

Distribution of Living Planktonic Foraminifera in the Coastal Upwelling Region of Kenya, Africa

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Seventeen planktonic foraminiferal species have been encountered in the plankton samples collected off the Kenya coast; the most abundant species are *Globigerinella aequilateralis*, *Globigerinoides ruber*, *G. sacculifer*, *Pulleniatina obliquiloculata*, *Globorotalia tumida* and *Neogloboquadrina duterrei* and rare species being *Globigerina quinqueloba* and *Hastigerina pelagica*. The fauna has a close similarity with that of the Gulf Stream in north Atlantic besides showing affinities with foraminiferal assemblages met with in waters near the equator. The faunal characteristics as related to hydrology and the role of some ecological parameters like temperature and salinity have been delineated. The evidence obtained from statistical analysis of the data of most sensitive species proves that temperature is the most important of the two factors in controlling distribution patterns of planktonic Foraminifera.

Active research on upwelling areas is mainly due to their impact on local climate¹ and regional fisheries^{2,3}. The upwelling zone of northeast Africa is unique in the world because of the Somali Current⁴ flowing along the African coast, which exists only during southwest monsoon in the Indian Ocean. Among marine organisms, planktonic Foraminifera are extensively being used for deciphering upwelling characteristics as prevailing in ocean waters and sediments⁵. Contributions from the east African region to the knowledge on planktonic Foraminifera are few⁶⁻⁸, but some seasonal observations of this group of organisms are either limited or yet to be confirmed. It is from this view point in supplementing the information, the present study has been undertaken.

Materials and Methods

Plankton samples (11) were collected during 16-20 August 1983, on board *O R V Sagar Kanya* from locations along 3 transects (TR I-off Port Mombasa; II-off Formosa Bay; III-off Pate Bay) off the coast of Kenya (Fig. 1), using Heron-Tranter net (mouth area of 0.25 m² and 150 µm mesh size). All the samples from vertical standard net hauls (from 200m depth to the surface) were preserved in buffered formalin. Counts of specimens of planktonic Foraminifera were expressed as density in 1000 m³ of water. Surface water temperature and salinity data were collected at the time of plankton sampling.

Cluster⁹ and regression analyses¹⁰ for the co-existence of some ecologically sensitive species (cold- and warm-tolerant species) and for the prediction of these species using environmental parameters like temper-

ature and salinity with which they have great affinity, were carried out respectively on the logarithmically transformed data¹¹. Dendrograms were drawn for grouping of the species, for different transects (Fig. 2B). Significantly correlated species were related by linear regression model, $Y = a_0 + a_1X$, where a_1 being regression coefficient and Y and X were explained elsewhere in the text.

Also, a multiple regression model, $Y = a_0 + a_1X_1 + a_2X_2$, where Y = faunal abundance, X_1 = temperature, X_2 = salinity, a_1 and a_2 are regression coefficients, was fitted. For significant models, variability explained by them was also calculated¹⁰.

