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Planktonic Foraminifera in waters off the Coromandel coast, Bay of Bengal

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Living planktonic foraminifers have been studied in relation to their ecology and distribution with plankton samples collected in January from the east coast of India. During this period, upwelling occurs in the northwestern Bay of Bengal and as a result, besides higher populations of Foraminifera in the northeastern part of the coast, upwelling indicator species such as *Globigerina bulloides* and *Neogloboquadrina dutertrei* are also discernible in the fauna. Species diversity, equitability, and coexistence of various foraminiferal species of the samples are compared. Further, the degree of faunal affinity for different sites is discussed.

Oceanographic applications of Recent planktonic Foraminifera in palaeoecology and palaeoclimatology are well known. As stated by Phleger[1] and Bé[2], sufficient work is not carried out on the distribution of living planktonic Foraminifera from plankton tows, though a wealth of information exists on this group in sediments of the world oceans. In general, previous studies[3-6] on planktonic Foraminifera from the Bay of Bengal are limited to oceanic areas. It is from this viewpoint for comparison purpose, in the present study, abundance and distributional trends of the fauna mostly in neretic waters along the Coromandel coast of India are reported with some ecological implications using physical factors such as temperature and salinity.

Materials and Methods

During cruise 130 of *R V Gaveshani* in January 1984, 22 plankton samples of both surface (0-10 m) and vertical tows (0-200 m) were collected from 19 stations (Fig.1) in coastal waters between Visakhapatnam and Nagapattinam. The samples were obtained with the Heron-Tranter net (mouth area, 0.25 m^2; net length, 2.5 m; aperture size, 150 μm). For making a quantitative study of the foraminiferal species, a Rigosha flow meter was fixed to the net. The term adults refers to the specimens of planktonic Foraminifera ≥150 μm size and only these specimens were used for determining abundance of different species (Table 1), while others <150 μm size in the case of some species, were indistinguishable[7] since they being juveniles and hence ignored. However, total number of specimens per 1000 m^3 includes both adults and juveniles. The surface tows were made from all locations and the vertical tows only from sts 2, 6 and 7, where water depths were more than 200 m.

Statistical treatment of the data involved utilizing certain techniques such as Pearson correlation of coefficient for coexistence of foraminiferal species[8], cluster analysis[9] for grouping the species into various clusters of different similarity levels us-

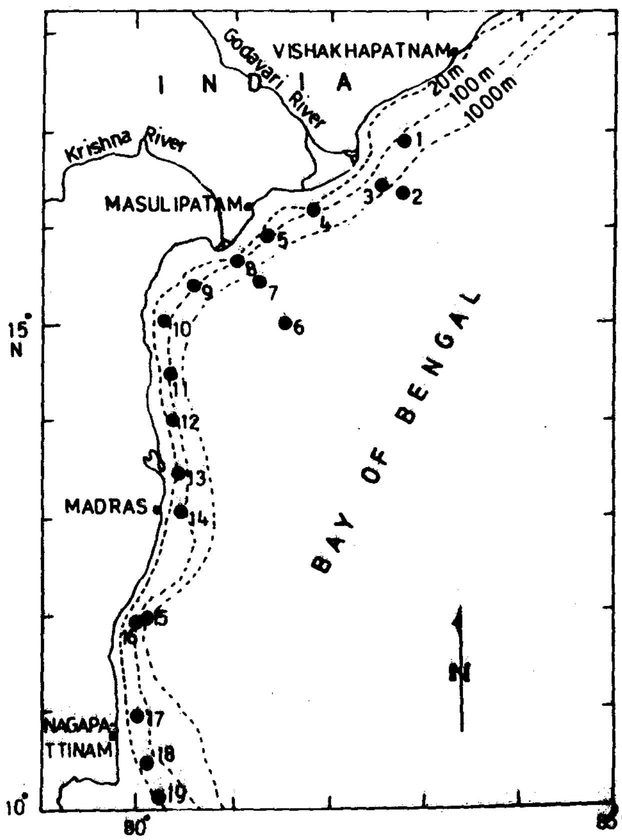

Fig. 1—Locations of plankton samples

ing correlation coefficient as similarity index, ANOVA technique[10], and a trellis diagram[11].

