

Zooplankton standing stock, community structure and diversity in the northern Arabian Sea

S.C. Goswami & Y. Shrivastava

National Institute of Oceanography, Dona Paula, Goa-403004

ABSTRACT

The effects of large scale oil spill, which occurred during the Gulf War in 1991 on zooplankton standing stock, community structure and diversity in the northern Arabian Sea were studied. Surface (1-0m) and vertical zooplankton hauls (200-0m, 250-0m and 500-0m) were taken during *FORV Sagar Sampada* cruise 94 (12-23 September 1991). The shelf region was rich in zooplankton standing stock than the oceanic waters. Highest standing value (581 ml/100m³) was obtained at a coastal station (lat. 22° 07' N and long. 67° 03' E) and was due to swarm of gammarid amphipods and shoal of sergestid shrimp *Acetes johni*. Herbivores dominated the zooplankton community and copepods were most abundant (36.9 to 71.7%). The other important taxa were siphonophores, euphausiids, chaetognaths and decapod larvae. Copepod population showed distinct coastal and oceanic communities. Niche partitioning among congeners particularly the members of genus *Pleuromamma* was discernible. Species diversity was higher in the oceanic waters and an inverse relationship between standing stock and species diversity was the general trend. High standing stock, faunal and species diversity values indicated no apparent impact of oil spill on plankton population in the studied area.

INTRODUCTION

Zooplankton investigations in the Indian Ocean pertain mostly to taxonomy, zoogeography and ecology. Information on zooplankton standing stock (biomass), community structure and diversity with particular reference to oil spill is scarce. The Gulf War during January and February 1991 resulted in a massive oil spill of 6 to 8 million barrels into the sea. There were apprehensions that this oil might reach the Indian coast due to wind and surface currents and influence marine resources. To monitor the effects of this oil spill on marine biota, zooplankton studies were carried out in the northern Arabian Sea and results are presented in the paper.

MATERIALS AND METHODS

The present study is based on 74 samples collected during *FORV Sagar Sampada* cruise 94 (12 to 23 September 1991). Sampling was done at 44 stations located in the northern Arabian Sea between lat. 16° and 23°N and long. 62° and 73°E (Fig.1). Surface zooplankton samples were taken at all stations (44 samples) while vertical hauls were made to the surface from 200 m (15 samples), 250 m (10 samples) and 500 m (5 samples). All the samples were collected using a Bongo net fitted with a precalibrated digital flowmeter. The net was towed at 2 knot speed for 10 minutes and the samples were preserved in 5% formaldehyde. Zooplankton standing stock was determined as displacement volume. An aliquot of 6.25 to 10% of the sample was examined for numerical abundance. To evaluate spatial variability, a one-way analysis of variance (ANOVA) test was done and a probability of ≤ 0.05 was taken to indicate significant differences. Species diversity 'D' indice was calculated after transforming the zooplankton counts to their numbers per cubicmeter (Margalef, 1968). Environmental parameters such as water temperature, salinity and dissolved oxygen were determined using standard procedures (Strickland & Parsons, 1972). For study of diel variability in plankton population, the zooplankton samples collected between 0600 to 1800 hrs and 1800 to 0600 hrs were considered arbitrarily as day and night samples respectively.