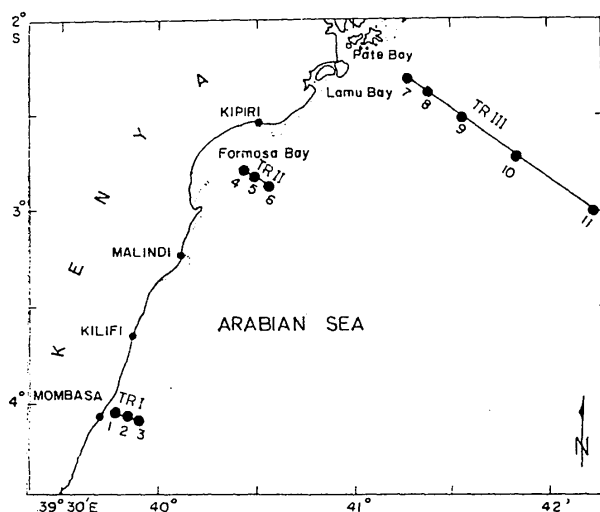


Fig. 1—Sampling sites off the Kenya coast

Results and Discussion

Oceanographic conditions—The surface sea currents in the northern Indian Ocean are greatly influenced by monsoonal winds. The present study of samples collected during August 1983, represents peak period of southwest monsoon (April-September). During this time, a branch of South Equatorial Current turns north between 5°S and the equator and flows along the African coast as the strong Somali Current with speeds up to 7 knots; after flowing further Socotra it joins the SW Monsoon Drift Current and then, flows eastwards between 5° and 10°N, south of Ceylon. Coastal upwelling occurs during this season along the African and Indian coasts.

The shelf of the east African coast is less than 40 km in width. In this study, surface temperature of the waters varies from 25.3° to 25.9°C and salinity from 35.17 to 35.54 × 10⁻³. Surface currents for the month of August in the Arabian Sea are shown¹².

Abundance and distribution of planktonic Foraminifera—In the transects, I, II, and III off Kenya coast, the ranges of foraminiferal abundance (no. of specimens in 1000 m³) are: 1860-3020, 1720-2880, and 3260-21580 respectively. The northern part of the coast off Pate Bay is fairly rich in concentration of planktonic Foraminifera and it increases with temperature and salinity, but in trs I and II, it does not show any apparent relation with the ecological factors (Fig. 2A) due to proximity to the coast where hydrographic conditions are normally unstable.

Seventeen species have been encountered in the plankton samples of this study and their distributional trends and abundance are shown in Fig. 2A and C.

(1) *Globigerina bulloides* d'Orbigny—Though this species is considered to be a subpolar species, it can even live in higher temperatures of tropical waters. Its presence is an indication of upwelling along the coast and has been noted at 6 locations with its abundance varying from 20 to 140 specimens in 1000 m³.

(2) *Globigerina calida* Parker—It is one of the species of tropical upwelling assemblage and occurs at 10 stations with a range of abundance from 20 to 380 in 1000 m³.

(3) *Globigerina falconensis* Blow—It is associated with upwelling. Like *G. bulloides*, it can live in waters of relatively higher temperatures in tropics. It is found at 5 locations.

(4) *Globigerina quinqueloba* Natland—It is found only at one sampling site (st 11) and its predominant distribution is known to be in higher latitudes.

(5) *Globigerinella aequilateralis* (Brady)—This species is as abundant as *G. ruber* and is found at all sites. The range of concentration is 240-2840 in 1000

m³. Highest concentration of 2840 specimens in 1000 m³ is observed at st 11. It is the most abundant species in the Agulhas-Somali Current and some areas of Madagascar in Indian Ocean¹³.

(6) *Hastigerina pelagica* (d'Orbigny)—It occurs at one location (st 2) with concentration being 40 in 1000 m³. Its maximum concentration is found in the Agulhas Current of Indian Ocean and this species is commonly seen in tropical upwelling areas¹³.

(7) *Globigerinoides conglobatus* (Brady)—In Indian Ocean, this species is more abundant in the Arabian Sea than in other areas¹⁴. Zhang¹⁵ reported maximum concentration of 38% in the northern part of the eastern Arabian Sea. It is found in the present study at 11 locations with abundance varying from 20 to 240 in 1000 m³.

(8) *Globigerinoides ruber* d'Orbigny—This species occurs at all stations and varies in concentration from 160 to 2740 in 1000 m³. In the northern Indian Ocean, it is most abundant in northeastern part of the Arabian Sea⁶. Its worldwide distribution shows that it prefers waters with salinities ≥ 36 × 10⁻³ and coexists mostly with *G. sacculifer*.

