,-M.A.; Seasonal fluctuations in plankton biomass and productivity in the ecosystems of the Somali current, Gulf of Aden, and southern Red Sea Large-marine-ecosystems-of-the-Indian-Ocean:-Assessment,-sustainability,-and-managemen Sherman,-K.-(ed.); Okemwa,-E.N.-(ed.); Ntiba,-M.J.-(ed.) Malden,-MA-USA Blackwell-Science 1998 pp. 143-174**

The international Indian Ocean Expedition cruises from 1959 to 1965 and the Indian Ocean experiment of 1979 showed that during the southwest Monsoon (SWM) in summer strong upwelling along the Somali coast leads to primary production at least  $1.0 \text{ g C m}^{-2} \text{ super}^{-1}$  and high plankton biomass, whereas during the Northeast Monsoon (NEM) in winter, the productivity is  $0.3 \text{ g C m}^{-2} \text{ super}^{-1}$ , but the zooplankton stock does not substantially decrease. New data was obtained during the Netherlands Indian Ocean Programme, 1992 to 1993, with cruises at the onset and at the peak of the SWM and in the NEM. Hydrography and biology in summer corresponded with earlier studies. Main upwelling occurred between 7 degree and 11 degree N, with diatom blooms and high densities of the upwelling copepod *Calanoides carinatus*. This enrichment was diluted over a vast area by the strong wind and the Somali current, into the Great whirl and along Socotra into the Arabian Sea. During the NEM, picoplankton predominated, but a deep chlorophyll maximum (DCM) was largely absent. Periods of strong wind induced relatively high upper nutrient concentrations, and most of it was consumed by heterotrophic flagellates less than 10  $\mu$ m in size. Total mesozooplankton biomass in the NEM was surprisingly large. *C. carinatus* was absent in the epipelagic zone in winter. Biomass of mesopelagic fish and crustaceans was greatest during the NEM, and increase from summer to winter in the size of lanternfish and of the swimming crab, *Charybdis smithii* suggested the occurrence of seasonal growth linked to the monsoons. In spring and summer the Red Sea and the Gulf of Aden were oligotrophic. Picoplankton was comprised of *Prochlorococcus*, with highest numbers at the DCM, and two strains of *Synechococcus*. In August, a phytoplankton bloom was encountered south of Strait Bab-el-Mandab. In winter upper layer waters were far from nitrate depleted in both the Gulf of Aden and the southern Red Sea. In the latter area, diatom blooms occurred, corroborating the high chlorophyll concentrations suggested by the coastal zone color scanner archives. Mesozooplankton biomass had doubled compared with spring and summer. The wind-induced entrainment of nutrients, favored by the low mixed-layer temperature in winter, might explain why productivity and plankton biomass during the NEM are high in these areas and in the northern Somali Basin, as compared with the eastern Banda Sea, a seasonal upwelling area with a warm, oligotrophic upper layer during winter.

**Baars,-M.A. Seasonal fluctuations in plankton biomass and productivity in the ecosystems of the Somali Current, Gulf of Aden, and southern Red Sea STATUS-AND-FUTURE-OF-LARGE-MARINE-ECOSYSTEMS-OF-THE-INDIAN-OCEAN.-A-REPORT-OF-THE-INTERNATIONAL-SYMPOSIUM-AND-WORKSHOP. Okemwa,-E.;Ntiba,-M.J.;Sherman,-K.-**

The International Indian Ocean Expeditions (IIOE) cruises from 1959 to 1965 and the Indian Ocean Experiment (INDEX) of 1979 showed that during the SW monsoon in summer, strong upwelling along the Somali coast leads to higher primary production and high plankton biomass, whereas during the NE monsoon in winter the productivity decreases, but the zooplankton stock does not substantially decrease. New data were obtained during the Netherlands Indian Ocean Programme (NIOP), 1992-1993, with cruises at the onset and at the peak of the SW monsoon, and in the NE monsoon. Hydrography and biology in summer corresponded with earlier studies. Main upwelling occurred between 7 degree -11 degree N, with diatom blooms and high densities of the upwelling copepod *Calanoides carinatus*. This enrichment was diluted over a vast area by the strong wind and the Somali Current, into the Great Whirl and along Socotra into the Arabian Sea. During the NE monsoon, picoplankton predominated but a deep chlorophyll maximum was largely absent. Total mesozooplankton biomass in the NE monsoon was surprisingly large. *C. carinatus* was absent in the epipelagic zone in winter, and diapausing populations were found at depths of 300-1500 m over a wide areas, including the entire Gulf of Aden. Biomass of mesopelagic fish and crustaceans was greatest during the NE monsoon, and increases from summer to winter in the size of lanternfish and of the swimming crab *Charybdis smithii* suggested to occurrence of seasonal growth linked to the monsoons.

**Beckmann,-W.Mesozooplankton distribution on a transect from the Gulf of Aden to the Central Red Sea during the winter monsoon. OCEANOL.-ACTA. 1984. vol. 7, no. 1, pp. 87-**

Quantitative mesozooplankton samples were taken at five locations on a transect from the Gulf of Aden to the central Red Sea during March 1979. The horizontal and vertical distribution of the species was clearly related to hydrographic features. In the Red Sea, the zooplankton standing stock decreased from south to north. Contrary to earlier reports, the largest zooplankton standing stock in both the southern and central Red Sea seems to occur in winter due to the import of organisms from the Gulf of Aden with the surface current.

**Boettger-Schnack Summer distribution of micro- and small mesozooplankton in the Red Sea and Gulf of Aden, with special reference to non-calanoid copepods MAR.-ECOL.-PROG.-SER. 1995 vol. 118, no. 1-3, pp. 81-102**

From the Gulf of Aden along a transect to the central-northern Red Sea the abundance and taxonomic composition of metazoan plankton was studied during the southwest monsoon period (summer 1987). Samples were taken with 0.055 mm mesh nets down to a maximum depth of 1050 m. In the epipelagic zone, a distinct decrease in total plankton abundance was observed from south to north, which was much more pronounced in biomass (by a factor of up to 10) as compared to numbers (by a factor of 2). This could partly be explained by differences in the taxonomic and/or size composition of the planktonic fauna. Among non-calanoid copepods, 40 out of 75 species or taxa investigated decreased in abundance from south to north. Sixteen of these species were completely absent in the central-northern area. Nineteen species or taxa, however, showed the opposite feature of a higher abundance in the central-northern Red Sea. The stations were grouped according to similarities in the taxonomic composition of non-calanoid copepods in the epipelagic zone. The following 3 geographical regions could be separated: (1) Gulf of Aden and Strait of Bab al Mandab; (2) southern Red Sea; and (3) central-northern Red Sea. In the meso- and bathypelagic zones, regional differences were not evident.

**Boettger-Schnack, The microcopepod fauna in the Gulf of Aqaba, northern Red Sea: species diversity and distribution of Oncaeiidae (Poecilostomatoida)**

A total of 23 species and three groups of form variants of oncaeid copepods have been identified, which were collected in small mesh net samples taken along a transect from the northernmost Red Sea (>27 degree N) to the Gulf of Aqaba down to a maximum depth of 800 m. Two of the species were present only in the Red Sea main basin, but were not recorded in the Gulf. By comparing the present results with previously published data from the central and southern Red Sea a first assessment of the zoogeographical distribution of Oncaeiidae in the entire Red Sea has been achieved. The species diversity of Oncaeiidae in the Gulf of Aqaba appears to be considerably lower compared to the southern Red Sea, where 31 oncaeid species and four groups of form variants have been found. The observed latitudinal gradient in species numbers of Oncaeiidae generally corresponds to the gradients observed for various other zooplankton taxa in the Red Sea. First data on the vertical distribution of oncaeid species in the Gulf are provided.