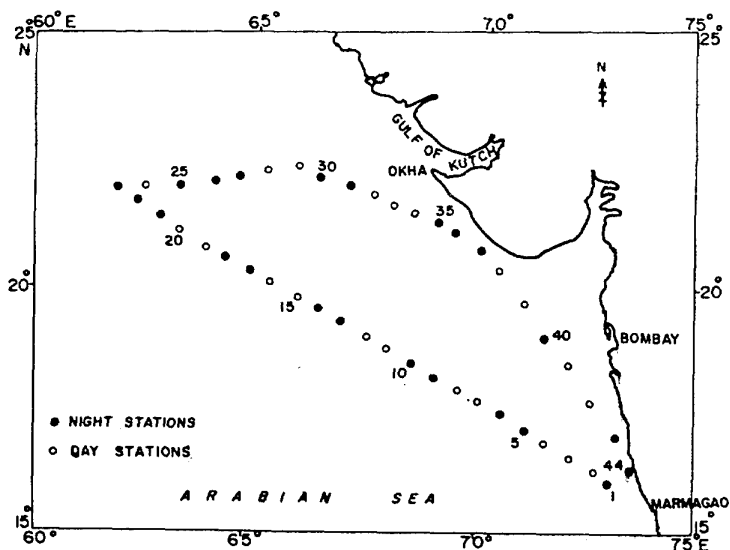


Fig. 1- Station positions

RESULTS AND DISCUSSION

The northern Arabian Sea is closed by landmass on its northern boundary. There is semi annual reversal of surface currents. The flow pattern consists of several eddies and meanders (Qasim, 1982). These factors seem to influence the biological, physical and chemical characteristics of the region. The water temperature, salinity and dissolved oxygen values at surface ranged from 26.9° to 28.7° C, 35.05 to 36.93 × 10⁻³ and 400 to 475 µmol/l respectively. In general, the temperature and dissolved oxygen increased from north to south while salinity showed the reverse trend. High salinity in the northern region was reported probably due to excess evaporation over precipitation and to high salinity water coming from the Persian Gulf (Qasim, 1982). The dissolved oxygen values were low at depths between 200 to 500 m. Naqvi (1987) reported occurrence of oxygen deficient conditions at depth between 150 to 1000 m in the Arabian Sea.

Zooplankton standing stock and composition

The standing stock values (Figs 2,3) ranged from 3 to 581 ml/100m³ (av. = 78 ml/100³, n = 74). Diel variations were discernible with higher values at night (av. = 137 ml/100m³) as compared to those of day (av. = 54 ml/100m³). The average values obtained from the zooplankton samples from the surface, 200 to 0m, 250 to 0m and 500 to 0m depths at day were 28, 54, 65 and 84 ml/100m³ while the corresponding values at night were 137, 57, 85 and 53 ml/100m³ respectively. The lowest value of 3 ml/100m³ was recorded from the surface layer during the day. High visibility and the typical escapist behaviour of zooplankton to avoid predators were the possible reasons given for the poor occurrence of zooplankton in the surface layers (Achuthankutty *et al.* 1992). Higher average values at night could be due to vertical migration of zooplankton. In general, the standing stock values were more in the north and northeastern region. The highest value (581 ml/100m³) obtained was at st. 31 (lat. 22° 0'N and long. 67° 3'E). The value is higher than the record value (280 ml/100m³) reported earlier from the north and the northeastern Arabian Sea (lat. 22° 4' N and long. 67° 3' E) during March (Paulinose & Arvindakshan, 1977) but lower than recently reported value (1200 ml/100m³) from the same area in the months of March and November (Goswami *et al.* 1992). Price *et al.* (1993) gave mean zooplankton standing stock value of 103 ml/100m³ in the western Gulf based on postwar data of 1992.

Twenty-six taxa were present in the collections from different sampling strata. The distribution of 19 common taxa at 4 depths during day and night is given in Tables 1,2. The remaining 7 groups included foraminiferans, ctenophores, cladocerans, mysids, cumaceans, isopods and echinoderm larvae. These groups occurred sporadically and in small numbers (%) and were considered together as others. Based on overall mean number the percentage occurrence of various groups in order of abundance was copepods (56.95), siphonophores (10.54), euphausiids (7.15), chaetognaths (6.53), decapod larvae (4.97), amphipods (3.86), hydromedusae (2.08), appendiculari-