(9) *Globigerinoides sacculifer* (Brady)—Of all the species obtained from the Kenya coast, it is the most abundant and occurs at all locations. Very high concentrations of this species are reported in northeastern area of Indian Ocean¹³. Minimum and Maximum concentrations of this species are: 760 (st 4) and 12160 (st 11) in 1000 m³ respectively. It is dominant in waters having salinity < 36 × 10⁻³ and is more abundant in the equatorial waters of Indian Ocean.

(10) *Orbulina universa* d'Orbigny—In the Kenya coast, its concentration varies from 20 to 160 specimens in 1000 m³, although the general trend of this species is to occur in higher frequencies in upwelling areas. Higher concentrations of this species have been reported in the eastern side of Indian Ocean¹³.

(11) *Pulleniatina obliquiloculata* (Parker and Jones)—It is found at all sites with concentration in the range of 20-440 in 1000 m³ and is known to be predominant in tropical waters during winter.

(12) *Globorotalia menardii* (d'Orbigny)—It is associated with the upwelling regimes, though it is sparse in this study, occurring only at 3 sites. According to Bé and Tolderlund¹³, this species is more abundant in Indian Ocean than in Atlantic, the maximum concentration > 50% is found in the area southeast of Madagascar. Its known distribution is in equatorial and warm temperate waters.

(13) *Globorotalia tumida* (Brady)—This species occurs at all locations with specimen abundance varying from 20 to 1980 in 1000 m³. Despite being a tropical species, it is of interest to mention that it is