**Boettger-Schnack, -R. The microcopepod fauna in the Eastern Mediterranean and Arabian seas: A comparison with the Red Sea fauna ECOLOGY-AND-MORPHOLOGY-OF-COPEPODS. Ferrari, -F.D.; Bradley, -B.P.-eds. 1994 vol. 292-293 pp. 271-282**

Multiple opening-closing nets of 0.05 mm mesh size were employed to study the community structure and vertical distribution of microcopepods at selected stations in the Red Sea,

Arabian Sea and Eastern Mediterranean Sea down to a maximum depth of 1850 m. Calanoids, cyclopoids (*Oithona* and *Paraithona*) and poecilostomatoids (mainly *Oncaea*) were the 3 most abundant orders. In the epipelagic zone (0-100 m), these orders occurred at similar abundance levels, whereas in the meso- and bathypelagic zones the poecilostomatoid genus *Oncaea* dominated numerically by about 60-80% of all copepodids. The species diversity of *Oncaea* in the Red Sea is compared with preliminary results from the two adjacent regions. In the deep Eastern Mediterranean Sea, the number of species appears to be similar to that in the deep Red Sea and low as compared to the deep Arabian Sea. In this latter area an extremely speciose *Oncaea* fauna was found at depth below the oxygen-minimum-zone (900-1850 m). These results are related to the differences in the hydrographic conditions of these 3 areas.

**Casanova,B.-(Spatial and structural evolution on the euphausiid populations from the Antarctic to the Gulf of Aden. Invest.-Pesq.-Barc., 1980. 44(2), 377-394**

Samples collected from the Antarctic Ocean to South Africa and along the eastern Africa coast to the Gulf of Aden have enabled the authors to identify about 10,000 euphausiids belonging to 40 species. The study of their geographical distribution, completed by measures of diversity, has indicated 3 faunistic areas: an Antarctic one, with a small range of species (4 specimens from 4 species, 3 of which are cold forms and the fourth, *Euphausia hanseni*- living in the African Atlantic waters is here mentioned for the first time); a south African area, fairly diversified (24 specimens from 14 species), a meeting point principally constituted by temperate forms with immigrants from the 3 oceans; lastly, an east African area, quite diversified (228 specimens from 35 species), with strong tropical characteristics, the diversification of which according to the latitude shows the increasing complexification under the influences of waters and currents.

**Druzhinin,A.D.; Some data on snappers (Lutjanidae) from the Gulf of Aden area Vopr.-Ikhtiol., 1980 20(1), 12-19.**

*Lutjanus duodecimlineatus*, *L. lineolatus*- and *L. sebae*- occur most frequently in the area. *L. duodecimlineatus*- reach the length of 36.5 cm and the age of 4 years while *L. lineolatus*- and *L. sebae*- reached 32.5 cm and 3 years and 73.5 cm and 11 years respectively. The highest growth rate was recorded in *L. sebae*- and the lowest in *L. vaigiensis*-. The spawning of 5 snapper species was observed south of Socotra Island in March. In most individuals of *L. duodecimlineatus*, *L. lineolatus*, *L. sebae*- and *L. vaigiensis*- the fat content was very low at that time. *L. duodecimlineatus*, *L. gibbus*, *L. kasmira*, *L. lineolatus*, *L. rikulatus*- and *L. sebae*- feed on animal food and can be included among zooplankton eaters.

**Fabricius,-K.E.; Herbivory in asymbiotic soft corals SCIENCE-WASH. 1995 vol. 268, no. 5207, pp. 90-92**

A zooxanthellae-free soft coral from the Red Sea feeds almost exclusively on phytoplankton, a mode of nutrition so far unknown for corals. Herbivory was also found in three other azooxanthellate soft corals. In tropical oligotrophic waters, phytoplankton biomass density may be an order of magnitude higher than that of zooplankton. Use of this resource allows these azooxanthellate cnidarians to be highly productive in flow-exposed oligotrophic reef waters.

**Fatima,-M.Euphausiids of Somalian waters and Gulf of Aden collected in S.W. monsoon season. PAK.-J.-SCI.-IND.-RES. 1987. vol. 30, no. 12, pp. 935-937**

Fifteen species of Euphausiacea belonging to 5 genera were reported from the coastal waters of Somalia and Gulf of Aden. Ten species were found in the Gulf of Aden and eleven were collected off Somalian coast. Five species were common in the Gulf and Western Indian Ocean (0 degree -10 degree N) while 4 of these species were also reported from Red Sea. Bathypelagic species of the genus *Thysanopoda* were present off Somalian waters and absent in the Gulf Aden samples. Sex ratio and abundance are also discussed.

**Fenaux,R.-(Preliminary data on ecology of appendicularians in Gulf of Elat Isr.-J.-Zool., 1979 28(4), 177-192.**

Species and numbers of appendicularians were recorded from monthly plankton samples over 1 yr in the water off Elat. The vertical distribution of the species was determined by sampling at 3 depth levels. Twenty species were identified, including 1 genus and 5 species which are new records for the Red Sea (*Pelagopleura*- sp., *Oikopleura cornutogastra*, *Fritillaria gracilis*, *F. haplostoma*, *F. messanensis*- and *F. venusta*-). The most frequent and abundant species were: *O. longicauda*, *O. rufescens*, *F. borealis sargassi*, *O. fusiformis*, *F. formica digitata*- and

*O. graciloides*-. Significant positive correlations were found between water temperature the abundance of all these species excepting *O. rufescens*-.

**Ganichev,-P.A Assessment of primary productivity in the Arabian Sea waters by chemical parameters in periods of northeastern and southwestern monsoons The-main-results-of-YugNIRO-complex-research-in-the-Azov-Black-Sea-Region-and-the-World-Ocean-in-1994-Osnovnye-resul'-taty-kompleksnykh-issledovaniy-YugNIRO-v-Azovo-Chernomorskom-bassejne-i-Mirovom-okeane-v-1994-godu Yakovlev,-V.N.-(ed.) Kerch, YugNIRO 1995 vol. 41, pp. 94-96**

Primary production (PP) level, the Arabian Sea region, with the exception of upwelling zones, is usually characterised as oligotrophic and transitional mesotrophic. But as to zooplankton level, these waters are attributed to mesotrophic, and as to fisheries potential to productive. Non-correspondence in assessment of the PP and the higher links of trophic chain indicate the

underestimates of PP. PP is assessed using computation method, taking into account level of phosphates assimilation by phytoplankton in euphotic layer and their regeneration. Winter (north-eastern) monsoon was taken from October to April, summer (south-western) one, from June to August. For these periods average primary production indices were calculated for 1957-1992 in the centres of 2 degrees trapeziums. PP indices fluctuate within the limits of 0.11-1.65 g/m<sup>2</sup> a day in winter. The field of low indices (less than 0.50 g/m<sup>2</sup> a day) is observed in north, north-eastern and south-western parts of the region. The central area is occupied by waters with local patches of high (more than 1.50 g/m<sup>2</sup> a day) and low (less than 0.50 g/m<sup>2</sup> a day) primary production. Average PP was 0.61 g/m<sup>2</sup> a day; so this area productivity in this season is intermediate from mesotrophy to euphotrophy. Average PP indices during summer monsoon are 2.33 g/m<sup>2</sup> a day. Variations of PP indices is high, 0.37-4.84 g /m<sup>2</sup> a day. The highest indices (more than 3 g/m<sup>2</sup> a day) are observed 100-300 km away from the Arabian peninsula and along the stream of Somali upwelling waters. Local zones of less productive waters (less than 1.0 g/m<sup>2</sup> a day) were observed in eastern area, in the centre and to the north-east of Aden Gulf mouth. Both in winter and summer PP is equal to mesotrophic and even eutrophic level of zooplankton and the higher links in trophic chain.

