

Effect of pollution on the distribution of chaetognaths in the nearshore waters of Bombay

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Chaetognath fauna inhabiting the polluted waters was compared with that of clean waters for evaluating the impact of pollution. Regular observations at 11 locations off Bombay coast indicated a steady decline in chaetognath population in areas polluted with sewage. Incidence of chaetognaths at sewage polluted areas was limited mostly to periods of high tide; with population density much less (max 10m^{-3}) than that of areas free of pollution (max 40m^{-3}). *Sagitta bedoti* was the only tolerant species in sewage polluted areas. Areas polluted with industrial effluent showed better water quality and chaetognaths maintained steady and comparable population density ($14\text{-}17\text{m}^{-3}$). *Sagitta bedoti* dominated the area from June to December while *S. ocellata* became abundant from January to May. A decrease in the intensity of pollution was associated with an increase in the population density of *Sagitta enflata* and *S. pulchra*. *Krohnitta pacifica*, *S. bombayensis* and *S. robusta* were restricted to areas free of pollution.

Studies around the coast of Bombay indicate the accumulating tendency of pollutants affecting the water quality¹⁻³ and biological productivity⁴ of some locations. Even though zooplankton forms a less effective parameter to evaluate the intensity of pollution, systematic studies on standing stock and diversity will serve as reliable indices for biological monitoring⁵. Chaetognaths, being a common constituent of the zooplankton community and also because of their sensitive nature should be useful in such investigation. Preliminary studies on chaetognaths around the nearshore waters of Bombay show adverse effects of pollution on these organisms⁶. Considering this, a comprehensive study of the group has been taken up along 3 transects off Bombay and the results presented in this paper.

Materials and Methods

Samples for zooplankton and chemical parameters were collected from 11 stations along 3 transects opposite 3 creeks at Versova, Mahim and Thana (Fig. 1) between November 1979 and December 1980 at monthly intervals covering the ebb and flood periods. Creeks at Versova and Mahim were polluted with sewage while creek at Thana received industrial effluent.

Zooplankton collections were made by oblique

hauls using HT net (mouth area 0.25m^2 ; mesh size 0.3mm) with an attached TSK flowmeter. Water samples from surface and bottom from all stations were analysed for salinity, pH, DO, reactive phosphorous, nitrite and nitrate following the methods of Strickland and Parsons⁷. As the adverse effects of pollution in the creek and nearshore environments are more during the premonsoon period (February-May), diurnal observations were made

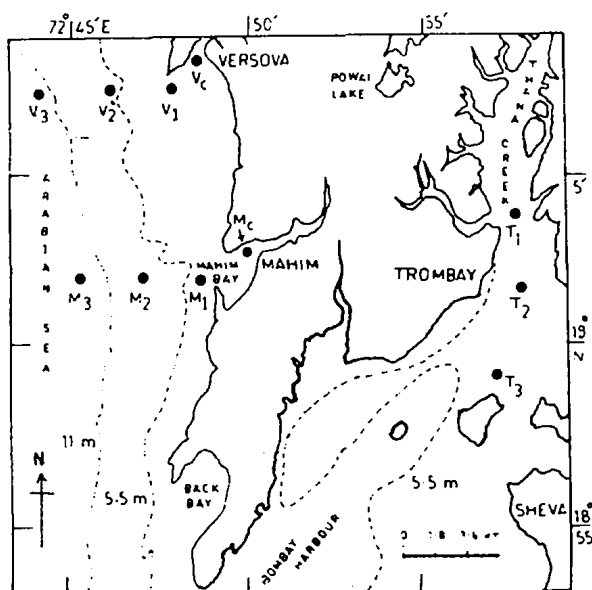


Fig. 1—Location of stations

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during February 1981 at selected stations namely V_c , V_3 , M_1 and T_1 . Observations over the 24 h period were made at hourly interval during day and once in 2 h during night.