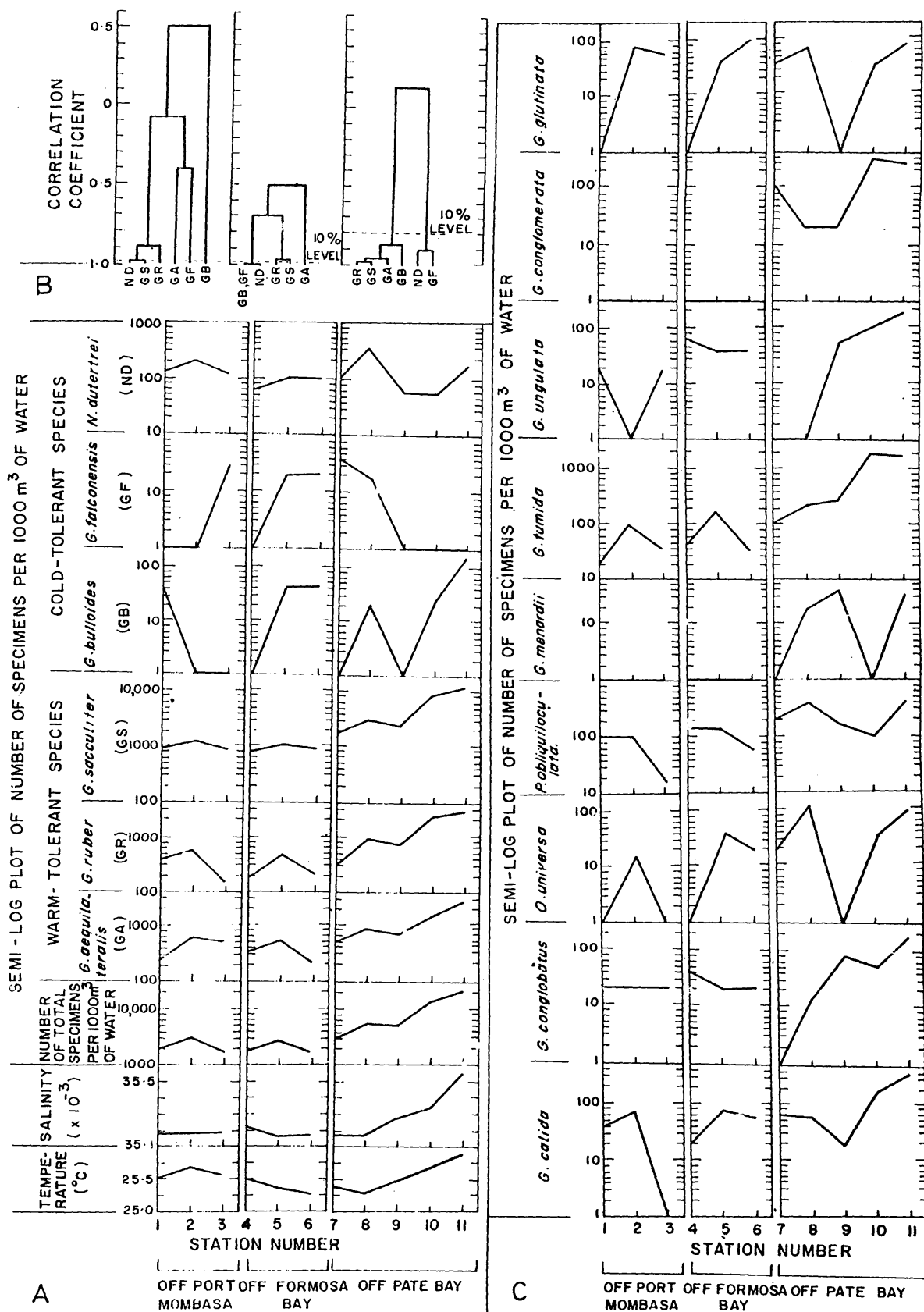


Fig. 2—Distributional patterns and abundance (A and C) of planktonic foraminiferal species; dendrograms (B) of some ecologically sensitive species

predominantly distributed in waters of temperature as low as 17°C in the southwest Pacific¹⁶.

(14) *Globorotalia unguolata* (Bermudez)—This is a common species in equatorial waters. In the present study, its density ranges from 20 to 220 specimens in 1000 m³ and is found at 8 sites.

(15) *Globoquadrina conglomerata* (Schwager)—This Indo-Pacific species is found only at 5 locations, abundance varying from 20 to 320 in 1000 m³. It is normally restricted to equatorial waters and its highest concentration is known to occur in the area west of the Maldive islands in Indian Ocean¹³.

(16) *Neogloboquadrina dutertrei* (d'Orbigny)—It is a productivity-cum-upwelling indicator species and occurs with concentration ranging from 60 to 520 in 1000 m³. It is more abundant in the east coast of Africa and in south of Java Sea than in other parts of Indian Ocean¹³.

(17) *Globigerinita glutinata* (Egger)—This cosmopolitan species occurs at all but 3 locations. Its occurrence is common in the upwelling regions and it is most abundant between Somalia and the Maldive islands in Indian Ocean¹³.

Of the faunal list as given above, species which are most dominant in the area of this study in the order of abundance are *G. sacculifer*, *G. ruber*, *G. aequilateralis*, *G. tumida*, *P. obliquiloculata*, and *N. dutertrei*. Others, viz. *G. calida*, *G. conglobatus*, *O. universa*, *G. unguolata* and *G. glutinata* are subdominant. The less abundant species are *G. bulloides*, *G. falconensis*, *G. menardii*, and *G. conglomerata* and the rare species include *G. quinqueloba*, and *H. pelagica*.

Relationship between faunal characteristics and hydrology—In the lower latitudes of the Pacific, Indian, and Atlantic Oceans, North and South Equatorial Currents flow westwards and they continue along the eastern sides of the continents in strong currents such as the Gulf Stream, Somali, and Kuro-Shio. Of these current systems, Somali is more conspicuous only during summer. Like Gulf Stream, it transports the same quantity of water i.e., about $50 \times 10^6 \text{ m}^3 \cdot \text{sec}^{-1}$.