**Getahun,-A.The Red Sea as an extension of the Indian Ocean Large-marine-ecosystems-of-the-Indian-Ocean:-Assessment,-sustainability,-and-management Sherman,-K.-(ed.); Okemwa,-E.N.-(ed.); Ntiba,-M.J.-(ed.) Malden,-MA-USA Blackwell-Science 1998 pp. 277-281**

The Red Sea is a relatively young sea, believed to have originated in the early Tertiary period, between the Eocene and Oligocene epochs. Although it was formed as a result of the expansion of the Mediterranean Sea, thus receiving its first biota from the Mediterranean Sea, it has an overwhelming similarity to the Gulf of Aden and the Indian Ocean. Formation of the Gulf of Aden, the Red Sea, and the Rift Valley of Africa was clearly associated in some way with the Carlsberg Ridge in the northwest Indian Ocean. Other data also indicate that the heat flow of the Gulf of Aden and the Red Sea are similar, being two or three times the world average and very different from results obtained from the Mediterranean sea and the Atlantic Ocean. The biota, including phytoplankton, zooplankton and fish fauna, are almost identical to the tropical Indian Ocean biota. This chapter shows the relationship between the Red Sea and the Indian Ocean with respect to geophysical, chemical, and biologic phenomena, with special attention being paid to the evolution and spread of the Red sea fish fauna.

**Gibson,-V.R.;Zooplankton investigations in Gulf waters north and south of the Straits of Hormoz. PROCEEDINGS-OF-THE-SYMPOSIUM-ON-THE-COASTAL-AND-MARINE-ENVIRONMENT-OF-THE-RED-SEA,-GULF-OF-ADEN-AND-TROPICAL-WESTERN-INDIAN-OCEAN,-KHARTOUM,-9-14-JANUARY-1980.-VOLUME-2. 1980. pp. 501-517**

Quantitative zooplankton (23 samples) and (34 samples) collections were made throughout the Gulf north of the Straits of Hormoz and at several places in the Gulf of Oman in spring

1977. Zooplankton biomass in the oblique tows ranged from 0.11 to 2.00 cc/m identical with 3 and .52 to 2.27. cc/m sub(3) the waters north and south of Straits respectively. Significantly higher volumes were recorded from the gulf of Oman. The numerical abundance of zooplankton varied from 79 to 5098/m super(3). Copepods comprised 50% of the plankton in over one-half of the collections. The highest zooplankton columns occurred in the central area and there were no significant differences in the quantities of zooplankton between day and night. Thirteen species of pontellid copepods were identified in neuston samples, including eight species that represent new records. (Publ. in coop. with UNESCO Div. of Marine Sciences, Paris (France); Saudi-sudanese Red Sea Joint Comm., Jeddah (Saudi Arabia)).

**Gibson,-V.R.; Zooplankton investigations in Gulf waters north and south of the Straits of Hormoz. PROCEEDINGS-OF-THE-SYMPIOSIUM-ON-THE-COASTAL-AND-MARINE-ENVIRONMENT-OF-THE-RED-SEA,-GULF-OF-ADEN-AND-TROPICAL-WESTERN-INDIAN-OCEAN,-KHARTOUM,-9-14-JANUARY-1980.-VOLUME-2. 1980. pp. 501-517**

Quantitative zooplankton (23 samples) and (34 samples) collections were made throughout the Gulf north of the Straits of Hormoz and at several places in the Gulf of Oman in spring 1977. Zooplankton biomass in the oblique tows ranged from 0.11 to 2.00 cc/m identical with 3 and .52 to 2.27. cc/m sub(3) the waters north and south of Straits respectively. Significantly higher volumes were recorded from the gulf of Oman. The numerical abundance of zooplankton varied from 79 to 5098/m super(3). Copepods comprised 50% of the plankton in over one-half of the collections. The highest zooplankton columns occurred in the central area and there were no significant differences in the quantities of zooplankton between day and night. Thirteen species of pontellid copepods were identified in neuston samples, including eight species that represent new records. (Publ. in coop. with UNESCO Div. of Marine Sciences, Paris (France); Saudi-sudanese Red Sea Joint Comm., Jeddah (Saudi Arabia)).

**Godeaux,-G.Distribution of Thaliacea on a transect from the Gulf of Aden to the Central Red Sea during the winter monsoon (March 1979 OCEANOL.-ACTA. 1987. vol. 10, no. 2, pp. 197-204).**

Ten vertical samplings were carried out at five different stations. Eight species of Salps and six species of Doliolids were collected and their distribution examined. No Pyrosoma was caught. Catches below 100 m were not very numerous. Several species of Salps and Doliolids

known from the northern Red Sea and its appendages were present in the catches: *Brooksia rostrata*, *Ritteriella amboinensis*, *Iasis zonaria*, *Thalia cicar*, *Salpa cylindrica*, *Doliolina indicum*, *D. muelleri*, *D. krohni*, *Doliolum nationalis* and *D. denticulatum*. *Doliolina indicum*, common in the northern part of the Sea and in the Gulf of Aqaba, was the most frequently caught species of Doliolid. *Pegea confoederata*, a new record, was locally very abundant. The standing stock of Thaliacea was very low, except at the N'Djebel Tair and Commission Plain stations.

**Herring,-P.J.; The vertical distribution of biomass in the Arabian Sea near Oman (19 degree N, 59 degree E) during the southwest monsoon, and its relation to the oxygen minimum Southampton Oceanography Centre Empress Dock, European Way, Conference-Final-report-of-SCOR; IOC-Working-Group-93-'-Pelagic-Biogeography'-- Noordwijkerhout,-The-Netherlands,-9-July-14-July-1995 Pierrot-Bults,-A.C.-(ed.); Spoel,-S.-van-der-(ed.) Paris-France UNESCO 1998 no. 142, pp. 171-175**

An oceanic station off the coast of Oman, at 19°N 59°E, was sampled with an RMT1+8 midwater trawl system in August 1994, during the southwest monsoon. Day and night samples were taken (at 100 m depth intervals) to a maximum depth of 1000 m. The vertical distribution of the zooplankton and micronekton were compared with that of the very intense oxygen minimum layer extending from about 100-1000 m. Additional samples were taken between 1200 m and 1800 m, at the lower margin of the oxygen minimum. Overall biomass levels were relatively low, with the highest RMTS values in the top loom both by day and by night. The RMT8 standing stock under 1 m super(2) in the upper 1000 m was 9.65g by day and 5.69g by night (based on wet volume). These values are low compared with the NIOZ RMTS data for more southerly stations. In the daytime series a secondary biomass peak was

present at 300-400 m largely attributable to myctophid and gonostomatid fish. Increased biomass levels of both fish and decapod crustaceans occurred by day at 900-1000 m and slight increases in biomass were found at 1200-1400 m. It is clear that a substantial part of the midwater population spends much of its time in the dysoxic layer. For some of the mesopelagic crustaceans this is correlated with an increase in gill area. Similar respiratory adaptations are likely to be present in other animals. Additional RMT1+8 stations were worked over the slope in about 500 m depth and on the shelf edge (200 m). The shelf edge samples were dominated by medusae and the daytime slope samples were very clearly stratified. At night very few animals remained below the oxycline. Swimming crabs were abundant in the upper loom.

