

Ecology and distribution of Recent planktonic Foraminifera in eastern part of Arabian Sea

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Thirty species of living planktonic Foraminifera have been studied from 97 plankton tows collected from the eastern Arabian Sea with an accent on their ecological and distributional aspects. Species density is higher with less dominance in the deep (0-200 m) than in the surface (0-10 m) tows. Further, latitudinal gradient of some species which have a definite bearing on hydrography of the sea, has been outlined. Relative production of planktonic Foraminifera shows that it is high in the southern Arabian Sea south of 15°N, but low in the northern one from 15°N northwards based on mean total specimens occurring in plankton samples of the areas of study.

Recent planktonic Foraminifera are one of the most studied groups of marine organisms for deciphering oceanographic conditions on a global scale. But information on these foraminifers in Indian coastal waters is still inadequate and requires further faunal survey, although notable contributions on the fauna have been made earlier¹ for certain areas in Indian Ocean. It is therefore in the present line of study, an effort is made to gain information with regard to distributional and ecological patterns of planktonic Foraminifera in both slope and shelf waters of the eastern Arabian Sea off India.

Materials and Methods

Ninety-seven plankton samples of both surface (0-10 m) and vertical (0-200 m) tows were taken using Heron-Tranter net (mouth area, 0.25 m²; net length, 2.5 m; and mesh aperture, 150 µm) during *R V Gaveshani* (hereinafter referred to as *RVG*) cruises 82 and 151 from 56 stations in the Arabian Sea (Fig. 1). The samples were stained with rose bengal at the time of collection for later separation of living planktonic Foraminifera in the laboratory. For quantitative estimation of foraminiferal species, a Rigosha flow meter was fixed to the net. The data were processed for studying relations between ecological factors and the fauna with Pearson coefficient of correlation² at 5% level of significance. Species diversity³ was calculated with Shannon-Wiener function, $H(S)$ and evenness, e was computed with Heip's index⁴.

Results and Discussion

Planktonic Foraminifera were studied from 2 areas in the Arabian Sea (Fig. 1): area I (*RVG* cruise

No. 82, sts 1-21) in MONEX square between 11°-15° N and 68°-71°30' E and area II (*RVG* cruise No. 151, sts 22-56) north of 15°N extending from Marmagao (15°14.5'N) to the northwest region off Gujarat (22°53.7'N).

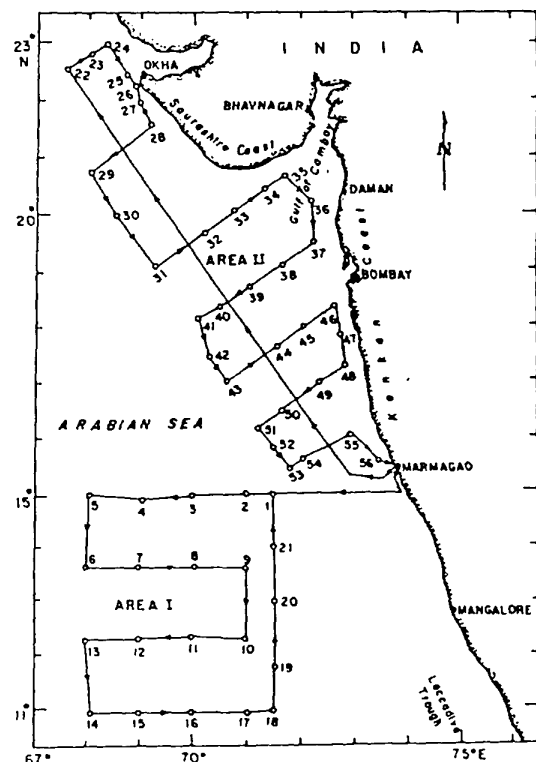


Fig. 1—Location of plankton samples

Foraminiferal abundance—In the northern Arabian Sea of area II, the ranges of foraminiferal concentrations of surface tows from slope (sts 29-31) and shelf (sts 22-28 and 32-35) waters of Saurashtra are 1316-4737 and 233-7895 specimens in 1000 m³ respectively, whereas those in the respective waters off the Konkan coast being 6571-399211 (slope sts 40-43 and 50-54) and 208-39333 (shelf sts 37-39, 44-49, 55 and 56) in 1000 m³. But in area I of southern Arabian Sea, surface tows show very high concentrations, > 60000 specimens in 1000 m³, at sts 6 and 11-13. The maximum density of 105515 in 1000 m³ is found at st 6. Lower concentrations of Foraminifera, < 10000 specimens in 1000 m³, are found at sts 7, 10, 15 and 21, the lowest being 4400 in 1000 m³ at st 7 (Fig. 2).

In the case of vertical tows, in the slope waters off Saurashtra (sts 29-31), the abundance is very poor varying from 123-959 specimens in 1000 m³, while in waters off the Konkan coast (sts 40-43 and 50-54), the concentrations are higher with a range of 4013-14986 in 1000 m³. Higher concentrations of planktonic Foraminifera are found in the southern Arabian Sea (area I) at sts 10, 11, 17 and 19 and lower densities in the northern part of this area from 15°N northwards.

The quantitative data suggest that the waters off Saurashtra and Cambay are particularly impoverished with regard to production of planktonic Foraminifera in contrast with waters of the Konkan coast and southern Arabian Sea. Also, investigation⁶ on organic production of the northern Arabian Sea reveals something of this finding and to the same effect for confirmation.