The vertical hauls of plankton (0-200m) of the present study correspond to the surface zone of Vinogradov¹⁷ in the water column and the Somali Current lies above 200m depth¹⁸. This current is regarded by Schott¹⁹ as the Indian Ocean equivalent of the Gulf Stream. Generally the aforementioned strong currents are very rich in concentration of planktonic Foraminifera and also, in diversity of the fauna^{8,20-26}. Indeed, the fauna of Somali Current is comparable with that of Gulf Stream and other areas in north Atlantic during summer^{20,21,25} and is dominated by principal species such as *G. aequilateralis*, *G. ruber*, *G. sacculifer*, *P. obliquiloculata*, *G. menardii*, *G. tumida*, *G. unguolata*, and *N. dutertrei* in the Kenya

coast. *G. sacculifer* is more abundant than *G. ruber* off Kenya. All the equatorial species—*G. conglobatus*, *G. sacculifer*, *P. obliquiloculata*, *G. menardii*, *G. tumida*, *G. unguolata*, and *G. conglomerata* in this study belong to South Equatorial Current in Indian Ocean.

Species present both in the Somali Current off Kenya and in south of the Gulf Stream²⁰ are *G. bulloides*, *G. quinqueloba*, *G. aequilateralis*, *H. pelagica*, *G. conglobatus*, *G. ruber*, *G. sacculifer*, *O. universa*, *G. menardii*, *N. dutertrei*, and *G. glutinata*. The fauna of the waters in Somali Current is quite distinct in the presence of *G. calida*, *G. falconensis*, *P. obliquiloculata*, *G. tumida*, *G. unguolata* and *G. conglomerata*, while Gulf Stream is characterized by species such as *G. inflata*, *G. punctulata*, and *N. pachyderma* in its northern part.

In general, the tropical and subtropical species are more numerous than upwelling species. *G. bulloides*, *G. falconensis*, and *N. dutertrei* are indicator species of upwelling. Of these, the first two are very low in concentration, while *N. dutertrei* is better represented in abundance. Zobel⁶ reported the occurrence of *G. bulloides* as scarce in the coast of Somalia during NE monsoon. It is negligible in concentration even during SW monsoon in the present study and it is possible that upwelling is somewhat weak in the southern region. Intensive upwelling, according to Wyrski¹² occurs in the northern part of east African coast between 5° and 11°N. Furthermore, these faunal characteristics can be explained due to prevalence of tropical conditions, which are more pronounced within 30° of the equator (between 0° and 30°N or between 0° and 30°S) or 20°C surface isotherm than the upwelling conditions existing along this part of the coast.

Comparisons with other studies in the African coastal waters—Zobel⁶ has recorded 15 species representing NE monsoon from Arabian Sea, which includes east African coast and found *G. aequilateralis*, *G. ruber*, *G. sacculifer*, and *G. menardii* as abundant species. Distributional patterns of these species in the African region reveal that *G. ruber* is very high in abundance in comparison with *G. sacculifer* off the Somali coast; *G. aequilateralis* occurs in significant numbers in the southern and central part of the coast, while *G. menardii* is abundant off the African continental slope. On the other hand, the present work shows dominance of some equatorial species, *G. sacculifer* and *G. tumida*; *G. menardii* occurs in low concentration in near coastal waters. Further, *G. sacculifer* is more abundant than *G. ruber* in the Kenya coast and sparse occurrence of *G. bulloides* indicates that upwelling is weak in the southern region off Kenya.

Present findings are in full agreement with observations made by Olausson *et al.*⁷, who reported 14 spe-

cies (from 4 sediment cores) off the coast of Somalia, the summer species being dominated by *G. aequilateralis*, *G. ruber*, *G. sacculifer*, *G. menardii*, and *G. tumida*.

Differences between Bremner's work²⁷ on the fauna from southwest African (namibian) continental margin and our study are to be expected, since the area studied by the former comes under transitional zone. As a result, *G. inflata* is most dominant. Other species next in the order of abundance being *G. quinqueloba*, *O. universa*, and *N. dutertrei*. Only one tropical species, *G. sacculifer* has been encountered in the northern region and is very rare.