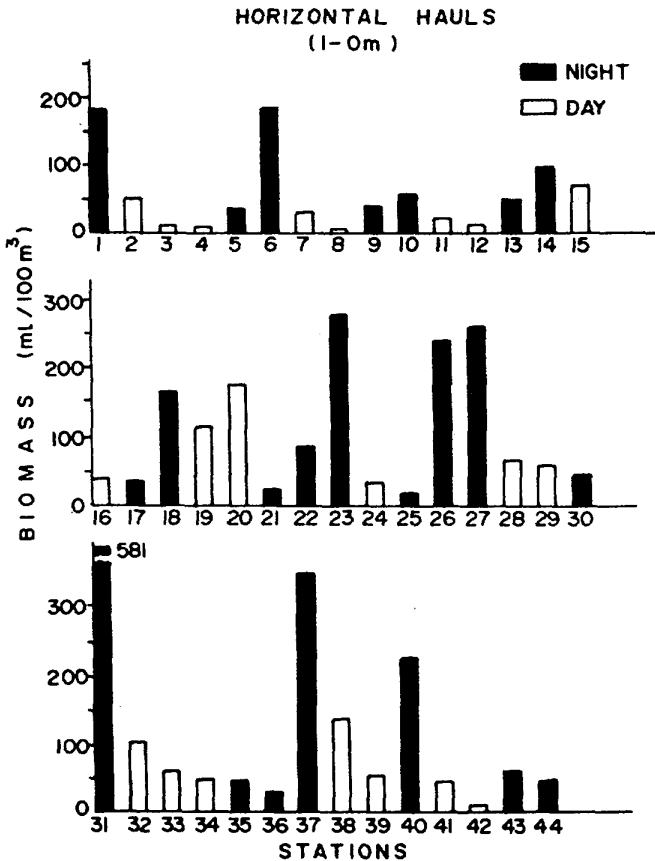


Fig.2- Zooplankton biomass distribution in surface layer

ans (1.63), salps and doliolids (1.13), fish eggs (1.1), mysids (0.94), polychaete larvae (0.9), ostracods (0.53), crustacean eggs (0.49), heteropods (0.38), pteropods (0.24), fish larvae (0.08) and others (0.5). Copepods were most common both in the surface and the water column (36.95 to 71.72%, overall mean 35315 individuals/100m³). Their minimum and maximum percentages were obtained in the zooplankton samples collected from surface and 250-0m depth (Table 1). No single group dominated the zooplankton population. The dominance of the copepods was overshadowed at a coastal station where shoal of sergestid shrimp (*Acetes johni*) in association with swarm of adult gammarid amphipods was observed at night. Diel variations in numerical abundance of zooplankton were also noticed in other areas. There was more

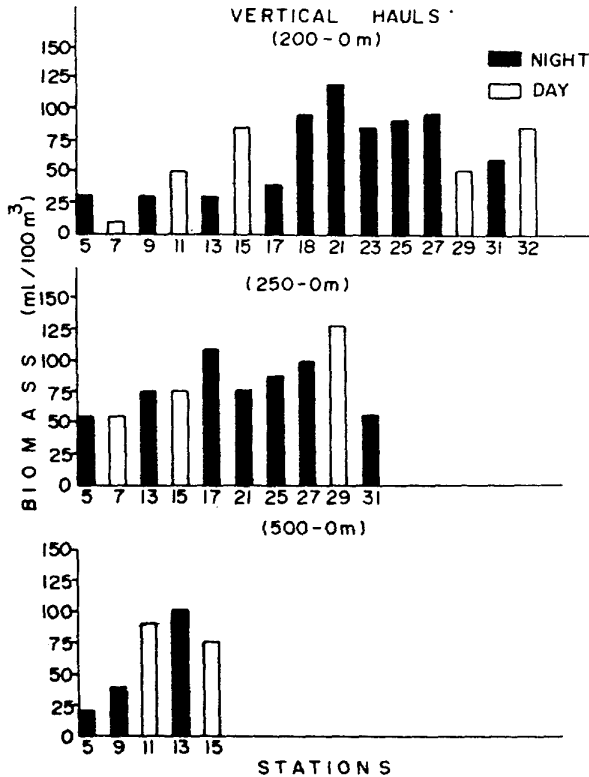


Fig.3- Zooplankton biomass distribution in the water column

than two-fold increase in counts in night samples (av. = 51278 organisms/100m³) as compared to the day samples (av. = 24461 organisms/100m³). Majority of the groups occurred abundantly in the night samples except halobates, polychaete larvae, crustacean eggs, fish eggs and fish larvae. Maximum number of fish eggs (629/100m³) and fish larvae (156/100m³) were recorded in the samples from surface and 500 to 0m depth respectively. Myctophidae formed the main component of ichthyoplankton. The zooplankton communities varied in the coastal and oceanic waters. Herbivores dominated the coastal waters. Copepods, cladocerans, ostracods, pteropods, sergestids and tunicates were common there. Carnivores such as siphonophores, hydromedusae, chaetognaths and poecilostomatid copepods occurred more in the oceanic waters.