Results and Discussion

Variations in different chemical parameters indicated change of water quality between the water of the creek and that off the open sea (Table 1). The sewage polluted areas (sts V_c and M_c) showed very low levels of dissolved oxygen ($0-4.8 \text{ mg.l}^{-1}$), high values of phosphate ($3-39.7 \text{ } \mu\text{g-at.l}^{-1}$) and nitrate ($4.2-37.1 \text{ } \mu\text{g-at.l}^{-1}$). However, the industrially polluted areas (sts T_1 to T_3) showed relatively better water quality with normal range of dissolved oxygen

($4-6.5 \text{ mg.l}^{-1}$), optimum levels of reactive phosphate ($1.6-6.5 \text{ } \mu\text{g-at.l}^{-1}$) and nitrate ($4.4-30.2 \text{ } \mu\text{g-at.l}^{-1}$). In general, dissolved oxygen had shown an increase towards the open sea with increasing distance from the creeks, while inorganic nutrients showed declining trend.

Distribution and species diversity

Versova transect: Along the Versova transect, peak in chaetognath population was observed during September to November at sts V_c and V_1 and from September to December at sts V_2 and V_3 (Table 2). Invariably during the monsoon months (June-August) chaetognaths were sparse at all stations. The population density gradually increased

Table 1—Range of fluctuations in different chemical parameters at selected stations during the study period (Values given are ranges, irrespective of tide)

Stations	Salinity ($\times 10^{-3}$)	Dissolved oxygen (mg.l^{-1})	Reactive phosphorous ($\mu\text{g-at.l}^{-1}$)	Nitrite ($\mu\text{g-at.l}^{-1}$)	Nitrate ($\mu\text{g-at.l}^{-1}$)
V_c	23.7-34.9	0.4-4.8	3.0-7.4	1.5-21.4	4.2-16.8
V_1	23.3-35.4	2.3-6.3	1.2-4.1	1.0-6.9	4.5-11.1
V_2	21.9-36.1	4.3-6.6	0.8-3.0	0.3-8.9	2.3-9.9
V_3	23.3-35.4	4.5-6.9	0.6-3.2	0.2-2.8	1.1-11.2
M_c	5.8-22.4	0-2.1	5.8-39.7	0.8-17.2	5.5-37.1
M_1	23.7-35.4	3.1-6.9	1.6-8.3	1.4-13.6	5.0-17.3
M_2	24.2-35.6	3.9-6.7	1.4-4.7	1.1-8.4	2.6-14.6
M_3	25.1-35.4	4.4-6.8	0.6-2.7	0.4-5.1	0.8-9.9
T_1	11.2-36.1	4.0-6.2	2.8-5.5	0.5-22.8	11.4-30.2
T_2	12.8-36.1	4.1-6.5	2.3-6.5	0.4-5.5	10.0-29.8
T_3	18.7-36.0	4.0-6.5	1.6-5.6	0.4-3.9	4.4-21.5

Table 2—Monthly fluctuations in chaetognath population ($\text{no} \times 100$). m^{-3} along the Versova transect during the flood (Fl) and ebb (Eb) periods

Months	Stations							
	V_c		V_1		V_2		V_3	
	Fl	Eb	Fl	Eb	Fl	Eb	Fl	Eb
Nov. '79	44	11*	253	5	507	56	1208	69
Dec.	229	15*	1143	651	170	490	231	860
Jan. '80	653	160	914	709	555	2190	593	2550
Feb.	—	—	11	13	1200	202	78	285
March	1280	5	183	175	53	67	13	11
April	3	—	50	—	30	50	14	35
May	544	288*	450	110	2327	1652	35	1350
June	—	—	—	—	—	—	—	—
July	80	—	80	10	156	380	676	1010
Aug.	300	7	113	20	110	320	27	413
Sept.	171	160	335	1392	2211	1135	4352	1840
Oct.	20267	1000	7721	17920	12412	16723	6181	11171
Nov.	2304	23	929	3972	560	2133	1129	10635
Dec.	80	8**	140	53**	3426	5920	914	8436

* 50% mortality; ** 100% mortality

from the creek towards the open sea (Table 2) and the respective values for sts V_c , V_1 , V_2 and V_3 were 11, 14, 21 and $18.m^{-3}$. Tidal variations on the incidence of chaetognaths were well defined and showed distinct variation between stations. At sts V_c and V_1 the flood phase sustained higher density of chaetognaths (av. 20 and $19.m^{-3}$ respectively) than the ebb (av. 1 and $9.m^{-3}$ respectively). However, at sts V_2 and V_3 the pattern was reversed with the population density varying from 18 to 24 and 12 to $24.m^{-3}$ during the flood and the ebb respectively. At st V_c during the ebb period of November and December 1979 and May and December 1980, 50-100% of the chaetognaths were found to be dead at the time of collection. In December 1980 collections 100% mortality of chaetognaths was observed upto st V_1 during ebb period.