Siesser²⁸ recorded 8 planktonic species from sediment cores off the southwestern Cape Town. This area also, belongs to transitional zone and species encountered are *G. bulloides*, *G. sacculifer*, *G. inflata*, *G. menardii*, *G. scitula*, *G. truncatulinoides*, *N. dutertrei*, and *N. pachyderma*.

The fauna of the present study is similar to that of Adegoke *et al.*²⁹, who recorded 24 species from the sediments of the Gulf of Guinea. The faunal affinity is closer with this region because of its proximity to the equator. All except one species, *G. conglomerata*, in this study, are present in the Gulf of Guinea. Species present in the Gulf of Guinea but not in the plankton off Kenya coast are *Sphaeroidinella dehiscens*, *Orbulina bilobata*, *Globorotalia crassaformis*, *G. hirsuta*, *G. inflata*, *G. menardii flexuosa*, *G. scitula*, and *G. truncatulinoides*. Boltovskoy³⁰ listed 15 species from plankton samples of the Gulf of Guinea and out of them, 4 species—*Globigerina rubescens*, *Globigerinoides tenellus*, *G. inflata*, and *Candeiana nitida* are not known from the Kenya coast. Presence of *G. bulloides* and *G. inflata* in the eastern tropical Atlantic has been attributed by him to upwelled cold waters. The fauna of Gulf of Guinea can be differentiated from the present study in the absence of *G. conglomerata* and in the greater abundance of certain tropical species like *G. sacculifer*, *G. ruber*, *N. dutertrei*, and *G. menardii*.

Out of 14 species reported from the near-surface waters off northwest Africa³¹, 3 species, *G. tenellus*, *G. inflata*, and *N. pachyderma* are not known off Kenya.

Ecology—Of the various ecological factors having influence on planktonic Foraminifera, physical factors like temperature and salinity are considered here. In general, in oceans, abundance of marine life is controlled by temperature. Latitudinal distribution and abundance of planktonic foraminiferal species shows it is temperature dependent¹³ and warm-water species of subtropical regions live within limits of 18°–24°C, whereas species of tropics in the range of 24°–30°C.

In the upwelling region of Somalia, temperatures recorded⁷ were 10°C lower and beyond this zone, normal temperatures above 25°C were found. In order to study nature of the distribution of planktonic Foraminifera to small changes in surface water temperature, the species off the coast of Kenya have been included under 2 groups²⁰⁻¹) cold-tolerant species comprising *G. bulloides*, *G. falconensis*, and *N. dutertrei* and 2) warm-tolerant species as those of warm subtropical and tropical faunal assemblages.

Only most ecologically sensitive species have been chosen to study their response with small changes in temperature of the surface waters at the time of sampling. This type of study is worth attempting in limited areas like upwelling zones in oceans, where relatively low temperatures prevail or regions such as in the north Atlantic wherein there is a mixing of warm waters of the Gulf Stream with cooler waters in north. In fact, it is one of the ways to confirm one hypothesis on a small scale, that warm-tolerant species increase in abundance with temperature under prevailing tropical conditions. Conversely, cold-tolerant species of cold upwelled waters increase in concentration with decrease in temperature.

Planktonic Foraminifera are generally regarded as stenohaline. Till now, there is no definite information regarding limits of salinity in which planktonic Foraminifera can live without any adverse effect on their reproduction. Based on field observations, it is indeed apparent that decreased salinity of waters will result in reduction of number of species and specimen abundance of planktonic Foraminifera shoreward. According to Cheng and Cheng³², the 34×10^{-3} isohaline corresponds with the limits of predominant distribution of planktonic Foraminifera, while the 33×10^{-3} isohaline restricts their distribution towards the coast. These observations are, however, not agreeable with those of others elsewhere, for example, the work of Boltovskoy³⁰ in the eastern tropical Atlantic Ocean.