Species distribution

Copepods, siphonophores, euphuasiids, chaetognaths and decapod larvae were important taxa and constituted the major component of zooplankton population. An account of distribution of various taxa and their common species in the coastal and oceanic waters has been given below:

Table 1- Percentage occurrence of common zooplankton groups at four sampling depths in day and night samples (values in parentheses are night samples)

Groups	1-0m	200-0m	250-0m	500-0m	Average number (no./100m ³)
Copepods	9.85 (27.10)	23.68 (36.04)	29.38 (42.34)	24.02 (31.97)	35315
Siphonophores	3.32 (13.68)	3.80 (6.35)	2.83 (0.51)	9.02 (4.05)	6656
Euphausiids	0.98 (10.12)	1.75 (3.58)	1.26 (3.48)	3.46 (3.55)	4513
Chaetognaths	1.94 (3.04)	3.96 (3.79)	2.97 (3.16)	3.86 (3.17)	4120
Decapod larvae	1.33 (9.26)	1.92 (1.24)	1.41 (1.41)	1.87 (0.84)	3137
Amphipods	0.67 (4.64)	1.22 (1.10)	0.68 (1.81)	3.77 (1.14)	2435
Hydromedusae	0.32 (3.03)	0.59 (0.96)	0.10 (1.72)	0.46 (0.71)	1315
Appendicularians	0.27 (1.98)	1.26 (1.81)	0.11 (0.80)	0.39 (0.49)	1032
Salps & doliolids	0.73 (1.44)	0.37 (0.85)	0.10 (0.80)	0.39 (0.29)	828
Fish eggs	0.96 (0.57)	0.82 (0.41)	0.20 (0.62)	0.60 (0.27)	693
Mysids	0.31 (1.50)	0.17 (0.13)	0.12 (0.39)	0.84 (0.13)	596
Polychaete larvae	0.02 (0.11)	0.59 (0.34)	1.19 (0.39)	0.18 (0.31)	563
Ostracods	0.02 (0.06)	0.42 (0.41)	0.19 (0.31)	0.43 (0.46)	352
Gastropod larvae	0.03 (0.56)	0.12 (0.20)	0.10 (0.03)	0.28 (0.73)	331
Crustacean eggs	0.19 (0.12)	0.20 (0.26)	0.30 (0.15)	0.51 (0.33)	306
Heteropods	0.21 (0.23)	0.25 (0.27)	0.15 (0.17)	0.15 (0.11)	240
Pteropods	0.11 (0.25)	0.09 (0.06)	0.04 (0.05)	0.12 (0.17)	158
Fish larvae	0.06 (0.05)	0.22 (0.10)	0.13 (0.13)	0.25 (0.26)	156
Halobates	0.10 (0.02)	0.00 (0.00)	0.00 (0.22)	0.00 (0.03)	56
Others	0.51 (0.30)	0.26 (0.40)	0.04 (0.21)	0.20 (0.18)	319

Copepods — A total of 86 species of pelagic copepod belonging to 21 families were identified. Percentage occurrence of copepods belonging to different families at 4 sampling strata was tabulated (Table 3). Species of family Paracalanidae (*Paracalanus parvus*, *P. aculeatus*, *Acrocalanus gracilis*, *A. gibber* and *Acrocalanus* spp); Eucalanidae (*Eucalanus subcrassus*, *E. crassus*, *E. attenuatus* and *E. monachus*); Temoridae (*Temora turbinata* and *T. discaudata*); Acartiidae (*Acartia spinicauda*, *A. erythraea* and *A. negligens*); Centropagidae (*Centropages furcatus*, *C. tenuiremis*, *C. orsinni*, *C. trispinosus*, *C. dorsipinatus* and *C. alcockii*); Clausocalanidae (*Clausocalanus arcuicornis*); Pontellidae (*Labidocera pectinata*, *L. acuta*, *L. minuta*, *Calanopia minor*, *C. elliptica*, *Pontella danae*, *P. securifer*,

Table 2- Percentage occurrence of individuals of common zooplankton groups at four sampling depths (values in the parentheses are night samples)