Results and Discussion

Foraminiferal abundance and species distribution—The standing crop of planktonic Foraminifera varies from 1714 to 116308 specimens in 1000 m^3 of water (Fig.2). Higher populations generally occur in the northeastern portion of the coast (sts 1 to 10) and in the south, populations are usually small except at sts 12,14 and 15 of the inner shelf. Very high standing crops of planktonic Foraminifera in this study are a consequence of prevailing upwelling in January of nutrient-rich waters at the coastal areas of northwestern Bay of Bengal[12].

In contrast with vertical hauls, smaller populations of the fauna in surface hauls are dominated by species like *Globigerinella aequilateralis*, *Globigerinoides ruber*, *G. sacculifer*, and *Globigerinita glutinata.* Furthermore, at the locations where larger populations occur in the plankton hauls, they include rare species such as *Beella digitata*, *Hastigerina pelagica*, *Globigerinoides conglobatus*, *Orbulina universa*, *Pulleniatina obliquiloculata*, *Globorotalia anfracta*, *G. menardii*, *Globorotaloides hexagona* and *Turborotalita humilis.*

It is seen from Table 1 that the vertical hauls are represented by more number of species than the surface hauls and the ranges of number of species in the surface and vertical tows are 2-12 and 10-16 respectively (Fig.2). Species present in vertical tows but not in surface tows are *G. anfracta*, *G. menardii* and *T. humilis. P. obliquiloculata* is observed only in surface tows. The most widely distributed and dominant species in the east coast fauna are *Globigerina bulloides*, *G. aequilateralis*, *G. ruber*, *G. sacculifer* and *G. glutinata.*

Species diversity, $H(S)$ of the fauna ranges from 0.9 to 3.3 and equitability (ε) from 58.3 to 120% (Fig.2). As observed with the populations of planktonic Foraminifera, species diversity is also relatively high in the fauna of northeastern part of the east coast. The number of species, diversity index, $H(S)$ and total number of specimens in 1000 m^3 of water are directly related to each other. In the case of equitability (ε), it is not perfectly related in showing positive relation with $H(S)$. At sts 16 and 19, where equitability is $>100\%$, it implies that even if more number of species other than those listed in Table 1, have a chance to occur at these sites, species diversity index almost remains the same.

The mean number of specimens of planktonic Foraminifera in the surface hauls for 11 day stations and 8 night stations are 28101 and 29390 specimens in 1000 m^3 of water respectively. This observation suggests that in the coastal waters, perhaps planktonic Foraminifera behave like other groups of zooplankton in their diurnal migration showing greater abundance during night time. Further, in these tows, total concentration of planktonic forams varies with respect to stations ($F_{(7,112)}$ = 3.4787) and with respect to species ($F_{(16,112)}$ = 8.9956) at 1% level ($P<0.01$). Interraction between day and night time collections of species and stations is also significant ($F_{(7,112)}$ = 4.3557) at 1% level ($P<0.01$). For vertical tows, there are no night hauls in the present cruise. But the mean number of 3 day stations is 6661 specimens in 1000 m^3 of water, which in comparison with day stations of surface hauls is poor in abundance. In general, surface hauls are more rich in concentration of planktonic Foraminifera than vertical hauls.

Ecology—In Bay of Bengal, during this period, a northerly surface current system exists and it results in incursion of oceanic or high saline waters from the mouth of the Bay and from the equatorial region along the east coast. As a result, the quantitative survey of foraminiferal species (Table 1) is typified by dominance of equatorial species, viz. *G. conglobatus*, *G. sacculifer*, *P. obliquiloculata*, *G. menardii*, *G. tumida*, *G. ungulata* and *G. hexagona* in the coastal waters.

Upwelling process affects not only productivity of planktonic Foraminifera, but also brings about a change in the species composition of the fauna and there is a mixing of cool and warm water species. Of the two cool water species or upwelling indicator species — *G. bulloides* and *N. dutertrei* — present in the assemblage of the fauna, the former besides having a wider coverage in distribution is more abundant than the latter in the northern portion of the coast.

