

Copepods of the nearshore waters of Bombay

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Variability in copepod population was studied along 2 transects off Mahim and Versova during November 1979 to December 1980 covering eight stations from the creek towards the offshore area. Contribution of copepods to total zooplankton was 72.7 and 79.7% at Versova and Mahim transects respectively. The mean value of copepod (no. m^{-3}) was more at Mahim (310) than at Versova transect (213). The distribution pattern was influenced by the tidal phase with an increase towards the shore during the flood period and a reverse pattern during the ebb period. Sixty eight species were recorded from the area. *Acartia spinicauda*, *Acrocalanus similis* and *Paracalanus crassirostris* were the most common species. Species assemblage indicated the predominance of omnivores in the polluted regions. Dominance of *Acartia spinicauda* appears to be an indicator of polluted environment.

The deteriorating water quality at localised areas around Bombay has given additional impetus to zooplankton studies as one of the biological parameters to evaluate the production potential of the area¹. Copepods, being the dominant component of the zooplankton community, the species diversity can be used as an index in all such biological monitoring studies to characterise the water quality. Reports on the ecology of copepods from the coastal waters of Bombay are limited²⁻⁶. Considering this a detailed survey had been carried out along the nearshore waters of Bombay selecting locations which are polluted and relatively unpolluted.

Materials and Methods

A series of stations along the Versova and Mahim transects were selected for the present study (Fig. 1). Zooplankton and water samples were collected from all the stations during November 1979 to December 1980 covering ebb and flood tides. Due to navigational problem sampling could not be done in June. Zooplankton was collected by oblique hauls for 5 min, using HT net (mouth area 0.25 m^2 , and mesh size 0.3 mm) fitted with a TSK flow meter. The samples were preserved in 5% formalin. Copepods were sorted out and identified. Species diversity was calculated as per Margalef⁷ and Pielou⁸. The physico-chemical parameters considered are water temperature, pH, salinity, dissolved oxygen (DO),

BOD, phosphate, nitrite and nitrate. Water samples for the above parameters were collected from surface and bottom. The chemical estimations were done following standard methods.

Results

Physico-chemical parameters—The study area receives substantial amount of sewage and industrial waste which gets accumulated in creek areas. The prevailing physico-chemical conditions in the creek areas indicated the adverse effect of pollution (Table 1). Relatively higher DO was recorded at the offshore stations. Very often during the ebb tide DO values

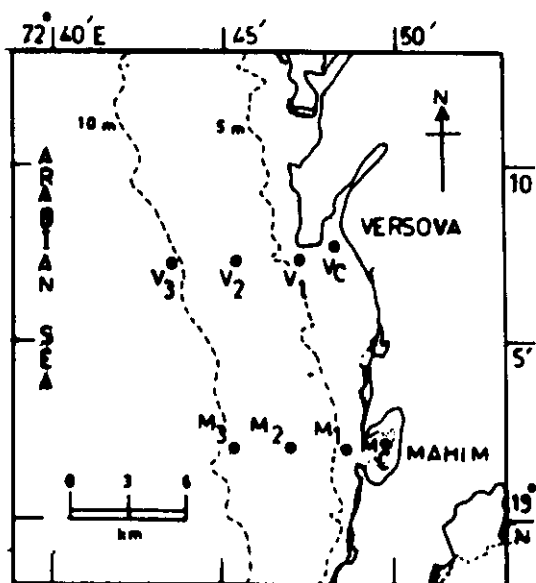


Fig. 1—Location of stations

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came down almost to zero level at Versova creek and Mahim creek. Substantial increase in phosphate and nitrate were recorded at the creek areas. However, these values decreased towards the offshore stations. The high concentrations of nutrients appeared to be due to the influence of sewage discharge into the creek area. In general, the water quality steadily improved towards seaward.