**Karbe,-L Plankton investigations in an exposed reef of the Central Red Sea (Shaab Baraoa, Sudan PROCEEDINGS-OF-THE-SYMPIOSIUM-ON-THE-COASTAL-AND-MARINE-ENVIRONMENT-OF-THE-RED-SEA,-GULF-OF-ADEN-AND-TROPICAL-WESTERN-INDIAN-OCEAN,-KHARTOUM,-9-14-JANUARY-1980.- VOLUME-2. 1980. pp. 519-539).**

As a part of a research programme on the interdependences between the offshore pelagic and the coastal reef environment, plankton investigations were carried out during a Reef Survey in October 1977 at Shaab Baraja, an exposed reef South of Ras Abu Shagara (Sudan). Seston, chloroplatic pigments and phytoplankton were found to be homogeneously distributed with no significant differences between fore reef and lagoon. Zooplankton biomass and species diversity were found to be higher during the night than during the daytime. The results of the plankton investigations at Shabb Baraja Reef are discussed with respect to observations on standing stock and vertical migrations of the oceanic Red Sea zooplankton. (Publ. in coop.

with: UNESCO Div. of Marine Sciences, Paris (France); Saudi-Sudanese Red Sea Joint Comm., Jeddah (Saudi Arabia))

**Khalil,-M.T.Abundance and diversity of surface zooplankton in the Gulf of Aqaba, Red Sea, Egypt J.-PLANKTON-RES. 1997 vol. 19, no. 7, pp. 927-936**

Surface zooplankton were studied in Egyptian coastal waters of the Gulf of Aqaba, from bimonthly samples from July 1994 to May 1995. Species diversity, numerical abundance and dynamics were analysed for each taxon, at six sites, inside three Protectorates. A total of 62 taxa and species were identified. At all sites, copepods were predominant in the standing crop with an average of 1945 ind. m<sup>-3</sup> and formed similar to 75.5%, numerically, of the total zooplankton community. The meroplanktonic larvae occupied the second rank and they constituted similar to 19.7% of the total zooplankton. Seasonally, the main peak of zooplankton abundance was recorded in winter (January) with an average of 3510 ind. m<sup>-3</sup>, while September was characterized by the lowest density (1906 ind. m<sup>-3</sup>). The relatively higher diversity values were recorded at Ras Mohammed Protectorate and a progressive decline in diversity was observed northward.

**Kleijne,-A.; Phytoplankton and foraminiferal frequencies in northern Indian Ocean and Red Sea surface waters. NETH.-J.-SEA-RES. 1989. vol. 24, no. 4, pp. 531-539**

This paper describes the distribution patterns of living planktonic foraminifers, coccolithophorids and picocyanobacteria along an east-west traverse in northern Indian Ocean and Red Sea surface waters during the southwestern monsoon. Both carbonate producing foraminifers and coccolithophorids increase in number with improved nutrient availability in the upwelling areas. Their relative frequencies in sediments underlying the upwelling zones will reflect the varying upwelling conditions, caused by fluctuations in monsoonal atmospheric circulation, and thus allow for the reconstruction of past climatic change in this area.

**Leakey,-R.J.G, Planktonic ciliates in the northwestern Indian Ocean: Their abundance and biomass in waters of contrasting productivity J.-PLANKTON-RES. 1996 vol. 18, no. 6, pp. 1063-1071**

The abundance and biomass of planktonic ciliates in the northwestern Indian Ocean ranged from 31/l and 0.1  $\mu$ g C/l in oligotrophic open-ocean waters to 823/l and 1.2  $\mu$ g C/l in more productive waters of the equator, northern Arabian Sea and Gulf of Oman.

**Lenz,-J.Zooplankton biomass and its relation to particulate matter in the upper 200 m of the Arabian Sea during the NE monsoon. The-Biology-of-the-Indian-Ocean-Proceedings-of-a-SCOR; IBP-PM; Unesco-; FAO; IABO-Symposium Zeitzschel,-B.- (ed.); Gerlach,-S.A.-(ed.) Berlin Springer-Verlag 1973 vol. 3, pp. 239-241**

Biomass measurements were made to give information about food webs. Zooplankton biomass was determined from formalin preserved samples. There are many methodological problems in the determination of the zooplankton biomass which complicates attempts for a world wide comparison. Zooplankton biomass results are tabulated. A comparison is made between displacement vol and dry wt methods. The amount of organic matter in a zooplankton sample is used as a rough measure of the energy transfer to the next level in the food chain. Seston was measured by filtering 2-4 l of water. Zooplankton is stated to be on average 4 times as abundant near the Gulf of Oman but the increase of seston is only light.

**Lenz,-J Planktological data from the central Red Sea and the Gulf of Aden R.V. Meteor , cruise No. 5/2, January-March 1987. BER.-INST.-MEERESKD.-CHRISTIAN-ALBRECHTS-UNIV.-KIEL. 1988. no. 180, 200 pp**

The volume presents planktological data obtained during cruise No. 5, leg 2 of the German research vessel "Meteor " to the Red Sea and the Gulf of Aden in February/March 1987. The following parameters were measured: seston, particulate organic carbon and nitrogen; chlorophyll a; primary production; abundance of pelagic bacteria, heterotrophic nanoflagellates and the blue-green alga *Synechococcus* spp.; growth and grazing of bacteria and nanoflagellates; respiration, nutrient excretion, standing stock and chemical composition of the plankton community in three different size classes within the euphotic zone; biomass of zooplankton; 100  $\mu$  m sampled at 5 depth intervals down to 500 m.

**McCreary,-J.P.,Jr A four-component ecosystem model of biological activity in the Arabian Sea PROG.-OCEANOGR. 1996 vol. 37, no. 3-4, pp. 193-240**

A coupled, physical-biological model is used to study the processes that determine the annual cycle of biological activity in the Arabian Sea. The physical model is a 2 one half -layer system with a surface mixed layer imbedded in the upper layer, and fluid is allowed to move between layers via entrainment, detrainment and mixing processes. The biological model consists of a set of advective-diffusive equations in each layer that determine the nitrogen concentrations in four compartments: nutrients, phytoplankton, zooplankton and detritus. Coupling is provided by the horizontal-velocity, layer-thickness, entrainment and detrainment fields from the physical solution. Surface forcing fields (such as wind stress and photosynthetically active radiation) are derived from monthly climatological data, and the source of nitrogen for the system is upward diffusion of nutrients from the deep ocean into the lower layer. Our main-run solution compares favorably with observed physical and biological fields; in particular, it is able to simulate all the prominent phytoplankton blooms visible in the CZCS data. Three bloom types develop in response to the physical processes of upwelling, detrainment and entrainment. Upwelling blooms are strong, long-lasting events that continue as long as the upwelling persists. They occur during the Southwest Monsoon off Somalia, Oman and India as a result of coastal alongshore winds, and at the mouth of the Gulf