Distribution and variation of species with latitude—Foraminiferal species, 30 in all, were found and studied quantitatively (Tables 1-3), and of them, *Globigerina bulloides*, *Globigerinella aequilateralis*, *Globigerinoides ruber*, *G. sacculifer*, *Globorotalia tumida* and *Globigerinita glutinata* are most abundant species. With the exception of a few species such as *Globigerina calida*, *Hastigerina pelagica* and others, viz. *Beella digitata*, *Globorotalia menardii*, *G. theyeri* and *Globigerinita iota*, present only in vertical tows, it is observed that most of the species show higher concentrations in 0-10 m than in 0-200 m plankton tows. Species encountered only in surface tows are *Globorotalia hirsuta*, *G. neoflexuosa* and *G. flexuosa*. Species occurring only in the northern Arabian Sea (area II) from 0-10 m tows are *Orbulina universa*, *G. hirsuta* and *G. neoflexuosa* and in 0-200 m tows, it is represented by a lone species, *G. menardii*. The southern part of the sea (area I), by contrast, is characterized by distinct species from surface tows

and they are *Hastigerina parapelagica*, *Globigerinoides tenellus*, *Globorotaloides hexagona*, *Globoquadrina conglomerata* and *Turborotalita humilis* in deep tows, besides the aforementioned first 3 species of 0-10 m tows, others include *B. digitata*, *Pulleniatina obliquiloculata*, *G. theyeri*, *G. unguolata*, *Candeiana nitida* and *G. iota*.

The stations and latitudinal distribution of some species from plankton tows (Figs 3 and 4), which are greatly influenced by hydrography of the sea are as follows:

Globigerina bulloides—It has a density range of 457-1016 specimens in 1000 m³ from surface tows of northeastern part of area I (sts 1-4 and 9) and in the region north of 15°N (area II), it occurs at sts 41-44 and 51-54 with concentrations varying from 172-12632 in 1000 m³, the highest density being at st 41 (18°N). In the case of 0-200 m tows from area I, it occurs in the central (sts 9-11 and 19) as well as in the northwestern regions (sts 1-3, 5 and 7) with abundance varying from 42-958 in 1000 m³. It is absent in Saurashtra waters and off the Konkan coast (sts 40-42 and 50-54), its density range is 28-186 in 1000 m³.

Globigerina falconensis—This species is more abundant in 0-10 m than in 0-200 m tows and like *G. bulloides*, it shows its maximum concentration at st 41 (18°N).

Globigerinella aequilateralis—Concentrations of this species from 0-10 m tows are low in the northern Arabian Sea with a range of 333-5263 specimens in 1000 m³. It is sparse off Saurashtra, though common off Konkan region. But higher densities varying from 800 to 64000 in 1000 m³ are found in the central and western parts of area I (south of 14°N) and lower concentrations in the area north of 14°N. In 0-200 m tows, it varies from 19 to 123 specimens in 1000 m³ off Saurashtra and 148-2000 in 1000 m³ off Konkan regions. Higher concentrations of this species are seen in the southern part of area I within 11°-13°N. In the region north of 15°N, density of this species is low (≤ 2000 in 1000 m³). In both surface and deep tows, it is more abundant south of 14°N.

Globigerinoides ruber—It increases in concentration in 0-10 m tows of the two areas in north-west direction between 13° and 18°N, but very high densities are found only in the northern Arabian Sea (15°N and further north). In 0-200 m tows of the eastern half of area I (70°-72°E), it increases from south to north, showing maximum concentration of 2035 specimens in 1000 m³ at st 2 (15°N) and in area II, highest concentration of 2889 in 1000 m³ is found north of 15°N (st 50). Generally, there is an increasing trend from south to north in the Arabian Sea and a