Copepoda population—Along the Versova transect the population density (no. m⁻³) varied from 0-2843 (Table 2) with the averages of 135, 276, 209 and 231 at sts Vc, V1, V2 and V3. The peak in copepod count was observed in October. In general, at sts Vc and V1, the flood period recorded higher density of copepods than the ebb period while a reverse pattern has been recorded at sts V2 and V3 which directly reflected on the percentage composition of copepods. At the Mahim transect population density varied from 1-4107 with peak in October/November 1980 (Table 3). Mean population counts of copepods at sts Mc, M1, M2 and M3 were respectively 44, 302, 447

and 426. At sts Mc and M1 the recorded population counts of copepods were more for the flood than the ebb while at M2 the difference between ebb and flood periods was not well marked (Table 3). Copepod counts were mostly higher for the ebb than the flood of st M3. Tidal variation in terms of percentage composition of copepods was not so well defined along the Mahim transect.

Distribution of different species—About 60 species were recorded from Versova transect of which 42 were rare inhabitants of the area. In the creek (st Vc) *Acartia spinicauda* was the most dominant species and represented throughout the period of study except, in October. Population density of *A. spinicauda* was more for the flood than the ebb period. In the creek *Acrocalanus similis*, *Paracalanus crassirostris*, *Eucalanus subcrassus*, *Canthocalanus pauper* and *Paracalanus parvus* were the other relatively common species (Fig. 2). At st V1 the trend in the pattern of distribution of above species was the same with better representation of the species in the

Table 1—Variation in different chemical parameters along the 2 transects (Values given are range irrespective of tide.)

| Sts | Salinity (× 10 ⁻³) | Dissolved oxygen (mg.l ⁻¹) | Reactive phosphorus (µg-at.l ⁻¹) | Nitrite (µg-at.l ⁻¹) | Nitrate (µ-at.l ⁻¹) |
|----------------|-----------------------------------|--|--|-------------------------------------|------------------------------------|
| V _c | 23.70-34.90 | 0.4-4.8 | 3.0-7.4 | 1.5-21.4 | 4.2-16.8 |
| V ₁ | 23.33-35.44 | 2.3-6.3 | 1.2-4.1 | 1.0-6.9 | 4.5-11.1 |
| V ₂ | 21.92-36.09 | 4.3-6.6 | 0.8-3.0 | 0.3-8.9 | 2.3-9.9 |
| V ₃ | 23.29-35.44 | 4.5-6.9 | 0.6-3.2 | 0.2-2.8 | 1.1-11.2 |
| M _c | 5.77-22.36 | 0.0-2.1 | 5.8-39.7 | 0.8-17.2 | 5.5-37.1 |
| M ₁ | 23.65-35.42 | 3.1-6.9 | 1.6-8.3 | 1.4-13.6 | 5.0-17.3 |
| M ₂ | 24.23-35.55 | 3.9-6.7 | 1.4-4.7 | 1.1-8.4 | 2.6-14.6 |
| M ₃ | 25.07-35.44 | 4.4-6.8 | 0.6-2.7 | 0.4-5.1 | 0.8-9.0 |

Table 2—Variation of copepod population (no. 100 m⁻³) during flood (F) and ebb (E) tides along Versova transect

| Months | St. Vc | | St. V1 | | St. V2 | | St. V3 | |
|------------|--------|------|--------|-------|--------|-------|--------|-------|
| | F | E | F | E | F | E | F | E |
| Nov. 1979 | 2973 | 700 | 8136 | 400 | 6470 | 5631 | 9306 | 5827 |
| Dec. | 10286 | 1169 | 10514 | 5120 | 7350 | 8200 | 2212 | 2800 |
| Jan. 1980 | 49067 | 4587 | 75429 | 26743 | 28471 | 38095 | 10541 | 31200 |
| Feb. | 563 | 714 | 800 | 3000 | 4400 | 9000 | 3216 | 13545 |
| March | 21333 | 2800 | 1223 | 3400 | 1540 | 4000 | 1333 | 1493 |
| April | — | 6400 | 7500 | 5568 | 6400 | 4200 | 17600 | 18700 |
| May | 47467 | 8533 | 6400 | 10 | 31030 | 52232 | 1459 | 77500 |
| June | — | — | — | — | — | — | — | — |
| July | 21210 | 2940 | 32430 | 5800 | 28000 | 52130 | 40533 | 72413 |
| Aug. | 27500 | 1400 | 19765 | 5400 | 11429 | 34310 | 18667 | 36780 |
| Sept. | 5160 | 2286 | 1548 | 4331 | 18424 | 3179 | 11264 | 4800 |
| Oct. | 101333 | 2571 | 284284 | 64640 | 93091 | 25084 | 57051 | 43442 |
| Nov. | 10368 | 2514 | 12387 | 52966 | 9800 | 35200 | 3388 | 99257 |
| Dec. | 16000 | 543 | 17550 | 4267 | 8565 | 16280 | 3429 | 12936 |
| April 1989 | 1590 | 4 | — | — | — | — | — | — |
| March 1990 | 408518 | 690 | — | — | — | — | — | — |