There was well defined increase in the population density of chaetognaths from the creek towards the offshore station. The respective percentage contribution of chaetognaths at each station to the total crop was 16, 21, 32 and 31 for sts V_c , V_1 , V_2 and V_3 . A total of six species were recorded from the transect. Species diversity increased from 3 at st V_c to 6 at st V_3 . *Sagitta bedoti* was the dominant species in the area (Fig. 2), contributing to the major part of the chaetognath population particularly during February to November. *S.enflata* was fairly common in the area. Quantitatively, *S.enflata* became more abundant at sts V_2 and V_3 and dominated the collections from November to December. *S.pulchra* was occasional inhabitant of the area with population maximum at st V_3 . *S.bombayensis*, a truly endemic species around the coast of Bombay, was recorded only once at st V_3 during December 1979. *Krohnitta pacifica* and *S.robusta* were observed only in May coinciding with the salinity maximum. Incidence of these typical oceanic species during high tide would also suggest the incursion of high saline water into the system.

Mahim transect: In general st M_c sustained very low population of chaetognaths even during the flood period. They were totally absent during April, June, September and December 1980 (Table 3). Except at st M_c the pattern of distribution of chaetognaths along the transect was comparable to that observed off Versova transect. The mean values of chaetognath population at sts M_c , M_1 , M_2 and M_3 were respectively <1 , 10, 17 and $24.m^{-3}$. Peak in chaetognath population was observed from September-November at st M_1 and September to December at sts M_2 and M_3 . Tidal fluctuation in the density of chaetognath population was marginal at st M_1 ($9-11.m^{-3}$) than at st M_2 ($8-25.m^{-3}$) and M_3

($8-40.m^{-3}$). Mortality of chaetognaths was observed only at st M_c with 100% dead specimens during March and May.

The percentage contribution of chaetognaths at st M_c was <1 while the values progressively increased from sts M_1 (19), M_2 (33) and M_3 (47). Species diversity increased from 2 at st M_c to 4 at st M_3 . *S.bedoti* was the dominant species along this transect (Fig. 3) and this species alone could tolerate the deteriorating water quality of Mahim creek. *S.bedoti* encountered at st M_c during December 1979 and May 1980 were in unhealthy state with damaged finrays. The distribution pattern of *S.bedoti* was similar to that of Versova transect with major contribution during February to November. *S.enflata* was very common during the postmonsoon season and often outnumbered *S.bedoti* population. At st M_c all specimens of *S.enflata* were in dead condition. *S.pulchra* started appearing at st M_1 and their population gradually increased towards sts M_2 and M_3 . *S.neglecta* was restricted to st M_3 with an isolated record in December 1980.

Thana transect: Unlike the transects off Versova and Mahim, chaetognath population of Thana transect was quite steady. At st T_1 peak in chaetognath population was recorded from October

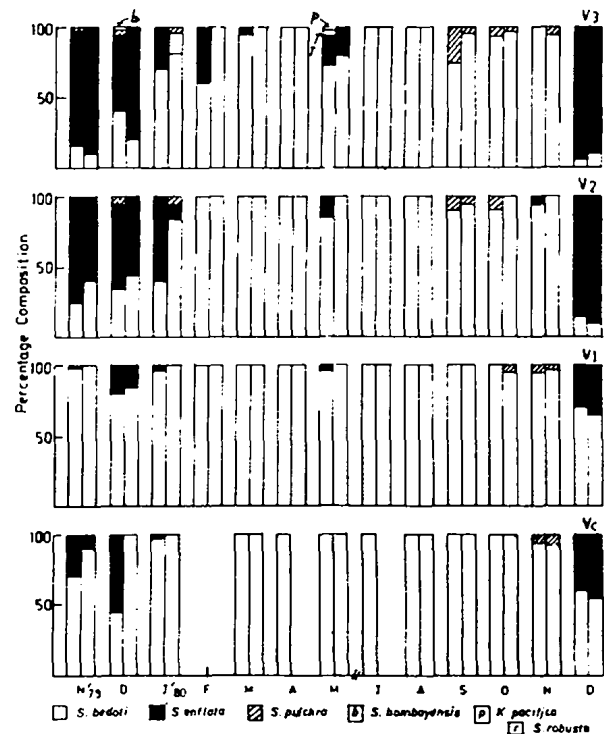


Fig. 2—Percentage composition of different species of chaetognaths along the Versova transect (The first bar of each month represents flood and the second ebb)