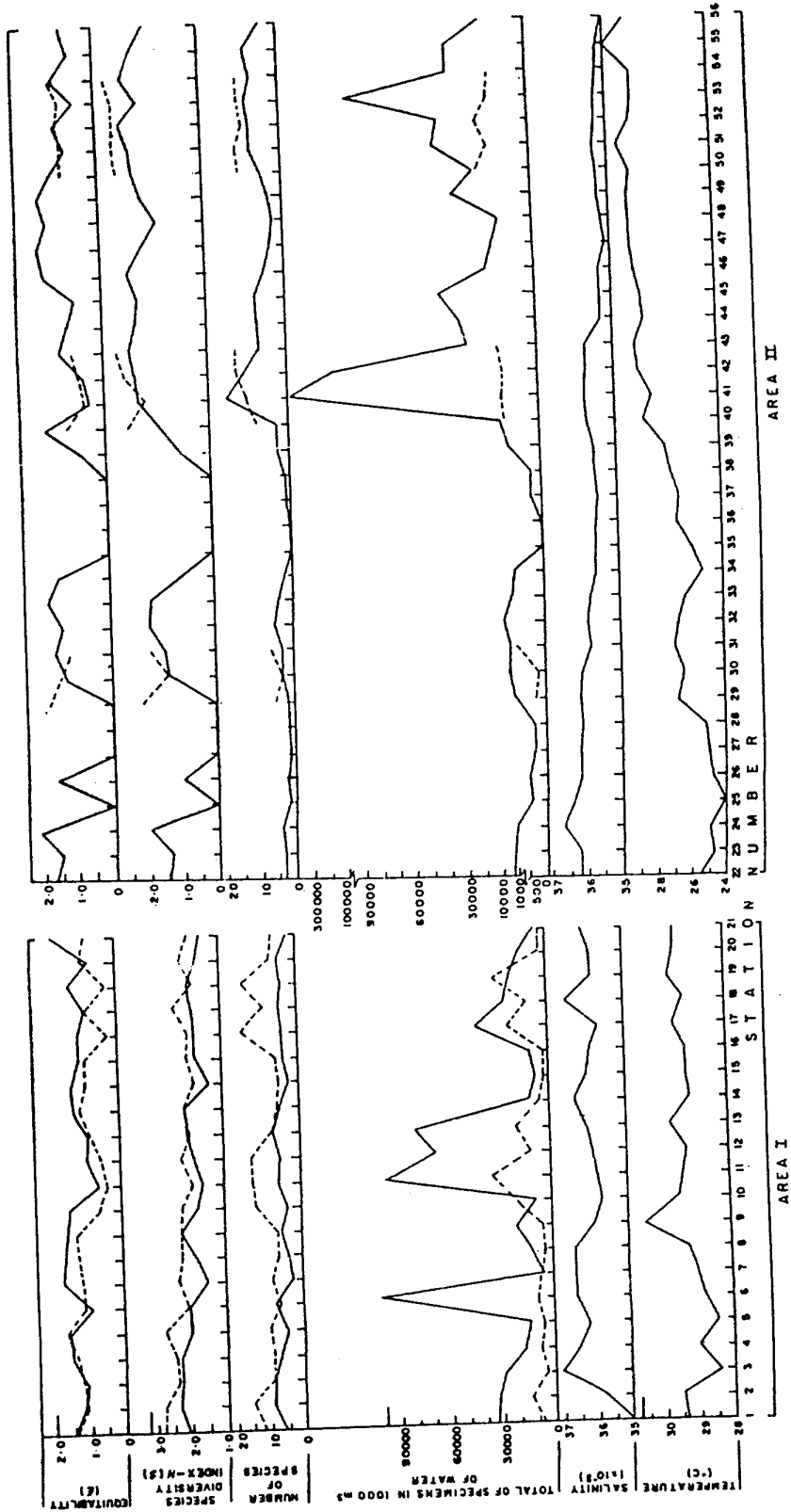


Fig. 2.—Distribution of temperature; salinity; total specimens in 1000 m³ of water; species number; diversity index $H(S)$; and equitability (E) at different sites (—, surface and - - - - -, vertical tows for showing faunal trends)

Table 1—Concentrations of foraminiferal species in 1000 m³ of water in surface tows (0-10 m) in area I

Station No.	Date (1980)	Total no. of specimens in 1000 m ³	<i>G. bulloides</i>	<i>G. calida</i>	<i>G. falconensis</i>	<i>G. glutinuloba</i>	<i>G. subaerens</i>	<i>G. aequiliteralis</i>	<i>H. parapetalgia</i>	<i>H. petaloga</i>	<i>G. tenuis</i>	<i>G. conglobatus</i>	<i>G. luber</i>	<i>G. sacculifer</i>	<i>P. obliquiloculata</i>	<i>G. unguilata</i>	<i>G. hexagona</i>	<i>G. conglomerata</i>	<i>N. duterret</i>	<i>G. nitida</i>	<i>G. glutinata</i>	<i>I. humilis</i>
1	3/11	32762	762	-	-	254	-	7619	-	-	-	-	7111	11175	-	-	-	-	-	-	5841	-
2	3/11	33016	1016	-	-	508	-	7111	-	-	-	254	6603	6857	254	-	254	-	-	-	10159	-
3	3/11	29714	457	-	-	-	-	5029	-	-	457	457	12800	5486	-	-	457	-	-	-	4114	-
4	4/11	16941	941	-	-	471	-	5176	-	-	-	941	4235	4706	-	-	-	-	-	-	471	-
5	4/11	14000	-	-	-	1000	-	1000	-	-	-	6000	4000	4000	-	-	-	-	-	-	2000	-
6	5/11	105515	-	-	-	865	865	45838	-	-	-	865	6919	27676	-	-	-	-	-	-	21622	-
7	5/11	4400	-	-	-	-	-	2000	-	-	-	-	800	1600	-	-	-	-	-	-	-	-
8	6/11	10400	-	-	-	-	-	2400	-	-	-	4800	2400	2400	-	-	-	-	800	-	-	-
9	6/11	20000	667	-	-	-	-	4000	-	-	-	1333	7333	5333	-	-	-	-	-	-	1333	-
10	7/11	9231	-	-	-	-	-	4308	615	-	-	-	3077	1231	-	-	-	-	-	-	-	-
11	7/11	96000	-	-	-	-	-	64000	-	-	-	1600	4800	19200	-	-	-	-	-	-	1600	-
12	7/11	66000	-	-	-	-	-	31000	-	-	-	-	9000	22000	1000	-	-	-	-	-	1000	2000
13	9/11	79272	-	-	-	-	-	41455	-	-	-	2909	6545	18909	-	-	-	-	-	-	727	-
14	9/11	11799	-	-	-	-	-	4491	-	-	-	561	1123	4491	-	-	-	-	-	-	561	-
15	9/11	6519	-	-	-	-	-	1185	-	-	-	1185	4148	4148	-	-	-	-	-	-	-	-
16	9/11	10400	-	-	-	-	-	800	-	-	-	1600	6400	800	-	-	-	-	-	-	800	-
17	9/11	43733	-	-	-	-	-	20267	-	-	-	6400	14933	1066	-	-	-	-	-	-	1067	-
18	10/11	24000	-	1777	-	-	-	2667	889	-	-	2667	15111	389	-	-	-	-	-	-	-	-
19	10/11	22025	-	3049	-	-	-	9143	-	-	-	1523	7619	762	-	-	-	-	-	-	-	-
20	10/11	16800	-	400	-	-	-	6800	-	-	-	400	400	8000	-	-	-	-	-	-	800	-
21	11/11	6106	-	-	-	-	-	1623	-	-	-	-	1623	2850	-	-	-	-	-	-	-	-

Table 2—Concentrations of foraminiferal species in 1000 m³ of water in surface tows (0-10 m) in area II