of Aden through Ekman pumping. Detrainment blooms are intense, short-lived events that develop when the mixed layer thins abruptly, thereby quickly increasing the depth-averaged light intensity available for phytoplankton growth. They occur during the fall in the central Arabian Sea, and during the spring throughout most of the basin. In contrast to the other bloom types, entrainment blooms are weak because entrainment steadily thickens the mixed layer, which in turn decreases the depth-averaged light intensity. There is an entrainment bloom in the central Arabian Sea during June in the solution, but it is not apparent in the CZCS data. Bloom dynamics are isolated in a suite of diagnostic calculations and test solutions. Some results from these analyses are the following. Entrainment is the primary nutrient source for the offshore bloom in the central Arabian Sea, but advection and recycling also contribute. The ultimate cause for the decay of the solution's spring (and fall) blooms is nutrient deprivation, but their rapid initial decay results from grazing and self shading. Zooplankton grazing is always an essential process, limiting phytoplankton concentrations during both bloom and oligotrophic periods. Detrital remineralization is also important: in a test solution without remineralization, nutrient levels drop markedly in every layer of the model and all blooms are severely weakened. Senescence, however, has little effect: in a test solution without senescence, its lack is almost completely compensated for by increased grazing. Finally, the model's detrainment blooms are too brief and intense in comparison to the CZCS data; this difference cannot be removed by altering biological parameters, which suggests that phytoplankton growth in the model is more sensitive to mixed-layer thickness than it is in the real ocean.

**Near,-D.H.Coastal plankton fauna of the Sudanese Red Sea. PROCEEDINGS-OF-THE-SYMPOSIUM-ON-THE-COASTAL-AND-MARINE-ENVIRONMENT-OF-THE-RED-SEA,-GULF-OF-ADEN-AND-TROPICAL-WESTERN-INDIAN-OCEAN,-KHARTOUM,-9-14-JANUARY-1980.-VOLUME-2. 1980. pp. 561-581**

Plankton samples were taken at monthly intervals during the period April 1972 to March 1973 from three stations at Dongonab bay (21 degree N) and one station at the coastal lagoon of Suakin (19 degree N). The maximum plankton abundance as determined by volume haul was recorded during April 1972, February and March 1973 at the four stations; yet the respective maxima of various stations differed. Further, the volumetric fluctuations throughout the year differed between the stations. The samples were composed mainly of zooplankton with very little phytoplankton. From the yearly percentage composition of plankton, the top sixteen groups at each station showed that six of these groups were common to all the stations while the remaining ten groups were common to only some of the stations. (Publ. in coop. with: UNESCO Div. of Marine Sciences, Paris (France); Saudi-Sudanese Red Sea Joint Comm., Jeddah (Saudi Arabia)).

**Ponomareva,-L.A. (Euphausiids of the Indian Ocean and the Red Sea). Moskva-USSR Nauka 1975 84 p.**

The study is mainly based on euphausiid material from 2390 plankton samples collected in the Indian Ocean during Oct-March 1959/60 and 1960/61. Data are presented on the sp composition, biology, vertical and quantitative distribution. The northern Indian Ocean (as far south as 40{degree}S) is inhabited by typically tropical euphausiid fauna. The area most rich in euphausiids is the Arabian Sea. The spp most commonly occurring in the 0-200m layer in the Indian Ocean are *Euphausia diomedea*, *E. distinguenda*, *Stylocheiron carinatum* and *Thysanopoda tricuspidata*. In the northern Indian Ocean eggs and early larval stages occurred

from Jan to June (no observations were made later in the yr), which suggests that euphausiids spawn several times during the yr. The eggs develop very rapidly (within <24h) and so do early larval stages. On reaching the nauplius-2 stage the development slows down and it takes the larva 10-12 days to develop into furcilia-1. The feeding is varied and mixed: none of the spp were observed to feed on phyto- or zooplankton exclusively. Migratory spp show diurnal feeding rhythms. Most of the spp occurring in the upper layers (down to 500 m) are distinct migrants; interzonal spp do not perform significant migrations rarely rising close to the surface and almost never occurring above 50-40 m. The Red Sea is inhabited by immigrants from the Gulf of Aden and by some endemic spp. The spp abundant in the Arabian Sea are also predominant here with the addition of *S. affine*.

**Rebik,-S.T.; Chub mackerel biology and stock assessment in the area of the Somali-Arabian upwelling. African-Fishes-and-Fisheries-Diversity-and-Utilisation-Poissons-et-Peches-Africains-Diversite-et-Utilisation Coetzee,-L.-(ed.); Gon,-J.-(ed.); Kulonowski,-C.-(ed.) Grahamstown-South-Africa FISA; PARADI 1998 pp. 163-164**

In the Indian Ocean chub mackerel *Scomber Japonicus* Houttuyn 1782 (*S. australasicus* Cuvier, 1831) is found near the Seychelles, Gulf of Aden and Red Sea, and also in the coastal waters of Oman, India, Indonesia, Australia, Mozambique and South Africa. Soviet long-distance vessels examining areas of coastal monsoon upwelling in the north-western Indian Ocean found, for the first time, dense concentrations of club mackerel in 1966 near Oman, in 1975 near Somali and in 1980 near South Yemen. During YugNIRO expeditions mackerel were sampled from waters off South Yemen (northern and eastern Gulf of Aden, the Sokotra Island area) which had been successfully exploited by Soviet long-distance fisheries until 1990, since mackerel were not exploited by the fisheries. Biology, distribution, abundance and habitat were studied during hydroacoustic and oceanographic surveys. An echosounder on frequencies 19,7 and 38kHz was applied. Mackerel were caught according to hydroacoustic records with midwater trawl (vertical opening 35m; horizontal 60m). An assessment of mackerel as a commercial stock was made by means of direct registration and mathematical modelling (VPA, cohort analysis). A working hypothesis was formulated that in the Western Arabian Sea the united Afro-Arabian subpopulation of chub mackerel is an independent part of the stock. Its habitat is connected with the Arabian Sea but it is limited by the Somali current in the east. Several features of mackerel in this area exist: fingerlings live separately; young fish forage on the shelf of Yemen. Oman. Somali (Southwards to cape Guardafui) annually from September until June and form commercially valuable concentrations in depths of 40-80m down to 350-400m. The size-age structure of the fish is

rather stable; at the base are fingerlings (5%) 19-24cm long; age 1+(92%) are 15-19cm. Fish 29-32cm are at age 2+; age 3+ fish make up only 3%. Fishes of the remaining age groups (length 27-40cm, 2 to 6 years) do form concentrations from time to time in the pelagic zone, in the vicinity of Socotra Island and in the open waters of the eastern Gulf of Aden at depths over 1000m. In the coastal zone, mackerel schools 180-350m long, and 10-35m in height are distributed in the bottom layer, in daytime, in depths of 120-400 m; at 5-6 p.m. mackerel ascend along the slope of the shelf to depths of 40-80m. Mackerel feed only in daytime near gradient zones; the main food for fingerlings are species from light-dispersing layers, such as zooplankton (Euphausiidae, Copepoda, Cavoliniidae), fish of Bregmacerotidae and Mictophidae and squids of Enoploteuthidae; older fishes feed mainly on fish also in light-dispersing layers. Mackerel spawn for the first time in the second year of life; spawning is likely to begin in July-August in offshore areas of the eastern Gulf of Aden. It is assumed that until reaching age 1+ mackerel spend more than a year in an epipelagic zone of the offshore areas of the Gulf of Aden and do not mix with fish from older age groups. The relationship between length, weight and age were calculated, and co-efficients of natural mortality, fishing mortality and general mortality were defined. Mackerel fingerlings in the commercial stock from Yemen waters made up 50-70 thousand tons, in Oman 30-100 thousand tons, in Somali 250-300 thousand tons; the total stock of fingerling was 330-470 thousand tons and the whole subpopulation consisted of not less than 440-640 thousand tons. The Mackerel stock has undergone considerable fluctuations which are characteristic for inhabitants of upwelling zones. Fisheries success will depend on an efficient system of stock control.