In the present study, temperature (Fig.2) of the surface waters varies 25.5°-26.6°C and salinity 28.9-33.1 ($\times 10^{-3}$). Generally, temperature and salinity show a lesser variability between locations in the inner part of the shelf of northern areas of the east coast. Consistent with the observations made by Cullen[6] in Bay of Bengal, it is possible in this investigation to study and verify the effect of one environmental factor, salinity alone on foraminiferal species distribution instead of temperature as the latter varies on a low range, i.e. it is more stable. On the other hand, the salinity values are extremely variable in the coastal waters and

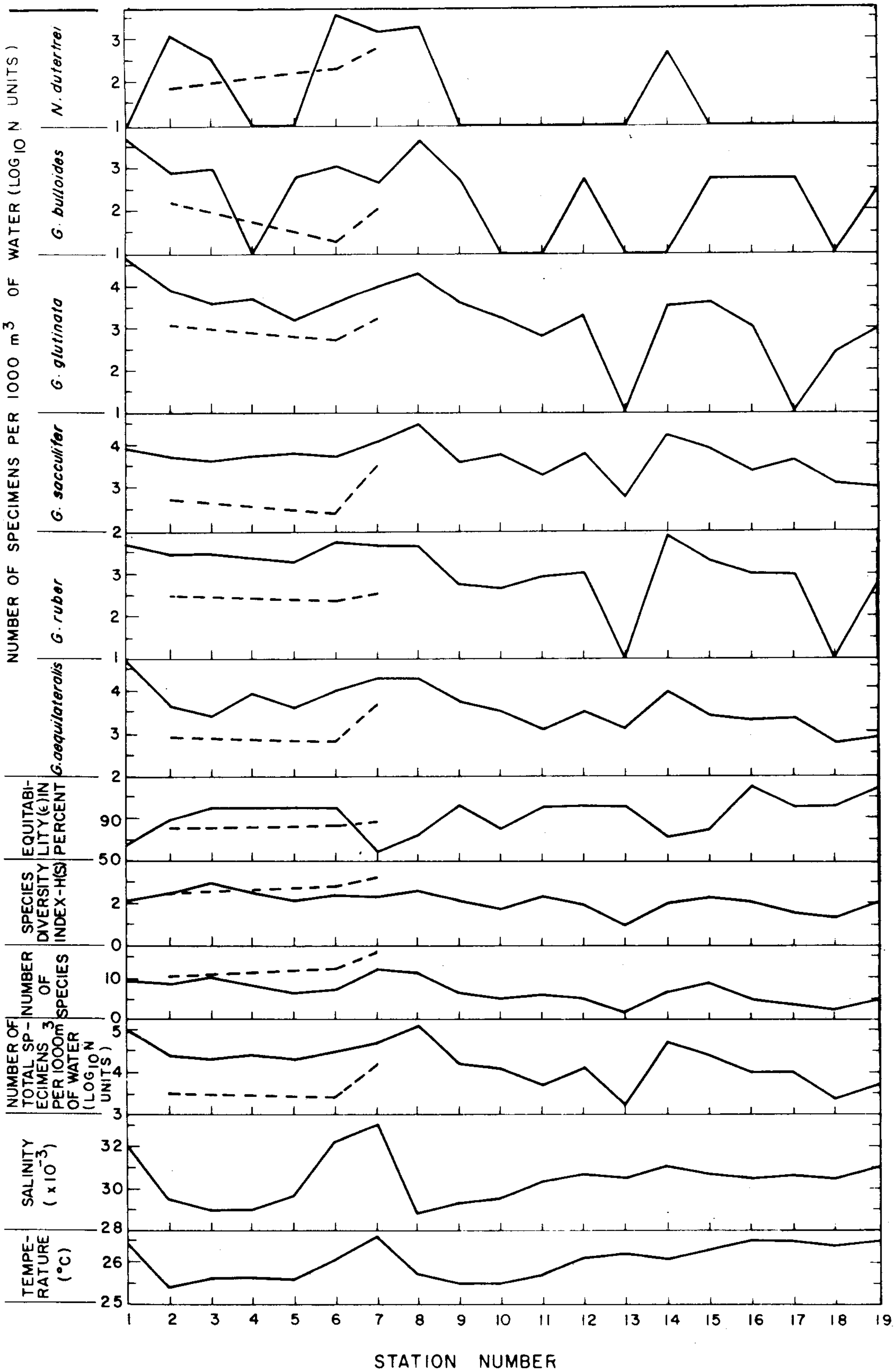

Fig. 2—Distribution of total number of foraminiferal specimens in 1000 m^3 of water, species, number of species, diversity index $H(S)$, equitability (ε) in percent, temperature, and salinity at different stations

Table 1 — Quantitative distribution of foraminiferal species in 1000 m^3 of water

Station No.	Date (1984)	Total no. of specimens in 1000 m^3	*G. bulloides*	*G. calida*	*G. falconensis*	*G. quinqueloba*	*G. aequilateralis*	*B. digitata*	*H. pelagica*	*G. conglobatus*	*G. ruber*	*G. sacculifer*	*O. universa*	*P. obliquiloculata*	*G. anfracta*	*G. menardii*	*G. tumida*	*G. ungulata*	*G. hexagona*	*N. dutertrei*	*G. glutinata*	*T. humilis*
Surface tows (0 - 10 m)																						
1	2/1	108923	3692	—	—	615	40000	—	—	—	3692	8615	—	2462	—	—	3692	615	—	—	37538	—