Station No.	Date (1985)	Total no. of specimens in 1000 m ³	<i>G. bulloides</i>	<i>G. calida</i>	<i>G. falconensis</i>	<i>G. quinqueloba</i>	<i>G. rubescens</i>	<i>G. aequilata</i>	<i>H. pelagica</i>	<i>G. conglobatus</i>	<i>G. tuber</i>	<i>G. sacculifer</i>	<i>G. anversae</i>	<i>G. obliquilocu-</i> <i>tata</i>	<i>G. anfracta</i>	<i>G. litorea</i>	<i>G. neoflexuosa</i>	<i>G. flexuosa</i>	<i>G. tumida</i>	<i>G. unguolata</i>	<i>M. dutertrei</i>	<i>G. nitida</i>	<i>G. glutinata</i>
22	18/3	3138	-	-	-	-	-	526	-	-	1053	-	-	-	-	-	-	-	-	-	-	-	1579
23	19/3	2778	-	-	-	556	-	-	-	-	956	-	-	-	-	-	-	-	-	-	-	-	1666
24	19/3	1212	-	-	-	303	-	-	-	-	303	303	-	-	-	-	-	-	-	-	-	-	303
25	19/3	357	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	222	-	-	-	357
26	19/3	444	-	-	-	-	-	-	-	-	250	-	-	-	-	-	-	-	-	-	-	-	222
27	19/3	250	-	-	-	-	-	-	-	-	-	233	-	-	-	-	-	-	-	-	-	-	-
28	19/3	233	-	-	-	-	-	-	-	-	-	1316	-	-	-	-	-	-	-	-	-	-	-
29	20/3	1316	-	-	-	-	-	526	-	-	1316	2895	-	-	-	-	-	-	-	-	-	-	-
30	20/3	4737	-	-	-	-	-	-	-	-	1316	2895	-	-	-	-	-	-	-	-	-	-	526
31	21/3	3421	-	-	-	-	-	-	-	263	2105	2895	-	-	-	-	-	-	-	-	-	-	2368
32	21/3	7895	-	263	-	-	-	-	-	-	571	1143	-	-	-	-	-	-	-	-	-	-	571
33	21/3	2571	-	-	-	-	-	-	286	-	526	263	-	-	-	-	-	-	-	-	-	-	-
34	22/3	789	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
35	22/3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	263
36	22/3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37	22/3	263	-	-	-	-	-	-	-	-	-	208	-	-	-	-	-	-	-	-	-	-	303
38	23/3	208	-	-	-	-	-	-	-	-	303	2424	-	-	-	-	-	-	-	-	-	-	-
39	23/3	3030	-	-	-	-	-	-	-	-	2571	2957	-	-	-	-	-	-	-	-	-	-	-
40	23/3	6571	-	-	-	-	-	1143	-	-	42368	52895	-	-	-	-	-	-	-	-	-	-	245526
41	23/3	399211	12632	526	11316	4211	6316	5263	1579	2105	1579	263	526	1579	6053	4211	263	263	263	263	4211	263	263
42	24/3	118571	2500	-	1429	357	357	3571	-	-	20714	25357	357	1071	-	357	3214	714	714	714	714	58571	
43	24/3	24957	857	-	571	-	-	857	-	-	4857	9857	-	-	-	-	-	-	-	-	286	-	6857
44	24/3	29159	263	-	-	-	-	526	263	263	9667	19000	-	-	-	-	-	-	-	-	-	-	6052
45	25/3	39333	-	333	-	333	-	333	-	667	1818	2727	-	-	-	-	-	-	-	-	-	-	5333
46	25/3	10606	-	303	606	-	-	-	-	-	2500	3000	-	-	-	-	-	-	-	-	-	-	3333
47	25/3	9000	-	-	-	-	-	-	-	-	698	2093	-	-	-	-	-	-	-	-	-	-	1250
48	25/3	3721	-	-	-	-	-	-	-	-	8192	12727	-	-	-	-	-	-	-	-	-	-	930
49	26/3	30969	-	-	-	-	-	957	-	357	3714	7714	-	-	-	-	-	-	-	-	-	-	6970
50	26/3	17714	-	-	-	-	-	-	-	-	4211	13947	-	-	-	-	-	-	-	-	-	-	357
51	26/3	40263	263	789	-	-	-	1942	263	-	4211	13947	-	-	-	-	-	-	-	-	-	-	4211
52	26/3	37170	755	1132	-	-	-	1387	-	-	3774	11509	-	-	-	-	-	-	-	-	-	-	3018
53	27/3	90270	172	345	-	-	-	1897	517	-	5962	19310	-	-	-	-	-	-	-	-	-	-	7759
54	27/3	30909	606	606	-	-	-	1212	-	-	7273	6687	-	-	-	-	-	-	-	-	-	-	3333
55	27/3	30750	-	125	-	-	-	1000	375	500	1125	6875	-	-	-	-	-	-	-	-	-	-	3625
56	27/3	9643	-	-	-	-	-	-	-	-	357	1429	-	-	-	-	-	-	-	-	-	-	1429

Table 3—Concentrations of foraminiferal species in 1000 m³ of water in vertical tows (0-200 m)