— = no sampling

Table 3—Variation of copepod population (no. 100 m⁻³) during flood (F) and ebb (E) tides along Mahim transect

| Months | St. M _c | | St. M ₁ | | St. M ₂ | | St. M ₃ | |
|------------|--------------------|-----|--------------------|-------|--------------------|--------|--------------------|--------|
| | F | E | F | E | F | E | F | E |
| Nov. 1979 | 1640 | — | 1314 | 6267 | 1312 | 8857 | 1225 | 1739 |
| Dec. | 2133 | 600 | 4240 | 2400 | 88518 | 67200 | 31624 | 68267 |
| Jan. 1980 | 9120 | 212 | 86857 | 32593 | 77576 | 102194 | 40000 | 6400 |
| Feb. | 80 | 15 | 18450 | 8100 | 5176 | 5188 | 4444 | 2306 |
| March | 16000 | 5 | 16625 | 24267 | 15125 | 78750 | 8000 | 33600 |
| April | 140 | — | 7000 | 6336 | 15515 | 5000 | 9035 | 7000 |
| May | 32000 | 800 | 109091 | 59400 | 133647 | 85527 | 8000 | 49412 |
| June | — | — | — | — | — | — | — | — |
| July | 72 | 32 | 23310 | 9930 | 30222 | 26480 | 34844 | 59415 |
| Aug. | 1230 | 50 | 10500 | 3110 | 20329 | 36410 | 82667 | 104310 |
| Sept. | 320 | 10 | 5200 | 9333 | 1878 | 9240 | 3657 | 12218 |
| Oct. | 26140 | 412 | 162400 | 80640 | 92315 | 58839 | 20329 | 64800 |
| Nov. | 18400 | 280 | 63360 | 34286 | 105503 | 75093 | 14400 | 407000 |
| Dec. | 70 | 22 | 135 | 747 | 3782 | 12760 | 1829 | 17067 |
| April 1989 | — | — | 7620 | 7714 | — | — | — | — |
| March 1990 | — | — | 66239 | 55128 | — | — | — | — |

— = no sampling

area. Population density of *A. spinicauda* and other common species at sts V₂ became more for the ebb than the flood (Fig. 3). The trend in the disposition of the species continued to be the same at sts V₃. However, counts of *A. spinicauda*, *A. similis* and *P. crassirostris* showed a sharp decrease in population density (Fig. 3).

Acartia sp. was more common at the creek area and the population density gradually reduced towards sts V₂ and V₃. Distribution pattern of *Labidocera* sp. and *E. marina* indicated an increasing trend towards station V₂ to V₃. Incidence of *L. pectinata*, *Tortanus barbatus* and *Acrocalanus gibber* was more at st V₃ than the other stations.

Mahim transect: Of the 58 species of copepods recorded from the area 41 were sparsely represented. The number of species found in the creek was quite low (17) and a steady increase was observed through other stations. In the creek *Acartia spinicauda* was the most dominant species even though the species was not represented throughout the period of study (Fig. 4). The other common species in the creek area were *Acrocalanus similis*, *Paracalanus crassirostris* and *Acartia* sp. At sts M₁ and M₂ *A. spinicauda*, *A. similis* and *P. crassirostris* indicated well defined increases in population density which came down at st M₃ (Fig. 5). *Eucalanus subcrassus* was recorded at sts M₁ to M₃ mainly during the postmonsoon period. *Canthocalanus pauper* was almost evenly distributed from sts M₁ to M₃. *Labidocera pectinata*, *Labidocera* sp. and *Tortanus barbatus*, were more common during the period of relatively higher salinity and recorded higher abundance towards the offshore (st M₃) than the other stations.