Groups	1-0m	200-0m	250-0m	500-0m
Copepods	4.58 (12.59)	7.13 (10.84)	19.41 (21.72)	10.18 (13.55)
Siphonophores	8.17 (33.99)	6.59 (10.15)	9.93 (1.79)	20.27 (9.11)
Euphausiids	3.56 (36.81)	4.12 (8.43)	6.50 (18.00)	11.41 (11.17)
Chaetognaths	7.72 (12.11)	10.22 (9.78)	16.81 (17.88)	13.96 (11.52)
Decapod larvae	6.96 (48.43)	6.52 (4.20)	10.42 (10.53)	8.94 (4.00)
Amphipods	4.54 (31.27)	5.35 (4.79)	6.53 (17.36)	23.12 (7.04)
Hydromedusae	3.97 (37.79)	4.75 (7.79)	1.98 (30.41)	5.19 (8.12)
Appendicularians	4.19 (31.54)	12.32 (18.66)	2.38 (18.18)	5.59 (7.14)
Salps & doliolids	14.58 (28.52)	4.77 (10.99)	12.23 (13.25)	10.74 (4.92)
Fish eggs	22.72 (13.42)	12.55 (6.27)	6.67 (20.81)	10.42 (7.14)
Mysids	8.69 (41.29)	3.15 (2.31)	4.62 (15.48)	21.06 (3.40)
Polychaete larvae	0.66 (3.28)	11.19 (6.35)	49.29 (16.09)	4.97 (8.17)
Ostracods	0.92 (3.05)	12.83 (12.33)	12.69 (20.48)	18.35 (19.35)
Gastropod larvae	1.36 (27.75)	3.62 (6.41)	3.02 (5.96)	50.60 (1.28)
Crustacean eggs	10.46 (6.30)	6.94 (9.15)	22.21 (11.44)	19.12 (14.38)
Heteropods	14.06 (16.06)	11.04 (11.56)	14.37 (16.56)	9.27 (7.08)
Pteropods	11.22 (25.91)	6.00 (4.26)	5.37 (8.06)	26.86 (12.32)
Fish larvae	6.46 (4.45)	0.00 (0.00)	20.30 (19.23)	23.56 (25.00)
Halobates	6.64 (3.10)	0.00 (0.00)	0.00 (90.26)	0.00 (0.00)
Others	26.30 (15.49)	8.76 (13.22)	2.19 (15.81)	10.38 (7.90)

P. spinipes, *Pontellopsis scotti*, *P. regalis*, *P. herdmani* and *Pontellopsis* spp.); Oithonidae (*Oithona rigida*, *O. brevicornis*, *O. plumifera* and *O. nana*); Macrosetellidae (*Miracia efferata* and *Macrosetella gracilis*) and Ectinosomidae (*Microsetella rosea*) were common in the zooplankton samples from the coastal regions. Species of the genera *Paracalanus*, *Acrocalanus*, *Centropages* and *Temora* were ubiquitous and distributed over larger areas. Numerous specimens of *T. turbinata* (5271 individuals/100m³) were obtained at st. 42 during day. This species was reported to be an opportunistic, positively related to the abundance of phytoplankton and other particulate matter (Paffenhoffer *et al.* 1988). Swarming of *T. turbinata* was observed from the west coast associated with monsoon (Stephen & Iyer, 1979).

The copepod community in the oceanic waters was constituted mainly by omnivore and carnivore forms. Species of families Calanidae (*Canthocalanus pauper*,; *Undinula vulgaris*, *U. darwini* and *Mesocalanus tenuicornis*); Candaci-

Table 3- Percentage occurrence of individuals belonging to common copepod family from four depths in day and night collections (Values in the parentheses are of night samples)