Station No.	Date	Total no. of specimens in 1000 m ³	<i>G. bulloides</i>	<i>G. calida</i>	<i>G. kalconensis</i>	<i>G. quinqueloba</i>	<i>G. tuberculans</i>	<i>G. aequilolateralis</i>	<i>H. parapealga</i>	<i>H. pelagica</i>	<i>B. dilatata</i>	<i>G. senellus</i>	<i>G. conglobatus</i>	<i>G. tuber</i>	<i>G. sacculifer</i>	<i>Q. unilacera</i>	<i>T. poliquiloculata</i>	<i>G. anfracta</i>	<i>G. menardii</i>	<i>G. theyert</i>	<i>G. lundada</i>	<i>G. unguata</i>	<i>G. hexagona</i>	<i>O. conglomerata</i>	<i>N. duterrei</i>	<i>G. nitida</i>	<i>G. glutinata</i>	<i>G. lota</i>	<i>I. humilis</i>
1	3/11	5487	321	-	71	71	748	71	36	955	1423	36	-	-	-	-	-	-	-	-	-	-	-	-	71	-	1283	-	-
2	3/11	12491	958	-	200	439	3431	40	40	80	2035	2434	-	-	-	-	-	-	-	40	-	-	-	120	439	-	2155	-	-
3	3/11	2913	80	-	-	40	638	40	40	80	1197	279	-	-	-	-	-	-	-	-	-	-	-	-	40	-	519	-	-
4	4/11	6300	-	123	-	123	1762	-	61	123	194	1594	1410	-	-	-	-	-	-	-	-	-	-	-	-	-	920	-	-
5	4/11	4593	157	104	-	209	626	-	-	104	261	987	-	-	-	-	-	52	-	-	-	-	-	-	-	-	1201	-	-
6	5/11	8922	-	-	-	205	4256	-	-	82	1391	1760	-	-	-	-	-	-	-	-	-	-	-	-	82	-	1146	-	-
7	5/11	5995	149	-	-	50	1635	-	-	297	1833	1337	-	-	-	-	-	-	-	-	-	-	-	198	-	347	-	-	-
8	6/11	3607	-	-	-	42	1231	-	-	42	127	1061	764	-	-	-	-	-	-	-	-	-	-	-	-	340	-	-	-
9	6/11	4614	129	-	-	-	776	-	-	216	1997	1164	-	-	-	-	-	-	-	-	-	-	-	-	-	345	-	-	-
10	7/11	20054	72	72	145	-	12163	72	1014	-	-	217	1520	2100	-	-	-	-	-	-	-	-	-	86	-	345	-	-	-
11	7/11	33664	384	128	64	-	22464	-	704	128	320	1536	4736	-	-	-	-	-	-	-	-	-	362	941	-	1159	-	-	-
12	7/11	10514	-	-	46	183	5669	-	91	46	229	914	2514	-	-	-	-	-	-	-	-	-	320	1472	-	996	-	-	384
13	8/11	18991	-	-	-	70	10713	-	-	557	1739	3617	-	-	-	-	-	-	-	-	-	-	91	274	-	274	-	-	46
14	9/11	6174	-	-	-	-	2577	-	-	60	899	1918	-	-	-	-	-	-	-	-	-	-	-	60	300	-	835	-	-
15	9/11	2601	-	-	-	-	926	-	-	44	350	1190	-	-	-	-	-	-	-	-	-	-	-	60	300	-	340	-	-
16	9/11	2462	-	-	-	-	1026	-	-	41	533	738	-	-	-	-	-	-	-	-	-	-	-	44	-	44	-	-	-
17	9/11	25910	-	230	-	58	14388	173	115	-	115	691	5295	58	-	-	-	-	-	-	41	-	-	41	-	41	-	-	-
18	10/11	11589	-	3085	75	-	5084	299	748	-	299	1121	-	-	-	-	-	-	-	-	-	-	403	58	288	59	306	58	58
19	10/11	31660	42	764	-	127	20329	42	764	42	85	934	6408	35	170	-	-	-	-	-	-	-	598	150	-	150	-	-	-
20	10/11	4039	-	-	-	-	2044	-	-	-	53	409	934	-	-	-	-	-	-	-	-	-	58	175	-	350	-	-	-
21	11/11	3690	-	-	-	-	496	-	-	-	124	1034	1860	-	-	-	-	-	-	-	-	-	-	41	-	41	-	-	-

cont'd

Table 3.—Concentrations of foraminiferal species in 1000 m³ of water in vertical tows (0-200 m)—Contd.

Station No.	Date	Total no. of specimens in 1000 m ³	<i>G. bulloides</i>	<i>G. calida</i>	<i>G. falconensis</i>	<i>G. quinqueloba</i>	<i>G. rubescens</i>	<i>G. aequilolateralis</i>	<i>H. parapejalica</i>	<i>H. pelagica</i>	<i>H. digitata</i>	<i>G. tenuis</i>	<i>G. conglobata</i>	<i>G. ruber</i>	<i>G. sacculifer</i>	<i>G. univertica</i>	<i>G. obliquiloculata</i>	<i>G. inflata</i>	<i>G. menardi</i>	<i>G. thayeri</i>	<i>G. tumida</i>	<i>G. unguata</i>	<i>G. hexagona</i>	<i>G. conglobata</i>	<i>N. dutertrei</i>	<i>G. nitida</i>	<i>G. glutinata</i>	<i>G. lacte</i>	<i>I. humilis</i>	
29	20/3	225	-	-	-	-	-	19	-	-	-	-	-	-	75	56	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30	20/3	123	-	-	-	-	-	-	-	-	-	-	-	35	70	-	-	-	-	-	-	-	-	-	-	-	18	-	-	-
31	21/3	959	-	-	-	-	-	123	-	27	-	-	-	479	151	-	-	14	-	-	-	-	-	-	-	164	-	-	-	-
40	23/3	4321	96	57	-	-	-	535	-	-	-	-	76	1568	1165	-	-	-	-	-	96	-	-	-	19	707	-	-	-	-
41	24/3	4807	65	-	129	65	16	210	-	-	-	-	49	696	340	-	-	-	16	-	49	-	-	-	49	3123	-	-	-	-
42	24/3	4013	121	13	13	40	13	148	-	54	-	-	13	658	956	13	-	13	-	-	242	-	-	-	40	1664	-	-	-	-
43	24/3	7075	-	57	-	-	-	707	-	38	-	-	38	1663	1955	57	19	19	-	-	1147	-	-	19	19	1300	-	-	-	38
50	26/3	14986	28	111	-	-	-	2000	-	347	-	-	181	2839	5125	111	-	-	-	-	2556	83	-	-	83	1472	-	-	-	-
51	26/3	8362	186	62	21	-	21	787	-	331	-	-	124	1234	3035	21	-	-	-	-	1946	-	-	-	21	973	-	-	-	-
52	26/3	14624	89	221	-	-	-	1588	-	603	-	-	29	1897	4103	74	-	-	-	-	4559	132	-	-	-	1529	-	-	-	-
53	27/3	8145	41	82	21	-	-	1258	-	103	-	-	-	1381	1629	-	-	21	-	-	2619	82	-	-	-	887	-	-	-	-
54	27/3	6342	36	198	18	-	-	1153	-	505	-	-	72	901	1950	108	-	-	-	-	1423	18	-	-	-	360	-	-	-	-

greater consistency in its distribution in deep than in surface plankton tows.