to November while at sts T₂ and T₃ the observed peaks were in July (Table 4). The average density at sts T₁, T₂ and T₃ was 16, 16 and 14.m⁻³ respectively. The fluctuations in the density of chaetognaths were marginal varying from 14 to 17.m⁻³ during the ebb and flood. Chaetognaths caught along this transect

did not show any abnormality except at st T₁ in November 1979 when 20% of them were in damaged condition.

The percentage contribution of chaetognaths at sts T₁, T₂ and T₃ was 35, 34 and 31 respectively (Fig. 4). Three species were found at st T₁ which indicated a marginal increase to 4 at sts T₂ and T₃. *S.bedoti* and *S.oceania* formed the most abundant species in the area. At sts T₁ and T₂, *S.bedoti* dominated during July to December, while *S.oceania* became predominant from January to June. The dominance of *S.oceania* over *S.bedoti* at st T₃ was limited extending from March to June. *S.pulchra* was rare in the Thana creek. *S.enflata* indicated sporadic appearance at sts T₂ and T₃.

Diurnal variations: The 24 h observation at st V₃ showed normal variations in DO (6.6-8.1.mg⁻¹) phosphate (0.22-3.15 µg-at.l⁻¹) and nitrate (1.44-6.76 µg-at.l⁻¹). At st T₂, DO concentration was at a lower range (3.08-7.04.mg.l⁻¹) with 2 isolated low values (1.5 and 1.8 mg.l⁻¹), slightly enhanced level of phosphate (2.4-8.3 µg-at.l⁻¹) and nitrate (2.3-8.8 µg-at.l⁻¹). At the polluted st V_c, DO level came down to 0 during ebb tide indicating a range of 0-6.7 mg.l⁻¹. Phosphate and nitrate at this station ranged from 2.1-30.74 and 0-12.3 µg-at.l⁻¹. Effect of pollution was less intense at st M₁ and the respective variation in DO, phosphate and nitrate was 0.4-5.3 mg.l⁻¹, 1.98-8.10 µg-at.l⁻¹ and 5.4-23.2 µg-at.l⁻¹.

Distribution of chaetognaths over the 24 h period at selected stations (V_c, M₁, T₂ and V₃) indicated variability in accordance with the prevailing water

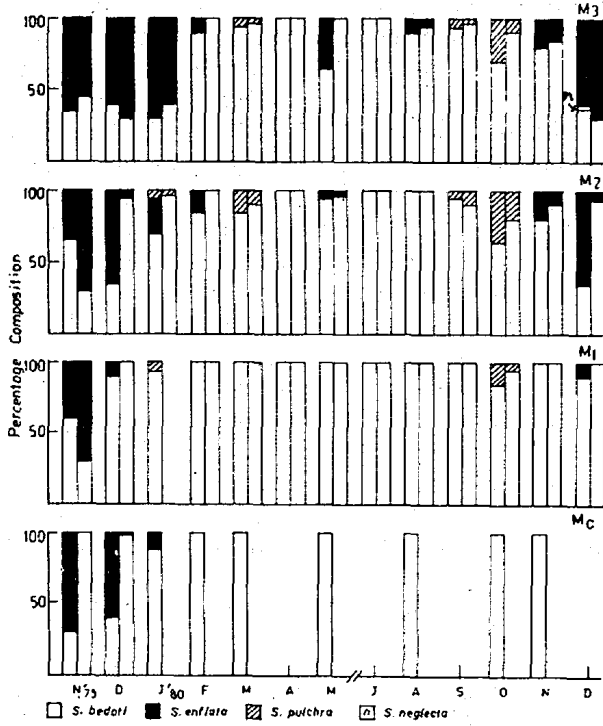


Fig. 3—Percentage composition of different species of chaetognaths along the Mahim transect (The first bar of each month represents flood and the second ebb)