Families	1-0 m	200-0 m	250-0 m	500-0 m
Calanidae	0.35 (0.11)	6.76 (1.73)	3.26 (2.33)	2.72 (2.60)
Eucalanidae	1.40 (2.31)	13.44 (6.13)	10.14 (8.89)	4.33 (2.08)
Paracalanidae	10.27 (13.56)	3.13 (4.16)	0.60 (1.54)	0.51 (1.64)
Clausocalanidae	0.68 (0.60)	2.96 (1.06)	0.36 (0.45)	0.57 (0.80)
Acartiidae	0.31 (0.33)	0.89 (0.49)	0.13 (0.11)	0.19 (0.21)
Centropagidae	4.02 (2.91)	0.86 (1.00)	0.19 (0.78)	0.29 (0.33)
Temoridae	4.33 (3.96)	4.49 (1.63)	0.85 (0.67)	0.63 (0.91)
Scolecithricidae	0.18 (0.12)	0.22 (0.29)	0.36 (0.29)	0.58 (0.64)
Candacidae	0.12 (0.06)	0.86 (1.00)	2.40 (2.41)	2.67 (3.58)
Pontellidae	29.67 (19.44)	4.14 (2.32)	3.26 (0.61)	1.47 (0.79)
Metridiidae	0.00 (0.03)	0.76 (5.61)	0.78 (2.58)	3.73 (12.68)
Lucicutidae	0.00 (0.04)	3.59 (5.99)	3.68 (5.11)	2.42 (3.56)
Augaptilidae	0.00 (0.00)	0.42 (1.12)	3.53 (3.44)	3.59 (3.38)
Aetideidae	0.00 (0.00)	0.67 (1.64)	3.98 (4.22)	3.79 (4.46)
Heterorhabdidae	0.00 (0.00)	0.57 (0.83)	2.26 (2.95)	3.62 (4.77)
Eucaetidae	0.06 (0.16)	0.34 (3.81)	3.26 (3.45)	4.21 (3.80)
Oncaeiidae	0.16 (0.41)	4.78 (2.29)	3.17 (3.01)	4.59 (5.09)
Corycaeiidae	0.70 (1.24)	3.10 (1.82)	3.64 (3.64)	2.87 (2.96)
Oithonidae	0.66 (1.42)	0.39 (0.84)	2.22 (1.64)	0.58 (0.63)
Sapphirinidae	0.00 (0.02)	0.67 (0.15)	1.39 (1.85)	0.25 (0.81)
Harpacticoidae	0.14 (0.21)	0.20 (0.08)	0.19 (0.16)	0.01 (0.06)

idae (*Candacia bradyi*, *C. pachyactyla*, *C. discaudata*, *C. aethiopica* and *Candacia* spp); Eucaetidae (*Euchaeta rimana*, *E. concinna*, *E. wolfendeni* and *Euchaeta* spp); Scolecithricidae (*Scolecithrix danae* and *S. bradyi*); Lucicutiidae (*Lucicutia flavicornis*, *L. ovalis* and *Lucicutia* spp); Metritiidae (*Gaussia princeps*, *Gaussis* spp, *Pleuromamma gracilis* and *P. indica*); Aetideidae (*Aetideus giesbrechtii*); Augaptilidae (*Haloptilus longicornis* and *Haloptilus* spp); Heterorhabdidae (*Heterorhabdus papilliger*); Oncaeiidae (*Oncea venusta* and *O. conifera*); Corycaeiidae (*Corycaeus gibbulus*, *C. catus*, *C. speciosus* and *Corycaeus* spp) and Sapphirinidae (*Sapphirina opalina*, *S. metallina*, *Copilia mirabilis* and *C. vitrea*) were abundant in collections from the oceanic realm. Certain species viz. *Cosmocalanus darwini*, *Scolecithrix danae*, *Lucicutia flavicornis*, *Candacia bradyi*,

Oncaea venusta and *Corycaeus gibbulus* were common in samples from the coastal waters. These species could be termed as intermediate. Their common occurrence in both habitats might be due to surface circulation and mixing of neritic and oceanic waters. Based on the spatial extent of distribution of different species, 3 groups of pelagic copepods such as oceanic, neritic and intermediate were identified (Pillai, 1974). The bathymetric distribution of copepod species showed 3 categories — i) species which occurred more in the epipelagic layer (200-0m); ii) forms recorded below 200 m and iii) species which were present throughout the sampling depth. Majority of the species belonged to the first category. Species such as *Paracalanus parvus*, *P. aculeatus*, *Acrocalanus gracilis*, *Eucalanus monachus*, *Centropages tenuiremis*, *C. furcatus*, *Candacia bradyi*, *Labidocera pectinata*, *Temora turbinata*, *Scolecithrix danae*, *Pontella securifer*, *Pontellopsis scotii* and *Pleuromamma gracilis* were common and invariably present in the epipelagic layer. *Eucalanus attenuatus*, *Lucicutia flavicornis*, *Euchaeta concinna*, *Aetideus giesbrechtii*, *Haloptilus longicornis*, *Heterorhabdus papilliger* and *Sapphirina opalina* occurred more in depth between 200 to 500m. The remaining species did not evince any definite distributional pattern and belonging to the third category. Members of families Paracalanidae and Pontellidae were observed during the day. The number of species belonging to different families increased at night. Niche partitioning on vertical ranges among congeneric species of genus *Pleuromamma* was observed. *P. gracilis* was recorded in upper layers in areas with dissolved oxygen content exceeding 45 $\mu\text{mol/l}$ where as *P. indica* was numerous at 500 m depth contour tolerating oxygen deficient waters. The variations could be assigned to resource partitioning or different migratory habits of the species (Roe, 1974).