Globigerinoides sacculifer—In Saurashtra waters (19°-22°N), this species from 0-10 m tows is sparsely distributed with a range of concentration 208-2895 specimens in 1000 m³, but very high concentrations are found at sts 41, 42, 49 and 51-53 off Konkan coast. In general, it is very abundant southwards of 19°N. Similar trend is also seen with this species from the vertical tows. From 0-200 m tows of area I, the range of variation of this species observed is greater within 11°-13°N. The southern part of this area is fairly rich in concentration with the highest density of 6408 specimens in 1000 m³ at st 19, whereas in the northern Arabian Sea north of 19°N, it is very sparse in abundance.

Pulleniatina obliquiloculata—Its concentration is higher in 0-10 m than in 0-200 m tows of the southern Arabian Sea (11°-15°N) in area I. It is absent in deep tows north of 15°N, but observed in a surface tow at st 41 (18°N).

Globorotalia hirsuta—In plankton samples collected from the Arabian Sea, it is found only at st 41 (18°N) in a surface tow with concentration of 263 specimens in 1000 m³.

Globorotalia tumida—It is absent in both 0-10 m and 0-200 m tows of the eastern Arabian Sea (11°-15°N) in area I. It occurs with a density of 222 specimens in 1000 m³ in a single surface tow at st 26 (22°N) off Saurashtra shelf waters, while in 0-10 m tows off the Konkan coast (15°-18°N), higher concentrations, > 10000 specimens in 1000 m³, are found at sts 44 and 52-55 with highest density of > 50000 in 1000 m³ at st 53 (north of 15°N). In deep tows off the Konkan coast within 15°-18°N, its concentration ranges from 49 to 4559 specimens in 1000 m³ with maximum density at st 52 (16°N).

Neogloboquadrina dutertrei—This species shows maximum concentration of 6545 specimens in 1000 m³ in 0-10 m tow at st 13 (15°N), while in deep tows, it is higher in density in the area between 11° and 15°N and occurs sparingly as in surface tows at sites north of 15°N.

Globigerinita glutinata—This is a very abundant species in 0-10 m tows of northern Arabian Sea. Very high concentrations (> 50000 specimens in 1000 m³) are found in slope waters north of 17°N at sts 41 and 42 of area II (Table 2). Its concentration is poor off Saurashtra. In area I, higher concentrations, > 10000 specimens in 1000 m³, are seen at sts 2 and 6 lying in 13°-15°N. In the case of vertical tows, higher densities, > 1500 in 1000 m³, are found at sts 2, 41, 42 and 52 (15°N and north of it) with highest concentration at st 41 (18°N).

Ecological considerations—The importance of physical factors, viz. temperature and salinity, and their control over distribution of various foraminiferal species and their abundance has previously been stressed^{5,6}. These factors are uniformly distributed in area I with coefficient of variation (*CV*) of 1.35%. Correlation coefficient analysis shows that temperature and salinity have a larger influence on species found in deep than in surface tows.

In waters over the continental slope of this area, mean (\bar{X}) total concentration of foraminiferal specimens in surface tows is 31366 in 1000 m³, which is threefold increase when compared with that of specimens noted in deep tows. The \bar{X} number of species in surface tows (5) is only half the number of species observed in vertical hauls. Further, *CV* of total concentration is more in surface (93.5%) than in vertical hauls (86.6%).

Average diversity index, $\overline{H(S)}$ is high in vertical hauls (2.2) showing negative correlation with number of species ($r = -0.545$). But it is low in surface hauls (1.9) and positively correlated with number of species ($r = 0.736$). Mean equitability ($\bar{\epsilon}$) in both surface and vertical hauls is negatively correlated with number of species having corresponding values of $r = -0.619$ and $r = -0.61$; the $\bar{\epsilon}$ is higher in surface (1.3) than in vertical hauls (0.97) in the distribution of individuals among species. Also, it is observed that total concentration and number of species are significantly correlated in both surface ($r = 0.594$) and vertical ($r = 0.740$) tows.

On the other hand in area II, \bar{X} total specimens in surface (27409 in 1000 m³) is 4 times the number of specimens observed in vertical hauls. Furthermore, means of total specimens in these plankton tows are low compared to those of area I. Very high *CV* is observed for total concentration in surface (250%), while in vertical hauls, it is only 77%. And correlation coefficient of total concentration with number of species is high and positive in both surface ($r = 0.782$) and vertical ($r = 0.716$) tows. \bar{X} number of species in the vertical (10) is twice of that observed in the surface hauls with *CV* of 36%, while for surface tows *CV* is 80%.

$\overline{H(S)}$ is higher in vertical tows (2.3) with less *CV* (16.8%) and is negatively correlated with number of species ($r = -0.993$). Conversely, for surface tows $\overline{H(S)}$ is 1.4, but with very high *CV* (60.8%) and is positively correlated with number of species ($r = 0.745$). The $\bar{\epsilon}$ is almost uniform in both surface (1.01) and vertical (1.12) tows. The $\bar{\epsilon}$ with number of species is highly negatively correlated ($r = -0.739$) in vertical hauls, but not significant in surface hauls. The

dispersion in the distribution of $\bar{\epsilon}$ is nearly double in surface (67%) when compared with that of vertical tows.