Table 4—Diversity index of copepods for different stations during ebb and flood (in parentheses) periods

| St. | Postmonsoon period | Premonsoon period | Monsoon period |
|----------------|--------------------|-------------------|----------------|
| | | | |
| V _c | .56(.65) | .45(.82) | .43(.51) |
| V ₁ | .64(.55) | .39(.74) | .44(.55) |
| V ₂ | .75(.70) | .68(.74) | .52(.56) |
| V ₃ | .72(.75) | .88(.90) | .43(.74) |
| M _c | .58(.40) | .46(.39) | .30(.44) |
| M ₁ | .51(.67) | .56(.50) | .49(.54) |
| M ₂ | .54(.69) | .80(.57) | .40(.61) |
| M ₃ | .77(.61) | .59(.77) | .46(.57) |
| | Index E | | |
| V _c | .44(.60) | .61(.82) | .75(.54) |
| V ₁ | .48(.44) | .65(.62) | .75(.52) |
| V ₂ | .60(.55) | .56(.63) | .58(.62) |
| V ₃ | .39(.48) | .69(.62) | .63(.62) |
| M _c | .61(.79) | .58(.76) | .71(.76) |
| M ₁ | .46(.66) | .61(.56) | .61(.63) |
| M ₂ | .47(.52) | .54(.69) | .65(.58) |
| M ₃ | .23(.52) | .62(.56) | .54(.58) |

Species diversity—Diversity index (D) is generally low in the area of study. Compared to postmonsoon (October-January) and premonsoon (February-May) periods the values of D were relatively low for the monsoon (June-September) period. D values were generally higher for the flood than the ebb period (Table 4). Evenness (E) indicates variation for the postmonsoon season while the remaining periods maintained comparable values between stations.

Species assemblage—Contribution of herbivorous, omnivorous and carnivorous groups to