2	2/1	28000	615	1385	—	154	4462	—	—	—	2462	4769	—	—	—	—	—	—	—	1231	8462	—
3	2/1	20000	889	—	—	444	2667	—	444	—	2667	4444	—	444	—	—	—	—	3111	444	3556	—
4	2/1	28000	—	—	667	1333	8000	667	—	—	2000	4667	—	—	—	—	—	667	—	—	4667	—
5	3/1	18667	533	533	—	—	3733	—	—	—	1600	5867	—	—	—	—	—	—	—	—	1600	—
6	3/1	31086	914	—	—	457	10057	—	—	—	5486	4571	—	—	—	—	—	—	—	3657	3657	—
7	3/1	50800	400	200	200	—	18600	—	—	200	3600	12000	—	—	—	—	1200	200	400	1600	9600	—
8	3/1	116308	4308	1231	615	615	18462	—	—	615	3692	32000	—	—	—	—	14769	—	—	1846	20923	—
9	4/1	14500	500	—	—	500	4500	—	—	—	500	4000	—	—	—	—	—	—	—	—	4000	—
10	4/1	12364	—	—	—	—	2909	—	—	—	364	6182	—	—	—	—	364	—	—	—	2182	—
11	4/1	5429	—	286	—	—	1143	—	—	—	857	2000	—	—	—	—	286	—	—	—	571	—
12	4/1	12706	471	—	—	—	2824	—	—	—	941	6118	—	—	—	—	—	—	—	—	1882	—
13	4/1	1714	—	—	—	—	1143	—	—	—	—	571	—	—	—	—	—	—	—	—	—	—
14	4/1	45176	—	—	—	—	9882	—	—	—	7529	20235	471	—	—	—	941	—	—	471	2824	—
15	10/1	24471	471	471	—	471	2353	—	471	—	1882	9882	—	—	—	—	941	—	—	—	3765	—
16	10/1	9600	533	—	—	—	2133	—	—	—	1067	2667	—	—	—	—	—	—	—	—	1067	—
17	10/1	9000	500	—	—	—	2500	—	—	—	1000	4500	—	—	—	—	—	—	—	—	—	—
18	10/1	2514	—	—	—	—	686	—	—	—	—	1143	—	—	—	—	—	—	—	—	229	—
19	10/1	4973	432	—	—	—	865	—	—	—	649	1081	—	—	—	—	—	—	—	—	1081	—
Vertical tows (0 - 200 m)																						
2	2/1	3453	173	—	—	29	748	29	29	—	259	518	—	—	—	—	—	—	201	58	1151	—
6	3/1	2277	21	21	—	21	656	41	41	—	185	226	21	—	—	—	—	—	246	205	472	—
7	3/1	14254	104	130	26	26	5478	26	—	104	339	3231	—	—	104	26	495	52	—	704	1746	26