**Reckermann,-M. Trophic interactions between picophytoplankton and micro- and nanozooplankton in the western Arabian Sea during the NE monsoon 1993 AQUAT.-MICROB.-ECOL. 1997 vol. 12, no. 3, pp. 263-273**

The grazing pressure of micro- and nanozooplankton on phytoplankton was estimated in serial dilution experiments in the northwestern Arabian Sea and its adjacent areas (the Somali Current, the Somali Basin, the Gulf of Aden and the southern Red Sea) during the NE monsoon 1992-1993. Microzooplankton grazing rates ( $g$ ) on total phytoplankton (analyzed as chl *a*) were generally exceeded by phytoplankton growth rates ( $g = 0.2$  to  $1.19$  d super(-1), mean  $0.48$  d super(-1);  $\mu = 0.52$  to  $1.12$  d super(-1), mean  $0.72$  d super(-1)), resulting in an average daily consumption of 38% of the phytoplankton standing stock and 67% of the primary production. Microzooplankton grazing on 4 picophytoplankton groups (Prochlorococcus spp., Synechococcus spp., and 2 picoeukaryotes) analyzed by flow cytometry showed growth ( $\mu = 0.27$  to  $0.92$  d super(-1), mean  $0.68$  d super(-1)) and grazing mortality rates ( $g = 0.26$  to  $0.73$  d super(-1), mean  $0.67$  d super(-1)) well in balance, with an average of 49% of the standing stock and 102% of the primary production grazed per day. Picophytoplankton growth and grazing mortality rates increased dramatically when grazers  $> 10 \mu m$  were removed. These results suggest a control of the small grazers by larger ones (trophic cascade) and a close coupling between picoautotrophic prey and small grazers. The trophic cascade within the microbial food web of the nanoplankton encompasses 3 trophic levels: picoplankton - small HNF - larger flagellates and ciliates.

**Saraswathy,-M.; Ecology of *Pleuromamma indica* Wolfenden (Copepoda-Calanoida) in the Indian Ocean. INDIAN-J.-MAR.-SCI. 1986. vol. 15, no. 4, pp. 219-222**

*Indica* was the only species among the 7 species of the genus, recorded in the area, to be present in 2 restricted areas, one near the mouth of the Gulf of Oman in the Arabian Sea and the other in the Bay of Bengal. High productivity, strong oxygen minimum above 500 m depth and a wide range of salinity varying from  $32 \times 10^3$  in Bay of Bengal to more than  $37 \times 10^3$  in the northern Arabian Sea were characteristics of the study area. *P. indica* showed a positive correlation with salinity and phosphate and a negative relationship with dissolved oxygen. The species was significantly positively correlated with salinity and phosphate. Size differences and distribution of the species are discussed.

**Schneider,-G.; (Standing stock and metabolism of ultra-, micro and mesoplankton in the Red Sea and the Gulf of Aden.).Bestand und Stoffumsatz des Ultra-, Mikro- und Mesoplanktons im Roten Meer und im Golf von Aden 1991. 167 pp**

This volume reports the results of RV Meteor cruise No. 5 leg 2 to the Central Red Sea and the Gulf of Aden in spring 1987. A total of 14 stations were investigated in the Central Red Sea (Sudanese waters) whereas only 4 stations were occupied in the Gulf of Aden. The results focus on the following three subjects. Standing stock and oxygen consumption of ultra- and micro-plankton. Biomass, size structure, and vertical distribution of zooplankton in the upper 500 m. Respiration and carbon turnover of zooplankton within the upper 200 m of the water column, the euphotic zone being distinguished from the upper mesopelagic zone. (orig./PW). (Available from TIB Hannover: RN 3292(205).) (Copyright (c) 1992 by FIZ. Citation no. 92:001594.)

**Schneider,-G.; Zooplankton standing stock and community size structure within the epipelagic zone: A comparison between the Central Red Sea and the Gulf of Aden MAR.-BIOL. 1994 vol. 119, no. 2, pp. 191-198**

Standing stock and size composition of the zooplankton community ( $>100 \mu\text{m}$ ) were studied in four depth strata of the upper 200 m of the water column during a Meteor cruise to the Central Red Sea and Gulf of Aden in spring 1987. The Central Red Sea was divided into a northern area of higher salinity and a less saline southern part. Both areas exhibited significant differences in zooplankton abundance and standing stock. The latter increased by the ratio 1:2:3 from the northern Central Red Sea to its southern part and further south to the Gulf of Aden. For size structure analysis samples were fractionated into three size classes (100 to 300, 300 to 500, 500 to 5000  $\mu\text{m}$ ). In the Central Red Sea the smallest size was dominant whereas in the Gulf of Aden the largest size fraction played a greater relative role than in the Central Red Sea. This shift in size structure of the zooplankton community from the Red Sea to the Gulf of Aden is apparently primarily related to ecosystem difference between both areas, leading to a change in species composition. In addition, size reduction of individual species common to both seas may be of some significance in the extreme environment of the Red Sea.

**Schneider,-G Zooplankton community metabolism in the upper 200 m of the central Red Sea and the Gulf of Aden. MAR.-ECOL.-PROG.-SER. 1991. vol. 77, no. 2-3, pp. 301-306**

A comparative study was conducted between the central Red Sea and the Gulf of Aden during spring in February/March 1987. Zooplankton ( $> 100 \mu\text{m}$ ) standing stock, determined as carbon and nitrogen content, and community respiration were measured in 2 layers: in the euphotic zone and in the underlying layer, the so-called lower epipelagic zone, down to 200 m. The euphotic zone exhibited a significantly higher biomass and respiration rate than the layer below. Standing stock and respiration in the Gulf of Aden exceeded those in the Red Sea by factors of 3 and 2 respectively (station means for the euphotic zone:  $10.3 \pm 1.3 \text{ mg C m}^{-3}$  and  $3.4 \pm 0.6 \text{ mg O}_2 \text{ m}^{-3} \text{ d}^{-1}$  in the Gulf of Aden;  $3.4 \pm 1.4 \text{ mg C m}^{-3}$  and  $2.6 \pm 0.9 \text{ mg O}_2 \text{ m}^{-3} \text{ d}^{-1}$  in the Red Sea). However, weight-specific respiration was highest in the Red Sea euphotic zone, amounting to an average of  $0.57 \pm 0.13 \text{ mg O}_2 \text{ mg C}^{-1} \text{ d}^{-1}$ . This corresponds to a daily carbon turnover rate of 17.2% body carbon per day whereas in the Gulf of Aden turnover averaged only 11.4% C/d.

**Schneider,-G.; On standing stock and metabolism of ultra-, micro- and mesoplankton in the Red Sea and the Gulf of Aden. BER.-INST.-MEERESKD.-CHRISTIAN-ALBRECHTS-UNIV.-KIEL. 1991. no. 205, 167 pp**

This volume reports the results of RV "Meteor" cruise No. 5 leg 2 to the central Red Sea and the Gulf of Aden in spring 1987. A total of 14 stations were investigated in the central Red Sea (Sudanese waters) whereas only 4 stations were occupied in the Gulf of Aden. The results focus on the following three subjects: Standing stock and oxygen consumption of ultra- and microplankton within the euphotic zone of both regions; biomass, size structure, and vertical distribution of zooplankton  $> 100 \mu\text{m}$  in the upper 500 m with the following depth strata: 0-25 m, 25-50 m, 50-100 m, 100-200 m, 200-500 m; respiration and carbon turnover of zooplankton  $> 100 \mu\text{m}$  within the upper 200 m of the water column, the euphotic zone being distinguished from the upper mesopelagic zone (1% light level - 200 m).