Table 3—Monthly fluctuations in chaetognath population (no ×100).m⁻³ along Mahim transect during the flood (Fl) and ebb (Eb) periods

Months	Stations							
	M _c		M ₁		M ₂		M ₃	
	F1	Eb	F1	Eb	F1	Eb	F1	Eb
Nov. '79	40**	—	100	580	148	857	69	444
Dec.	3**	2*	50	8	198	820	66	363
Jan. '80	160*	—	800	106	407	392	427	500
Feb.	8**	—	75	73	179	38	178	113
March	5***	3***	525	93	510	450	138	640
April	—	—	13	53	10	40	28	8
May	408***	—	5091	700	1929	776	1511	941
June	—	—	—	—	—	—	—	—
July	—	—	64	10	200	310	44	480
Aug.	10	—	90	40	553	640	267	710
Sept.	—	—	1800	2427	1680	5500	4206	19006
Oct.	140	—	2800	4608	2172	11768	2795	17280
Nov.	80	—	2304	2743	2482	8875	847	5920
Dec.	—	—	5	2	465	2240	41	5275

* 50% mortality; ** 75% mortality; *** 100% mortality

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quality. At the polluted stations of V_c and M_1 chaetognath population was invariably low irrespective of the tidal conditions and day/night variation. Fairly high range of salinity, characteristic

of the premonsoon season (February), did not encourage thriving of a rich population of chaetognaths. The recorded average values at sts V_c and M_1 were 1.34 and $1.06.m^{-3}$ respectively. Day and

Table 4—Monthly fluctuations in chaetognath population ($no \times 100$). m^{-3} along Thana transect during the flood (Fl) and ebb (Eb) periods

Months	Stations					
	T_1		T_2		T_3	
	Fl	Eb	Fl	Eb	Fl	Eb
Nov. '79	1832	240*	555	246	280	251
Dec.	3307	1486	700	2880	1416	2317
Jan. '80	600	1700	1531	832	800	2743
Feb.	640	1800	85	114	706	150
March	1760	237	1750	150	320	55
April	4500	41	855	294	2500	1320
May	45	229	100	11	50	225
June		21	2259	90	1810	775
July	2750	1500	4555	3125	2000	4706
Aug.	50	—	719	—	4023	240
Sept.	2167	526	2618	400	2259	4344
Oct.	3429	9007	3584	571	1560	1024
Nov.	750	4320	1577	13653	660	1280
Dec.	289	320	1190	268	1455	50