these variations, as small as 0.2-0.5 ppm, have a profound effect on abundance of foraminiferal species[13]. Compared with Arabian Sea, salinity of waters of Bay of Bengal is low through riverine input[14] and thereby species characteristic of low salinity waters show maximum in their abundance in the east coast fauna and they are *N. dutertrei*, *G. sacculifer* and *G. glutinata*. It is of interest to mention here that Equatorial Undercurrent, characterized by high salinities in the Equatorial Atlantic Current System, is deficient in *N. dutertrei*. This particular species is strongly influenced by small variations in salinity. *G. bulloides* occurs normally in waters of higher salinities and its predominance over *N. dutertrei* in the fauna is attributable to upwelling. Characteristics of the cold-water species, in general, show their association with low salinities, since there is a direct low temperature-low salinity relationship.

From regression analysis it is inferred that salinity and temperature together are not the only environmental parameters governing the abundance of species in surface hauls of neretic waters as variability explained is < 10%; this suggests that several other factors are interrelated in their control over distribution of species in these waters, whereas in the surface and vertical tows of oceanic areas, salinity and temperature have greater control over abundance of species (variability explained is > 70% by each parameter). This may be due to less influence of other ecological factors at these sites in deep-sea of the Bay.

Cluster analysis and comparison of the fauna at different sites—The dendrograms (Fig.3) show that in surface hauls (0-10 m) significant clusters at 5% level ($P<0.05$) are : a – (1,3,8), b — (5,9,10,16), c – (11,17), and d – (7,15) and the dominant species of these clusters being *G. bulloides*, (*G. aequilateralis*, *G. sacculifer*), *G. glutinata* and *G. hexagona* respectively. In the case of vertical tows, the clusters having high affinity at 5% level are : a – (3,5,8,9,10,12,13,14,15), b – (2,17), c – (9,18), d – (1,4), e – (6,11) and f – (7,16) and the corresponding dominant species in the clusters being *G. aequilateralis*, *N. dutertrei*, *G. glutinata*, *G. bulloides*, *B. digitata* and *G. hexagona*. These clusters show that species of each cluster always coexist living under the same environmental features.

Distribution of affinity index, according to Sanders[11], of the fauna of the sampling sites is indicated by a trellis diagram (Fig.4). This shows that in surface tows of the neretic waters, sts 10 and 12 have very great affinity index (> 90%) suggesting great abundance of more number of common