Siphonophores — Siphonophores were next abundant group, occurring commonly in the coastal waters. *Lensia* spp and *Diphyes* spp represented siphonophore population.

Euphausiids — These were sparsely distributed in the coastal region but were abundant in the oceanic area. Species belonging to 4 genera viz. *Euphaisia*, *Stylocheiron*, *Nematoscelis* and *Thysanopoda* were recorded. *E. diomediae* was the dominant species.

Chaetognaths — The population density of chaetognaths ranged from 24 to 2858/100m³. Their occurrence was more in samples taken between 15° and 18°N lat. Higher counts were obtained in the coastal region particularly at night. Twelve species belonging to 3 genera - *Sagitta*, *Pterosagitta* and *Krohnitta* were identified. The species in order of abundance were *Sagitta enflata*, *S. bedoti*, *S. neglecta*, *S. pacifica*, *S. robusta*, *S. pulchra*, *S. regularis*, *S. ferox*, *Pterosagitta draco*, *S. hexaptera*, *Krohnitta pacifica* and *S. lyra*. The first three species occurred more in coastal waters while the remaining in the oceanic area. Single specimen of *S. lyra* was obtained from a sample taken from 500 to 0m depth. This species was reported to be mesoplanktonic occurring in abundance below 700 m depth (Silas & Srinivasan, 1969).

Decapod larvae — Sergestids were most commonly (18.1 to 23.7) represented by species of genus *Lucifer* (*L. hanseni*, *L. typus* and *Lucifer* spp), *L. hanseni* being the most common. The other decapod groups comprised mainly of Penaeidea, Caridea, Stenopidea, Anomura and Brachyura. Penaeidea and brachyuran larvae were abundant in the coastal belt. The penaeid prawn larvae were represented by species of genera *Penaeus*, *Metapenaeus* and *Parapeneopsis*. Larvae of *M. dobsoni* were most abundant. The zoea and megalopa larvae of edible crabs represented the brachyuran population.

Hydromedusae were more in samples from the coastal area. The amphipods of the suborder Gammaridea and Hyperidea were common particularly between 22° and 24°N lat. The polychaetes were represented mainly by *Pelagobia* spp. The cladocerans were most abundant in the coastal waters, their population density decreased in the offshore region. *Evadne tergestina* and *Penilia avirostris* were the two species, former was dominant (62.8%). Tunicates were common in oceanic samples. *Oikopleura* spp were the representative of appendicularians. *Thalia democratica* and *Doliioletta* were common forms of salps and doliolids respectively.

Species diversity

The species diversity (D) values in the oceanic realm ranged between 6.4 and 9.2 (av. = 7.4) and in the coastal waters between 2.8 and 7.6 (av. = 5.5). Higher diversity values in the former habitat was due to stable environmental conditions prevailing there, which permitted the planktonic communities to diversify. The coastal belt of the Arabian Sea is enriched with nutrients during the southwest monsoon (June to September) resulting in phytoplankton abundance. High concentration of primary food generally results in swarming of few herbivores/omnivores such as copepods (*Temora turbinata*), gammarid amphipods (*Atylus* spp) and sergestid shrimps (*Acetes johni*). The swarming of zooplankters in the coastal waters resulted in low diversity but high biomass community. The increasing gradient in species diversity from estuaries to nearshore and coastal waters and oceanic areas was reported (Madhupratap, 1983).

Based on present data, zooplankton standing stock and species diversity, it can be concluded that there was no apparent effect of Gulf oil spill on plankton population in the western Exclusive Economic Zone (EEZ) of India. This corroborates the earlier observation on post spill zooplankton distribution in the NW Gulf (Al-Yamini *et al.* 1993).

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