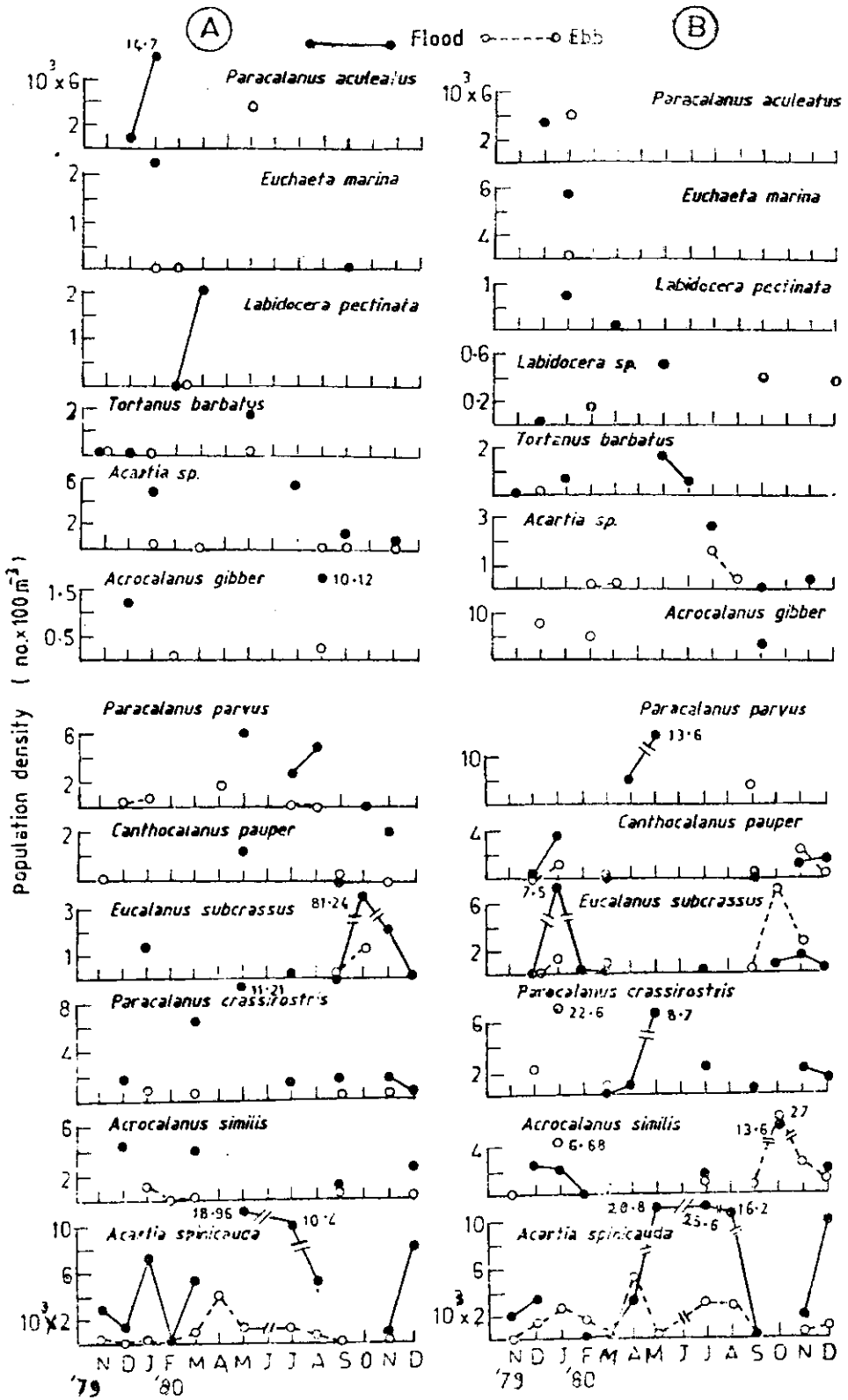


Fig. 2—Variations in the incidence of common species of copepods at sts. Vc (A) and VI (B)