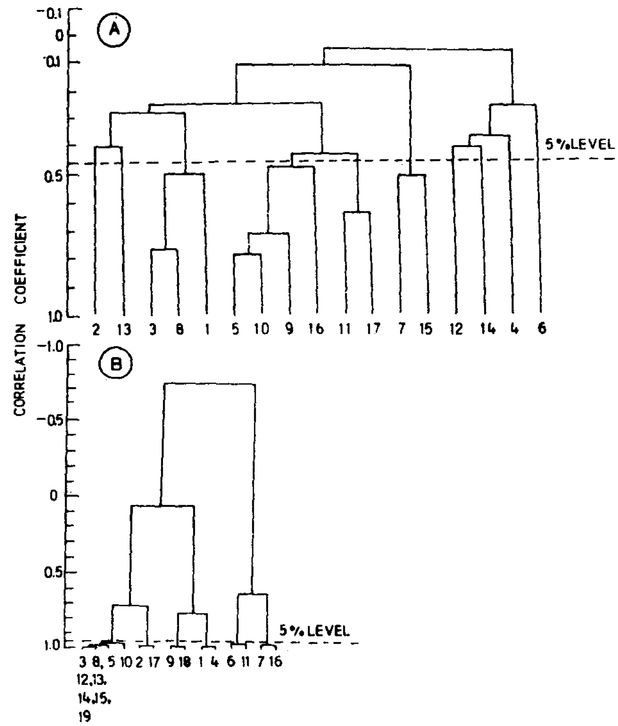

Fig. 3—Dendrograms for both surface (A) and vertical (B) tows showing coexistence of different foraminiferal species [(A) Surface tows (0-10 m) : 1. *Globigerina bulloides*, 2. *G. calida*, 3. *G. falconensis*, 4. *G. quinqueloba*, 5. *Globigerinella aequilateralis*, 6. *Beella digitata*, 7, *Hastigerina pelagica*, 8. *Globigerinoides conglobatus*, 9. *G. ruber*, 10. *G. sacculifer*, 11. *Orbulina universa*, 12. *Pulleniatina obliquiloculata*, 13. *Globorotalia tumida*, 14. *G. ungulata*, 15. *Globorotaloides hexagona*, 16. *Neogloboquadrina dutertrei*, 17. *Globigerinita glutinata*. (B) Vertical tows (0-200 m) : 1. *G. bulloides*, 2. *G. calida*, 3. *G. falconensis*, 4. *G. quinqueloba*, 5. *G. aequilateralis*, 6. *B. digitata*, 7. *H. pelagica*, 8. *G. conglobatus*, 9. *G. ruber*, 10. *G. sacculifer*, 11. *O. universa*, 12. *Globorotalia anfracta*, 13. *G. menardii*, 14. *G. tumida*, 15. *G. ungulata*, 16. *G. hexagona*, 17. *N. dutertrei*, 18. *G. glutinata*, 19. *Turborotalita humilis*]

species and also significant differences in the faunal relationship of this pair of stations with other sites along the coast. In 40% of the pairs of stations, the index of affinity is > 70%. Of these stations, sts 7 and 9 have higher faunal affinity (> 70%) with all other stations except st 3 (46%). Nearly 4% of the stations in pairs – (3,1), (4,3), (13,3), and (18,3) have affinity index < 40%. Sts 1,3 and 13 generally have low index ranging between 30 and 50% with other stations. In surface tows of oceanic areas or deep-sea sites (sts 2,6 and 7), sites 6 and 7 have more than 50 and 60% affinity index respectively with all other stations including st 2, while st 2 has < 40% affinity with sts 3,13 and 18 of neretic waters.

In vertical tows, the index between stations is high (> 50%), but < 80%.