Statistical interpretation of the faunal data with temperature and salinity—Variation is not much in the values of temperature and salinity between locations in trs I and II, but it is significant in tr III, where the total fauna is positively correlated with temperature ($r = 0.9004$) and salinity ($r = 0.9206$); Fig. 2A.

In tr I, the cluster having maximum affinity at 10% level is: (*G. sacculifer*, *N. dutertrei*), ($r = 0.9123$). *G. bulloides* and *G. aequilateralis* were significantly negatively correlated at 10% level ($r = -0.9936$). The cluster formed at the same level in tr II is: *G. bulloides*, *G. falconensis*, and *N. dutertrei* and in tr III, the clusters formed are: (1) *G. bulloides*, *G. aequilateralis*, *G. ruber*, and *G. sacculifer* and (2) *G. falconensis* and *N. dutertrei*. The cluster analysis suggests that members

of each cluster will always be together in their occurrence and they live under the same environmental conditions (Fig. 2B).

(a) *Relations of warm-tolerant species with temperature and salinity in the transects*—Only *G. aequilateralis* referred as GA ($r=0.9217$) and *G. sacculifer* as GS ($r=0.8714$) are positively correlated with temperature, but no species with salinity in tr I. In tr II, none of these species are highly correlated with temperature, which may be due to small variations in temperature of the waters at locations in the tr. and only *G. ruber* coded as GR ($r=-0.7385$) and *G. sacculifer* ($r=-0.8927$) with salinity are moderately high in correlation. In tr III, *G. aequilateralis* ($r=0.9044$), *G. ruber* ($r=0.8936$), and *G. sacculifer* ($r=0.9890$) are highly correlated with temperature for reasons as stated before, and *G. aequilateralis* ($r=0.9431$), *G. sacculifer* ($r=0.9174$), and *G. ruber* ($r=0.8708$) show also very high correlation with salinity (Fig. 2A). Thus, it can be inferred in a broad sense that the warm-tolerant species increase in abundance with relatively higher temperatures and salinities (Fig. 2A). Similar observations were made by Be²⁰ in north Atlantic. Generally all warm-tolerant species are stenothermic. In the case of *G. ruber*, according to Eade¹⁶, its distribution is controlled by temperature and peak abundance by salinity. *G. ruber* prefers salinity $\sim 36 \times 10^{-3}$, though it occurs in waters $< 33 \times 10^{-3}$ in the Bay of Bengal. As regards tolerance for salinity, *G. aequilateralis* and *G. ruber* are considered to be euryhaline, while *G. sacculifer* to be stenohaline.

(b) *Relations of cold-tolerant species with temperature and salinity in the transects*—Correlation of *G. bulloides* (GB) with temperature ($r=-0.8605$) is negative and with salinity ($r=0.8839$) is positive in tr I and in tr II, it is positive with temperature ($r=0.8715$), but negative and small with salinity. In tr III, r is positive both with temperature ($r=0.7954$) and salinity ($r=0.9001$). In all 3 trs, *G. falconensis* (GF) and *N. dutertrei* (ND) are negatively correlated with temperature except for *N. dutertrei* in tr I.

In tr I, *G. falconensis* ($r=0.8839$) and *N. dutertrei* ($r=0.0061$) are positively correlated with salinity, whereas in tr II, *G. falconensis* ($r=-0.9244$) and *N. dutertrei* ($r=-0.9823$) and in tr III, *G. falconensis* ($r=-0.6911$) and *N. dutertrei* ($r=-0.1799$) are negatively correlated with salinity (Fig. 2A).

The above study suggests that *G. bulloides* is well adapted to tropical conditions of high temperatures, though it is regarded as a high latitude species. *G. falconensis* and *N. dutertrei*, in general, increase in abundance with decrease in temperature of waters (Fig. 2A). Global trend of cold tolerant species, in fact, reveals that they have a wider range in latitudinal distribution as well as in tolerance for temperature. In

the case of salinity, the data show that *G. bulloides* increases in abundance with salinity in tropical waters. Though the variation of *N. dutertrei* is small with salinity, it is significant in tr II, where this species decreases in concentration with high salinity values (Fig. 2A).