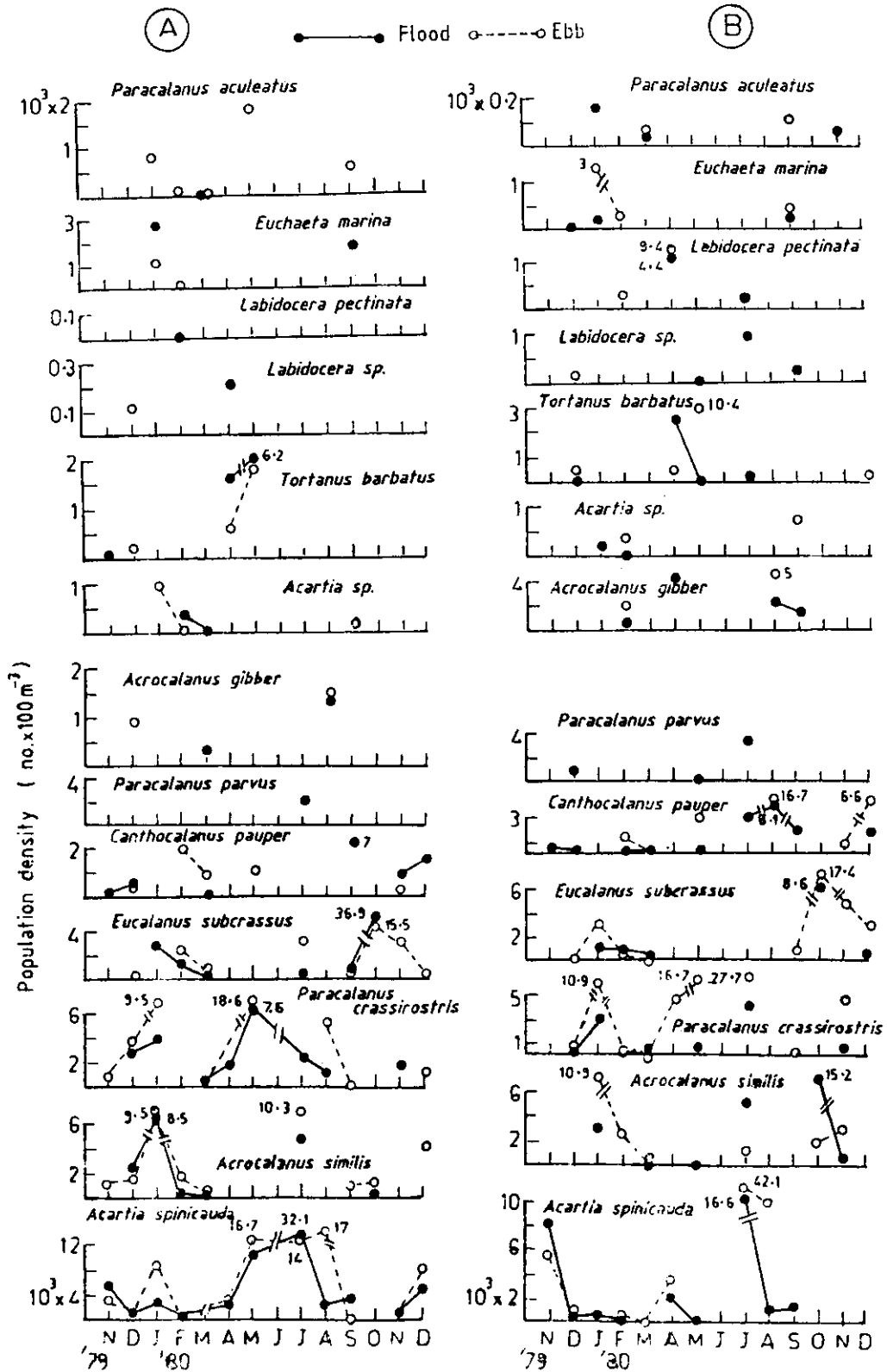


Fig. 3—Variations in the incidence of common species of copepods at sts V2(A) and V3(B)