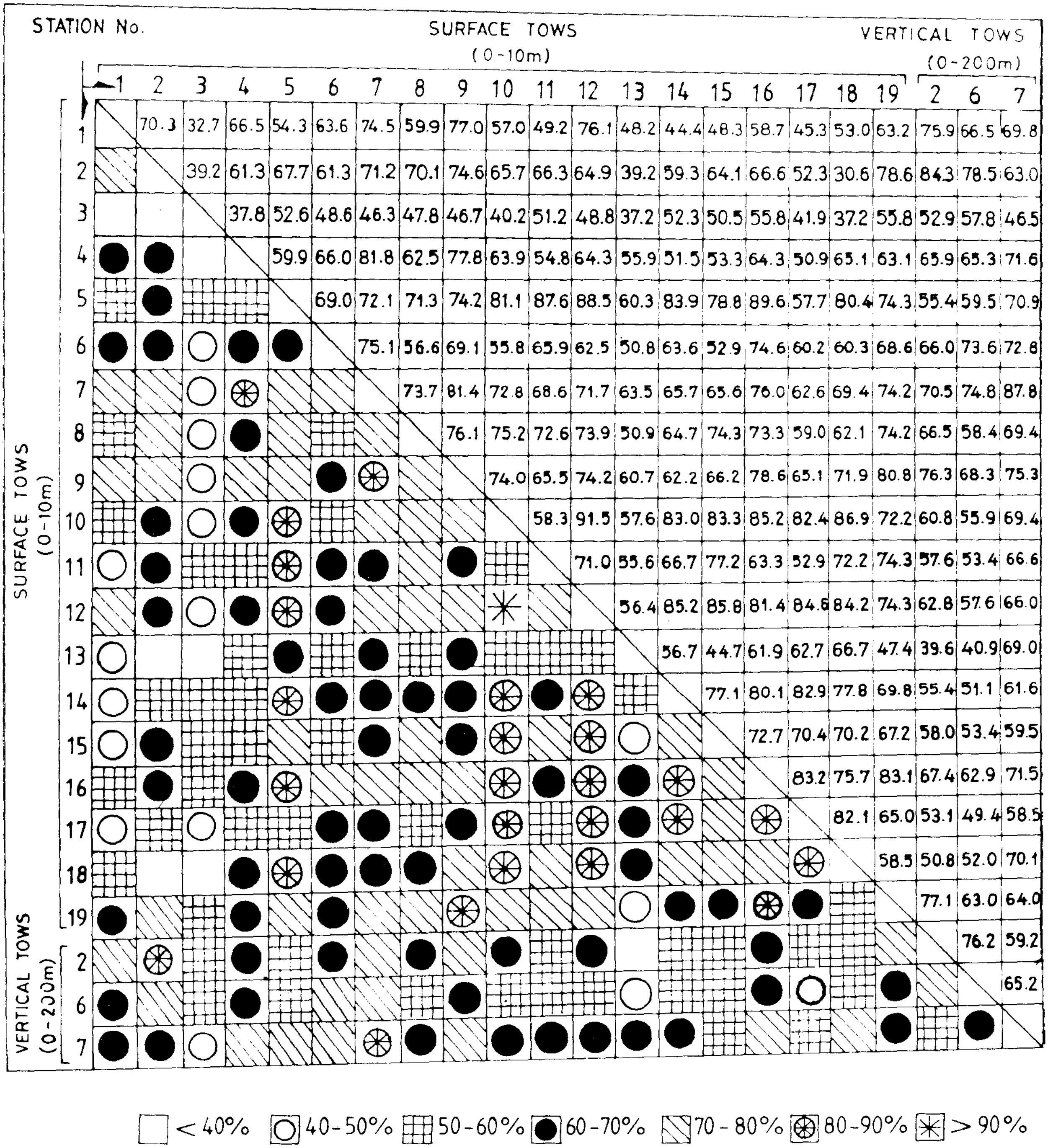

Fig. 4—Trellis diagram showing percentage affinity index between stations for the fauna, with depth in metres for plankton tows

Comparison of surface tows with vertical tows shows that all stations of surface tows have more than 50% affinity with stations of vertical tows except the pairs of stations – (3,7), (13,2), (13,6) and (17,6) where faunal affinity index ranges 40-50%.

It is concluded from this study that faunal patterns in the deeper offshore area (sts 2,6 and 7) and the shallow inshore (neretic) region, which includes other sites, are related to hydrographic differences of the two areas.

Acknowledgement

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References

1 Phleger F B, *Deep-Sea Res*, 2 (1954) 1.
2 Bé A W H, in *Oceanic micropaleontology*, edited by A T S Ramsey (Academic Press, New York) 1977, 1.
3 Frerichs W E, *Science*, 159 (1968) 1456.
4 Frerichs W E, *J Foraminiferal Res*, 1 (1971) 1.
5 Cullen J L & Prell W L, *Geol Soc Am Abstr Progr*, 10 (1978) 384.
6 Cullen J L, *Palaeogeogr Palaeoclimat Palaeoecol*, 35 (1981) 315.
7 Bé A W H, *Micropaleontology*, 5 (1959) 77.
8 Snedecor G W & Cochran W G, *Statistical methods* (Oxford and IBH Publishing Co, Calcutta) 1967, 593.
9 Sanders H L, *J Fish Res Bd Canada*, 35 (1978) 717.
10 Federer W T, *Experimental design* (Oxford and IBH Publishing Co, Calcutta) 1967, 544.
11 Sanders H L, *Limnol Oceanogr*, 5 (1960) 138.
12 Sankaranarayanan V N & Reddy C V G, *Bull Natl Inst Sci India*, 38 (1968) 148.
13 Jones J I, *Micropaleontology*, 13 (1967) 489.
14 Wyrtki K, in *The Biology of the Indian Ocean*, edited by B. Zeitzschel (Springer-Verlag, New York) 1973, 18.