Of the two physical factors considered here, temperature is the most important one in controlling distribution of the species. Another conclusion that can be drawn from the above observations is that *G. falconensis* and *N. dutertrei* prefer lower salinities and *G. bulloides* can live in higher salinities of waters. These observations are consistent with some of the findings of others elsewhere^{13,33-37}.

(c) *Regression analysis*—In tr I, no correlation of the total fauna and individual species with themselves and with the ecological factors was significant even though they are high. In tr II, the linear regression equations are:

$$(1) Y = 1.9998X + 0.0022, \text{ relation of GB}(Y) \text{ on GF}(X), r = 1, (F = 48886.5, P < 0.005).$$

$$(2) Y = 0.9999X - 59.9977, \text{ relation of GB}(Y) \text{ on ND}(X), r = 1, (F = 2870159.2, P < 0.005).$$

$$(3) Y = 0.5000X - 30.0027, \text{ relation of GF}(Y) \text{ on ND}(X), r = 1, (F = 15716.9, P < 0.01).$$

In all 3 cases, regression equations were highly significant, i.e., the presence of GF or ND is sufficient for knowing the abundance of GB, i.e., complete variability in the predicted abundance of Y could be explained by X in the model. Similar equations for tr III, between species being:

$$(1) Y = 0.8369X + 154.9631, \text{ relation of GA}(Y) \text{ on GR}(X), r = 0.9438, (F = 24.4717, P < 0.025).$$

$$(2) Y = 0.1951X + 244.5958, \text{ relation of GA}(Y) \text{ on GS}(X), r = 0.9719, (F = 51.10, P < 0.01).$$

$$(3) Y = 14.9712X - 801.0354, \text{ relation of GA}(Y) \text{ on GB}(X), r = 0.9430, (F = 24.07, P < 0.025).$$

$$(4) Y = 0.223X - 163.4888, \text{ relation of GR}(Y) \text{ on GS}(X), r = 0.9854, (F = 202.3, P < 0.01).$$

$$(5) Y = 0.0829X - 4.5776, \text{ relation of GF}(Y) \text{ on ND}(X), r = 0.8961, (F = 12.22, P < 0.05).$$

All these equations are highly significant as shown by F value given within brackets. The variability explained by the equations was more than 70% in each case.

The 2 parameters multiple regression equations for tr III are:

$$(1) Y = -113.83 + 54.01X_1 + 25.62X_2 \text{ for GA, } (F = 3.4804, P < 0.25).$$

$$(2) Y = -130.30 + 68.83X_1 + 24.78X_2 \text{ for GR.}$$

$$(3) Y = -122.14 + 86.84X_1 + 1.34 X_2 \text{ for GS, } (F = 4.36, P < 0.25).$$

$$(4) Y = -323.24 + 108.35X_1 + 108.91X_2 \text{ for GB.}$$

(5) $Y = -122.89 + 72.65X_1 + 14.96X_2$ for total fauna, ($F = 3.036$, $P < 0.25$).

Among the equations given above, only those of GA, GS, and total fauna were significant, but at a lower probability level. These models could explain only 50% of the variability in the predicted abundance. The unexplained variability can be attributed to many neglected factors like light, pH, oxygen, nutrients, food, etc., and also the interaction effects of these factors.

The concept of studying planktonic Foraminifera especially most sensitive species in relation to temperature and salinity of surface waters at the time of sampling is to provide for responses as manifested by their distribution patterns and abundance. But the multiple regression equations convince that many other ecological factors as mentioned by Bradshaw²⁴ and Bé and Hutson⁸ have to be taken into account so as to have a complete prediction of the abundance of planktonic foraminiferal species.

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