**Sharaf,-G.M. Distribution of zooplankton in offshore waters of the west coast of the United Arab Emirates KUWAIT-J.-SCI.-ENG. 1997 vol. 24, no. 1, pp. 131-144**

Seasonal fluctuations in the composition and abundance of zooplankton of the west coast of the UAE were investigated in 1993-1994. Zooplankton populations peaked in late spring and summer. The monthly numerical average of total zooplankton was about  $2740/\text{m}^3$ , with a biomass equal to  $412 \text{ mg}/\text{m}^3$ . Copepods dominated zooplankton counts accounting for about 51% of the total. Tunicates, cladocerans, mollusc larvae and chaetognaths were also dominant groups during the study, and together comprised about 31% of zooplankton. Spatial variations in abundance of almost all zooplankton species and groups were not significantly different, indicating a homogeneity in composition among stations.

Nine new geographical records, mostly copepods, were identified for the region. Species-diversity and evenness in species distribution were generally low compared to the Gulf of Oman and the Indian Ocean.

**Thiel,-H. Community structure and biomass of the benthos in the central deep Red Sea. PROCEEDINGS-OF-THE-SYMPOSIUM-ON-THE-COASTAL-AND-MARINE-ENVIRONMENT-OF-THE-RED-SEA,-GULF-OF-ADEN,-AND-TROPICAL-WESTERN-INDIAN-OCEAN,-KHARTOUM,-9-14-JANUARY-1980.-VOLUME-3. 1980. pp. 127-134**

The results of a cruise, undertaken in 1977, investigating the benthos of the Red Sea and evaluating effects of sediment mining and waste dumping are presented. The general low productivity of the Red Sea phytoplankton and zooplankton is reflected by a low standing stock of the benthos. Data indicate a decrease in benthic biomass from the base of the steep slope close to the reef with increasing depth. At the bottom, organic matter may accumulate at a high rate, possibly due to sediment slumping and organic wastes dumped from ships. (Publ. in coop. with: UNESCO Div. of Marine Sciences, Paris (France); Saudi-Sudanese Red Sea Joint Comm., Jeddah (Saudi Arabia)).

**Van-Couwelaar,-M. Zooplankton and micronekton biomass off Somalia and in the southern Red Sea during the SW monsoon of 1992 and the NE monsoon of 1993 DEEP-SEA-RES.-2-TOP.-STUD.-OCEANOGR. 1997 vol. 44, no. 6-7, pp. 1213-1234**

Spatial and seasonal variations in mesozooplankton, macrozooplankton and micronekton biomass distribution were studied in the Somali Basin and the southern Red Sea and Gulf of Aden. Cruises were made in May-June and July-August 1992 during the SW monsoon, and in January-February 1993 during the NE monsoon. Samples were taken in day and night series from stratified layers to depths of 600 or 1000 m, using an RMT1 + 8, combining two nets with mesh size of 0.34 mm and 4.5 mm, respectively. During the SW monsoon the mean zooplankton biomass from RMT1 samples (displacement volume 0-300 m, night) were low in the southern Red Sea and the Gulf of Aden, 14.0-17.5 ml m super(-2). At 11 degree N in the Somali Current, where coastal upwelling occurs, the maximum biomass value of 38.0 ml m super(-2) was recorded. Downstream from the upwelling in the Great Whirl, biomass values were lower, ranging from 21.0 to 35.9 ml m super(-2). In the Somali Basin south of 5 degree N the mesozooplankton biomass was lower than in the Somali Current and northern areas. During the NE monsoon large phytoplankton blooms occurred in the southern Red Sea and the Gulf of Aden, and the mean zooplankton biomass almost doubled to 23.9-40.2 ml m super(-2) compared with the SW monsoon. Primary production in the northern Somali Basin was much higher during the NE monsoon than recorded during earlier studies, and biomass values for the zooplankton therefore were not as low as might be expected. No statistical significant difference was found in the season's mean biomass values. This is remarkable because in the northern Somali Basin the mean phytoplankton carbon production during the NE monsoon was about two-thirds of the production during the SW monsoon. This seeming

paradox is probably due to large mesh sizes that did not retain the small size (herbivorous) zooplankton fraction present during the SW monsoon. The mean macrozooplankton and micronekton biomass from RMT8 samples (0-300 m night) in the southern Red Sea, the Gulf of Aden and the Somali Basin showed no significant seasonal difference. However, biomasses of mesopelagic fish and large crustaceans were high in the southern Red Sea during the SW monsoon, and were high in the Somali Current during the NE monsoon, whereas in the northern Somali Basin biomasses remained about the same. Biomasses of large crustaceans in the Gulf of Aden were higher during the NE monsoon. The pelagic swimming crab *Charybdis smithii* was found during the SW monsoon in the equatorial and northern Somali Basin, attaining high displacements. The species was not found in the Somali upwelling area during this season, whereas during the NE monsoon the highest displacements for *C. smithii* were recorded. Vertical profiles of biomass from RMT1 and RMT8 samples show that zooplankton and micronekton occur in the oxygen minimum zone and that the lowest oxygen concentrations in the sampled depth range (0.1-1 ml l super(-1)) do not seem to hamper diurnal vertical migration.

**Weikert,-H.** On the plankton of the central Red Sea. A first synopsis of results obtained from **PROCEEDINGS-OF-THE-SYMPOSIUM-ON-THE-COASTAL-AND-MARINE-ENVIRONMENT-OF-THE-RED-SEA,-GULF-OF-ADEN,-AND-TROPICAL-WESTERN-INDIAN-OCEAN,-KHARTOUM,-9-14-JANUARY-1980.-VOLUME-3.** 1980. pp. 135-167

The investigations on the plankton of the Red Sea reveal marked seasonal and geographic differences in the biota that are apparently related to regional peculiarities. In general, in the area of the Atlantis II Deep Central Red Sea, the phytoplankton standing stock in terms of chlorophyll A was higher in March and June 1979 than in November 1977. The primary production in 1979 showed an increase from spring (45 mgC/m super(2)d) to summer (100 mgC/m super(2)d). The oscillations observed are closely related to the availability of nutrients. Judging from the preliminary results, changes in standing stock and biomass of the zooplankton generally coincide with the seasonal variations in phytoplankton. (Publ. in coop. with: UNESCO Div. of Marine Sciences, Paris (France); Saudi-Sudanese Red Sea Joint Comm., Jeddah (Saudi Arabia)).