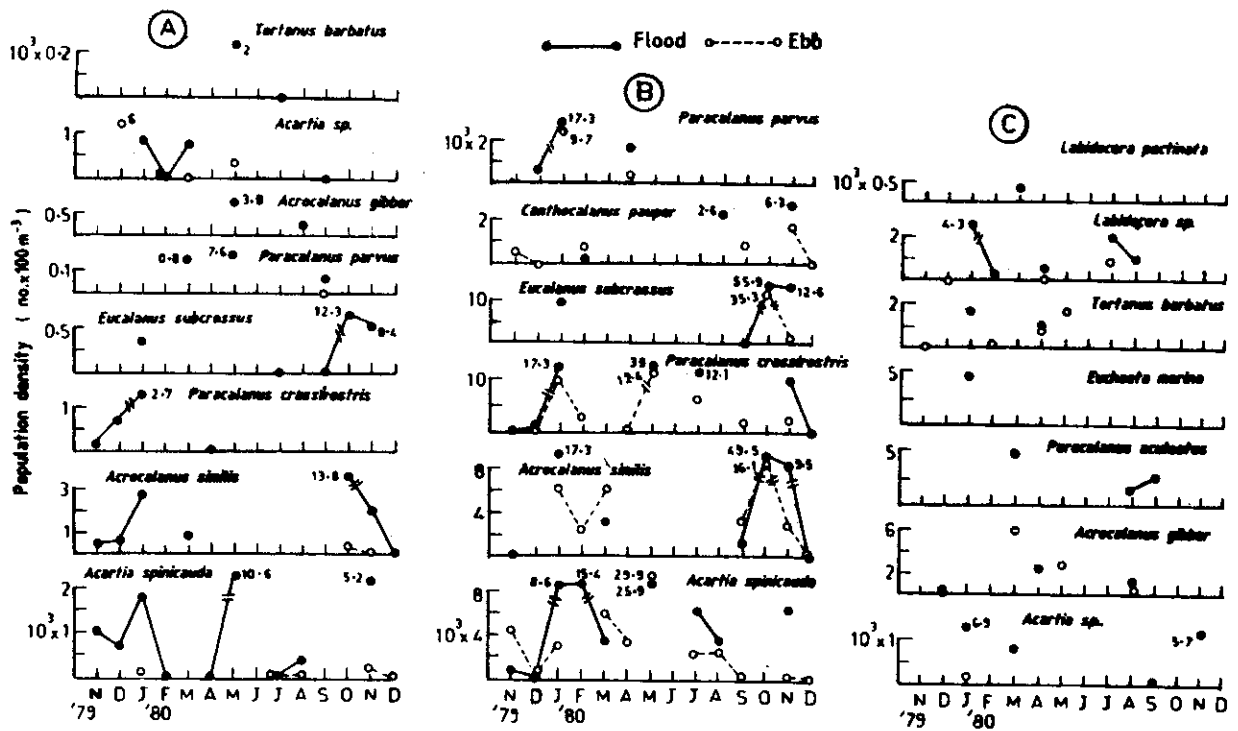


Fig. 4—Variations in the incidence of common species of copepods at sts Mc (A) and M1 (B, C)

the total copepods along the two transects fluctuated (Table 5). The herbivores along the Versova transect decreased from st Vc towards V3 while an opposite trend was observed along the Mahim transect. The population of omnivores were high in the creek, sts V1 and M1 which gradually decreased towards the offshore area. The percentage of carnivores was relatively low in the nearshore stations and steadily increased towards offshore.

Discussion

Copepods were the predominant group at all stations, except during the period of unusual aggregations of groups like mysids at Versova and polychaetes at Mahim and Versova. The mean value of total copepod (no. m⁻³) was higher at Mahim (310) than Versova (213). Copepod population contributed 72.7 and 79.6% to the total zooplankton count respectively for Versova and Mahim transects. Along the Versova transect copepod counts reduced during ebb tide at sts Vc (88%) and V1 (66%) while the density increased at V2 (11%) and V3 (57%). The decrease in copepod populations at sts Mc, M1 and M2 were respectively 93, 45 and 3% for the ebb period. However, at st M3 population during the ebb period increased by 71%. The deteriorating water quality at the creek stations (Table 1) directly influenced the incidence of copepods.

Table 5—Percentage contribution of herbivores, omnivores and carnivores to total copepods population

| Sts | Herbivores | Omnivores | Carnivores | Total |
|----------------|------------|-----------|------------|-------|
| V _c | 40.4 | 47.19 | 12.4 | 1894 |
| V ₁ | 34.08 | 47.02 | 18.89 | 2403 |
| V ₂ | 34.10 | 40.07 | 25.83 | 3953 |
| V ₃ | 28.10 | 33.09 | 28.81 | 5530 |
| M _c | 36.18 | 60.88 | 2.94 | 680 |
| M ₁ | 31.66 | 47.99 | 20.35 | 5366 |
| M ₂ | 40.98 | 39.33 | 19.70 | 8184 |
| M ₃ | 41.53 | 27.05 | 51.42 | 4259 |

A few zooplankton samples collected during 1989-90 from Versova creek and off Mahim (st M1) are useful for comparative evaluation (Tables 2 and 3). At st M1 the disposition of copepods did not indicate a consistent pattern, when compared with the data obtained for 1979-80. However, population density showed marginal variation between tides. In the Versova creek during the ebb period there was considerable reduction in population density which showed drastic reduction over the period of 9 years, suggesting the enhanced level of contaminants entering the creek system.