As observed in area I, temperature and salinity have a greater control over the fauna in deep than in surface tows in this area too.

Day and night variation in density of planktonic Foraminifera from plankton tows—As observed by some investigators⁷⁻¹¹, higher concentrations of planktonic Foraminifera are normally found in day time than in night plankton tows from oceanic areas, though there is an exception as shown by Boltovskoy¹² in the equatorial Atlantic. In the region of southern Arabian Sea beyond the continental shelf (sts 1-21 of *RVG* cruise 82), similar observations are made. But in the northern Arabian Sea of cruise 151, it is reverse and maybe due to most of the locations being shallow and close to the coast. Further, there is considerable variation between cruises especially in the night/day ratios for mean concentration of foraminiferal specimens (Table 4).

Foraminiferal species in relation to hydrography—Hydrographic conditions described herein are mainly concerned with the season representing dates of the cruises of *RVG* in this study. October-November are not only transition months, but they also suggest the beginning of NE monsoon. During NE monsoon season, surface currents of the Indian equatorial water in the Arabian Sea are northerly up to the end of January and thereafter, they become southerly.

In the present study, the salinity of waters at the locations in area I varies from 33 to 35.8 × 10⁻³ and temperature from 25° to 29.5°C. Relatively higher ranges of salinity and temperature were observed in the northern Arabian Sea (area II), salinity and temperature variations being 35-36.7 × 10⁻³ and 24-29.9°C respectively (Fig. 2).

It is obvious from variation with latitude in the distribution of a few species (Figs 3, 4 and Tables 1-3) in plankton tows of waters over the continental slope that *G. ruber*, *G. menardii* and *G. glutinata* are dominant species in the Arabian Sea from 15°N northward direction. Because of the arid climate that prevails in most areas around the northern Arabian Sea, it is subjected to evaporation which is generally

Table 4—Mean number of foraminiferal species in 1000 m³

Cruise	Surface tows (0-10 m)			Vertical tows (0-200 m)		
	Night	Day	Night/Day ratio	Night	Day	Night/Day ratio
RVG-82	25595	35695	0.717	9628	11388	0.345
RVG-151	36394	18924	1.923	6975	5848	1.193

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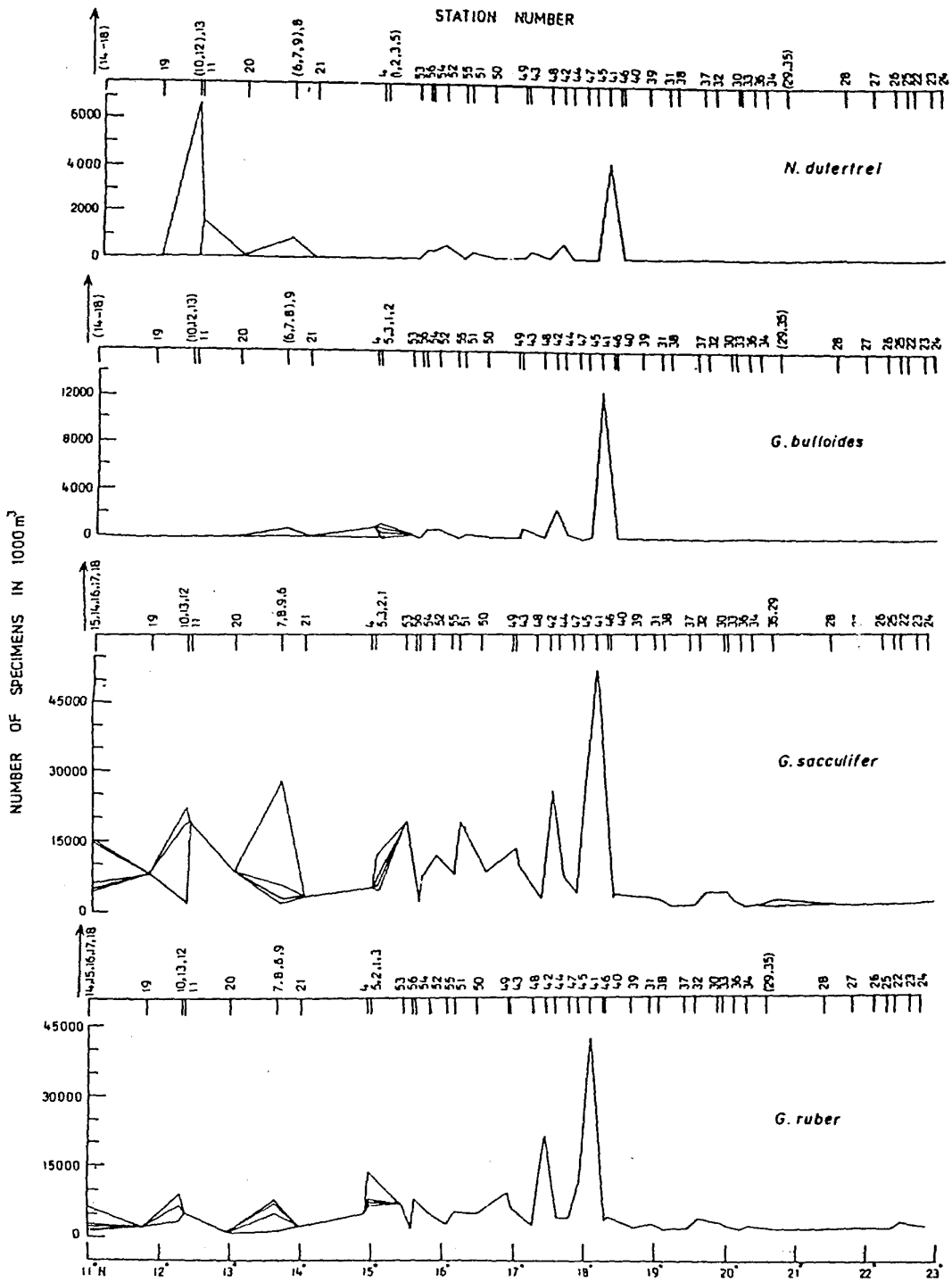