* 20% damaged

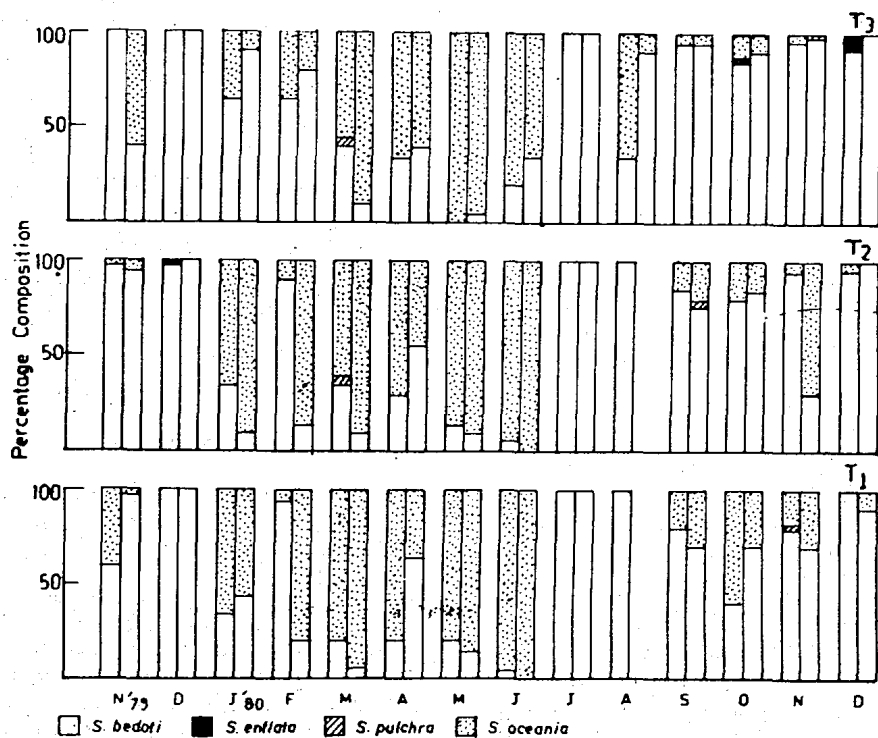


Fig. 4—Percentage composition of different species of chaetognaths along the Thana transect (The first bar of each month represents flood and the second ebb)

Table 5—Diurnal fluctuations in density of chaetognaths (no × 100).m⁻³ during February 1981 at selected stations (Values in parentheses indicate mean values)

Species	Stations							
	V _c		M ₁		T ₂		V ₃	
	Day	Night	Day	Night	Day	Night	Day	Night
<i>Sagitta bedoti</i>	6-219 (91)	6-477 (156)	2-279 (73)	24-464 (135)	112-3106 (532)	117-1621 (450)	81-972 (364)	126-1178 (337)
<i>Sagitta enflata</i>	1-2 (1)	1-36 (7)	—	—	—	—	4-98 (45)	3-38 (11)
<i>Sagitta oceania</i>	—	—	—	—	2-50 (14)	10-39 (13)	—	—
<i>Sagitta pulchra</i>	2-12 (2)	1-54 (12)	—	2-9 (4)	28-48 (7)	6-26 (7)	9-51 (5)	3-64 (20)
Dead chaetognaths (%)	20	15	10	5	—	—	—	—

night variation in the occurrence of different species was well defined, with the latter sustaining higher counts for *S.bedoti*, *S.enflata* and *S.pulchra* (Table 5). At st V_c, ebb to flood period indicated higher density of chaetognaths than flood to ebb (av. 1.8 and 0.8.m⁻³ respectively). While a reverse pattern was observed at M₁ (av. 0.7 and 1.3.m⁻³ respectively). Dead chaetognaths were restricted to these stations and mortality was maximum during the ebb phase of the tide.

At st V₃ average population density of chaetognaths was 4.m⁻³. Day/night variation in the occurrence of *S.bedoti* was marginal (Table 5). However, the less common species *S.enflata* and *S.pulchra* indicated diurnal variation. As observed during the year flood to ebb (av. 6.4.m⁻³) sustained higher density of chaetognaths than the ebb to flood period (av. 1.5.m⁻³).

The Thana creek maintained high population density of chaetognaths during the 24 h period (av. 5.m⁻³). Quantitative and qualitative difference between day and night samples were not observed (Table 5). Ebb to flood (av. 27.m⁻³) and flood to ebb (av. 7.8.m⁻³) difference was well marked.

Quantitative and qualitative distribution of chaetognaths along the different transects suggest wide fluctuations depending on the water quality. The sewage polluted creek environments (sts V_c and M_c) are comparable in having very low population of chaetognaths. During the low tide, chaetognath population was reduced by a factor of 20 at st V_c while at st M_c the group was recorded only twice. The 24 h observations at st V_c indicated that ebb to flood condition sustained higher population compared to that recorded at st V₃. The ratio of total number of species present in the polluted creeks and open ocean of Mahim and Versova were respectively 2:4 and 3:6.

A decrease in the intensity of pollution was associated with an increase in the population of *S.enflata* and *S.pulchra*, suggesting the sensitive nature of these organisms to pollutants.

Pollution due to industrial effluent appears to be not affecting the distribution of chaetognaths in the Thana system to the same extent as pollution due to sewage off Mahim and Versova. The most interior zone (st T₁) alone showed some variation in population density with higher density associated with high tide. *S.enflata*, a typical species in the coastal environment of west coast of India⁸ was very rare in the Thana creek. It appears that the low level of dissolved oxygen in the sewage polluted environment coupled with high BOD¹² might be adversely affecting the survival of these sensitive organisms. In the industrially polluted environment even though the water quality was fairly good, the indirect effect of pollutants, in terms of bioconcentration, might be one of the reason for the decline of chaetognaths.

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