**Wiebinga,-C.J.;** Abundance and productivity of bacterioplankton in relation to seasonal upwelling in the Northwest Indian Ocean **DEEP-SEA-RES.-1-OCEANOGR.-RES.-PAP.** 1997 vol. 44, no. 3, pp. 451-476

The role of bacterioplankton in the Somali Current, the Gulf of Aden and the Red Sea was studied during the SW- (May-August 1992) and NE-monsoon (January-February 1993). The diversity in physical and biological characteristics of the regions and seasons is reflected in a broad range of both phyto- and bacterioplankton production. During the SW-monsoon, the Somali current showed highest bacterial production (up to 849 mgC/m super(2)/day) in regions with enrichment of the surface waters by upwelling of cold, nutrient-rich, deep water. In contrast, the Gulf of Aden and the Red Sea were most productive during the NE-monsoon

(average 225 mgC/m<sup>2</sup>/day). Depth profiles of the upper 300 m in general showed a subsurface maximum in bacterial abundance and production at 20-70 m depth. Heterotrophic activity and primary production were closely correlated, indicating the dependence of bacterioplankton on local phytoplankton-derived organic carbon and their ability to adapt quickly to changes in the environment. The bacterial carbon demand in the upper 300 m of the water column was largely supplied by phytoplankton production in the euphotic zone. Bacterial production was 18 plus or minus 7% (average plus or minus S.D.) of primary production. Assuming an assimilation efficiency of 50% for marine bacteria, they consumed up to half of the carbon produced by the phytoplankton. Cycling of carbon within the euphotic zone appears to be achieved by intense grazing by (micro)zooplankton and subsequent remineralization.

**Weisse,-T.:Bacterivory in the northwestern Indian Ocean during the intermonsoon--northeast monsoon period Deep-Sea-Research-Part-2,-Topical-Studies-in-Oceanography [Deep-Sea-Res-2-Top-Stud-Oceanogr] 1999 vol. 46, no. 3-4, pp. 795-814**

Bacterial grazing loss rates were studied by radioactive labeling of natural bacteria with L-(4,5-<sup>3</sup>H) leucine and from the rate of disappearance of bacterial cells in the northwestern Indian Ocean. Bacterivory was measured in a mixed sample that had been combined from various depths across the euphotic zone. Experiments were performed on 26 occasions at 19 stations in the Gulf of Oman and the Arabian Sea during the intermonsoon--northeast monsoon period (November--December 1994). Combined uptake of radiolabeled bacteria (ULB) in 1--8 and 8--100  $\mu$ m size fractions was somewhat lower than loss of label (LBL) measured in the bacterial fraction (0.2--1.0  $\mu$ m), suggesting loss of radioactivity from the grazers due to metabolism. The less sensitive rate of disappearance of bacterial cells (LBC) was on average 51% higher than LBL estimates. Results from ULB and LBL measurements revealed that bacterivory was higher in the Gulf of Oman (average loss rate 4.1%/h) than in the Arabian Sea where rates were slightly higher inshore (1.7%/h) than in the central gyre. Heterotrophic nanoflagellates in the 1--8  $\mu$ m size fractions were identified as the primary bacterivores. Microzooplankton (8--100  $\mu$ m) accounted for 33% of total bacterivory in the Gulf of Oman but only 16% in the central Arabian Sea. Time-course experiments conducted at two stations indicated that diel changes in bacterivory may be substantial in the northwestern Indian Ocean.

**Wolff,-G.A.Smallwood,-B.J.Molecular characterisation of organic matter in sediments underlying the oxygen minimum zone at the Oman Margin, Arabian Sea Deep-Sea-Research-Part-2,-Topical-Studies-in-Oceanography [Deep-Sea-Res-2-Top-Stud-Oceanogr] 2000 vol. 47, no. 1-2, pp. 353-375**

Lipids in replicate sediment cores collected from a transect through the oxygen minimum zone across the Oman Margin continental slope ( similar to 400, 800, 1000 and 1250 m), have been analysed in order to assess the relative contributions of primary and secondary producer-derived material to the sediments. The high abundance of compounds that can be ascribed to

primary producers, namely diatoms, dinoflagellates, coccolithophores, Eustigmatophyceae and cyanobacteria, reflects the high productivity of surface waters, but there is little direct molecular evidence of zooplankton reworking of organic material, except at the deepest water site ( similar to 1250 m). There is, however, clear evidence of benthic re-working, probably by detritivore megafauna, at one of the sites near the base of the oxygen minimum zone ( similar to 1000 m). The relative abundance of biological markers that can be ascribed to aerobic and anaerobic bacteria in the sediments, namely the hopanoids and branched fatty acids, respectively, mirrors the concentrations of oxygen in overlying water. Considerable intra- and inter-site variability probably results from the spatial and temporal variability in production and from the complexity of sedimentation processes.

## **Bibliography KISR Reports:**

*The following are publications produced by researcher at KISR related to Zooplankton .*

Michel, H. B Diversity, distribution and biomass of zooplankton in the Western Arabian Gulf / H. B. Michel, Mariculture and Fisheries Department, Food Resources Division.

PUBLISHER: Kuwait : KISR, 1980.

CALL NO: MB 15 KISR/ PPI081/ FRM-P/ G

Al-Yamani, F., Zooplankton reference collection / I. Shalash, Mariculture and Fisheries Department, Food Resources Division

PUBLISHER: Kuwait : KISR, 1993

CALL NO: MB 82 KISR 4305.

Michel, H. B., Zooplankton diversity, distribution and abundance in Kuwait waters / H. B. Michel...[et al.], Mariculture and Fisheries Department, Food Resources Division.

PUBLISHER: Kuwait : KISR, 1983.

CALL NO.: MB 15 KISR 1069

## Internet Resources:

*The following are some sites found on the Web related to Zooplankton in Gulf of Aden, Gulf of Oman and Arabian Sea .NSTIC is not responsible for the content of these sites, nor is promoting any for them.*

1. Large Marine Ecosystem No. 33 Red Sea  
[na.nefsc.noaa.gov/lme/text/lme33.htm](http://na.nefsc.noaa.gov/lme/text/lme33.htm)
2. ORA - Species List - Dottybacks  
[www.orafarm.com/dottybacks.html](http://www.orafarm.com/dottybacks.html)
3. Arabian Sea  
[www.virtualology.com/virtualmuseumofnaturalhistory/aquatichall/thesevensesas/ARABIANS EA.ORG](http://www.virtualology.com/virtualmuseumofnaturalhistory/aquatichall/thesevensesas/ARABIANS EA.ORG)
4. Arabian Sea Micom  
[www.rsmas.miami.edu/groups/zoopec/Arabian\\_Sea\\_Micom.html](http://www.rsmas.miami.edu/groups/zoopec/Arabian_Sea_Micom.html)
5. phytoplankton  
[isd.kisr.edu.kw/isd/mfd/mfdlpub/phytoplankton.html](http://isd.kisr.edu.kw/isd/mfd/mfdlpub/phytoplankton.html)
6. FAO Fisheries Department - FAO Fisheries Circular No. 920 FIRM/ ...  
[www.fao.org/docrep/003/w4248e/w4248e34.htm](http://www.fao.org/docrep/003/w4248e/w4248e34.htm)
7. Behavioral observations of **zooplankton** in the **Red Sea ...**  
[www.auditory.org/asamtgs/asa96haw/4aAO/4aAO8.html](http://www.auditory.org/asamtgs/asa96haw/4aAO/4aAO8.html)

8. Ecosystem of Red Sea  
[www.awi-bremerhaven.de/Benthic/Ecosystem/Archive/AbsCornils01.html](http://www.awi-bremerhaven.de/Benthic/Ecosystem/Archive/AbsCornils01.html)
  
9. Sweetwater **Zooplankton** for Salt Water  
[www.petsmart.com/fish/shopping/saltwater\\_accessories/products/product\\_14220.sh](http://www.petsmart.com/fish/shopping/saltwater_accessories/products/product_14220.sh)
  
10. Botany  
[www.coop.uvic.ca/biocoop/common/oceanography.html](http://www.coop.uvic.ca/biocoop/common/oceanography.html)