Fig. 3—Latitudinal distribution of foraminiferal species at sampling sites for 0-10 m tows (arrow indicates direction of reading the stations in the order of increasing abundance; station numbers given within parentheses have the same number of specimens)

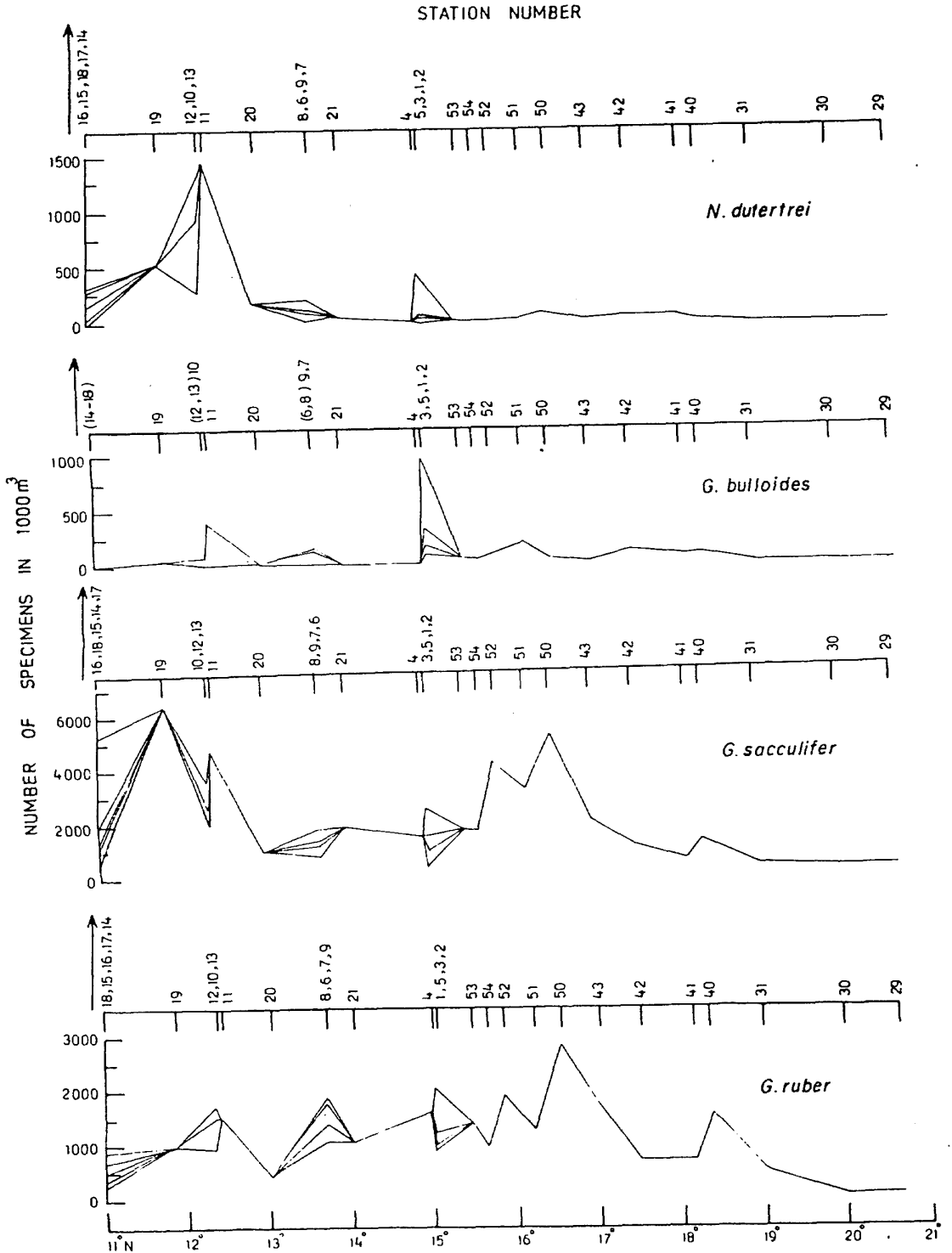


Fig. 4—Latitudinal distribution of foraminiferal species at sampling sites for 0-200 m tows (arrow indicates direction of reading the stations in the order of increasing abundance; station numbers given within parentheses have the same number of specimens)

very high¹³ when compared with precipitation during NE monsoon season and that leads to salinity increase of the waters. *G. falconensis* is mostly concentrated in the area between 15° and 18°10'N. The aforementioned species are common in waters of the Arabian Sea where salinity of waters is $\geq 36 \times 10^{-3}$. By contrast, *G. aequilateralis*, *G. sacculifer* and *N. dutertrei* are the most prevalent species in relatively low saline waters ($< 36 \times 10^{-3}$) of the southern Arabian Sea south of 15°N.

In the case of *G. tumida*, temperature seems to be the possible factor mainly controlling its distribution¹⁴ instead of salinity. Due to weak upwelling that occurs in the southeastern Arabian Sea and over the Laccadive trough¹⁵, *G. bulloides* and *N. dutertrei* are encountered in area I as previously reported by Zhang¹⁶. These species are conspicuously absent in Saurashtra waters, but they do occur off Konkan coast, since upwelling characteristics have been observed off Bombay¹⁷ and in areas north of Bombay and off Gulf of Cambay¹⁸ during NE monsoon season.

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