The total number of species recorded during the present investigations were more than that reported earlier for the nearshore waters of Bombay^{5,9}. About 50% of the copepods species in the present collections

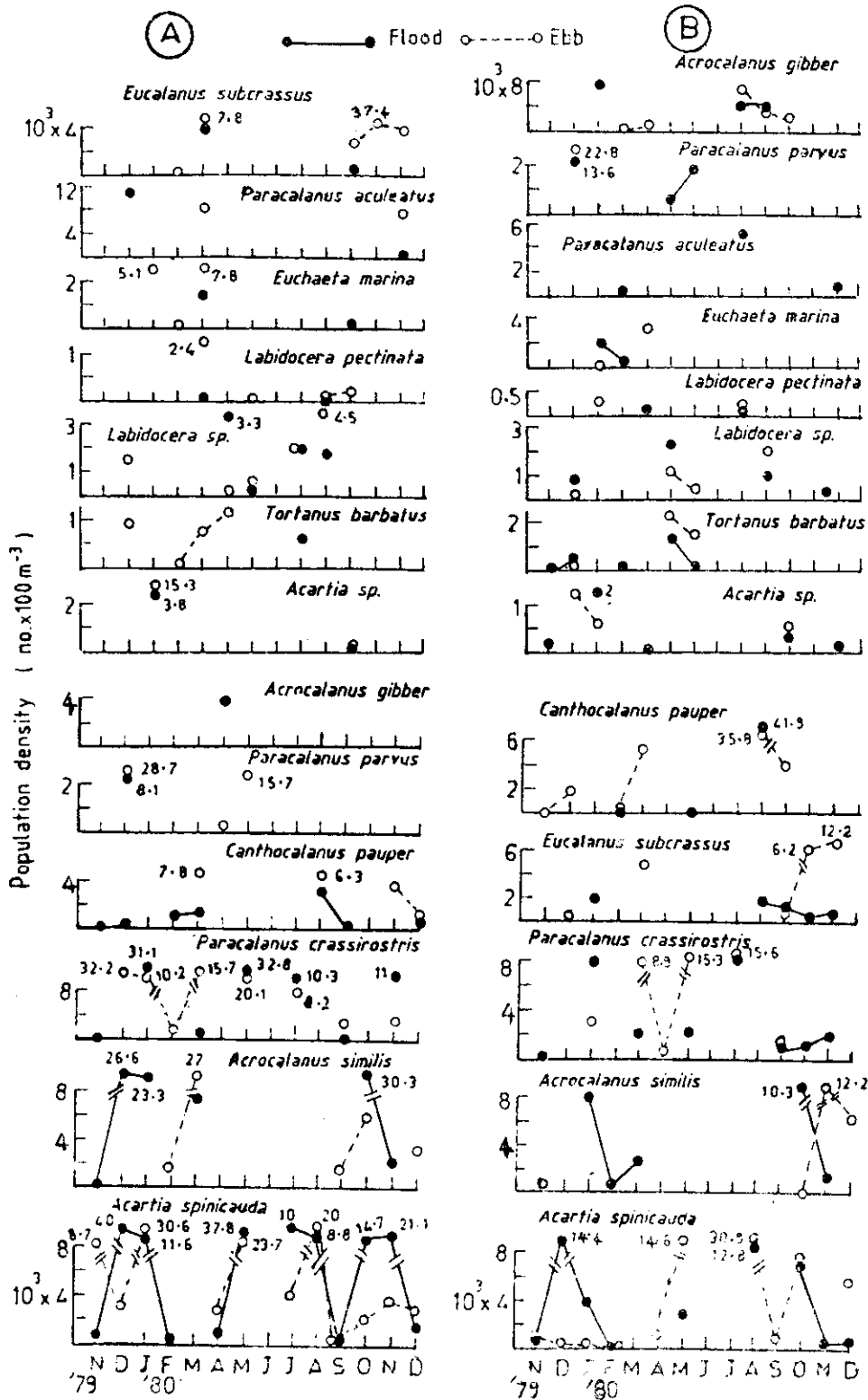


Fig. 5—Variations in the incidence of common species of copepods at sts M2 (A) and M3 (B)

were sporadically represented in the area. *Acartia spinicauda* was the dominant species in the area and their population density was higher in the creek and adjacent stations. The dominance of Acartiidae in the sewage polluted coast of Messina has been reported^{10,11}.

The species assemblage at various stations indicated well defined variability between the polluted and relatively unpolluted areas. The omnivorous group contributed the major part of the copepod population at the creek and nearshore areas of both the transects. Among the omnivores *Acartia spinicauda* was the most common species and their abundance appeared to be an index to the prevailing pollution load.

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