Chapter 6

Distribution of recent foraminifera in surface sediments

6.1. Introduction

The recent foraminifera constitute the larger part of the foraminiferal population recovered from the surface sediments. As relict foraminifera helped understand past environment of the area, study of recent foraminiferal distribution is necessary to understand factors affecting foraminiferal abundance, diversity, assemblage, etc. The relationship between foraminiferal characteristics and environmental parameters is established from such studies and are further used to understand the past climatic changes. Different ecological factors play different role in shaping foraminiferal characteristics. Since the ecological factors vary from region to region, it is important to study the regional foraminiferal distribution. Such ecological studies on foraminifera have been carried out by various workers from different parts of the world oceans (Boltovskoy and Wright, 1976; Murray, 1991; 2006; Sen Gupta, 1999, etc). From the Indian Ocean, surface foraminiferal distribution has been documented by several workers and such studies carried out from the regions adjacent to the Indian subcontinent have been summarized by Khare et al. (2007) and Bhalla et al. (2007). As mentioned in the previous chapter, based on this literature review, the area off the central east coast of India was selected for detailed study of surface distribution of foraminifera with respect to the changing ecological parameters. Therefore, the objective of the present study was to understand the distribution of foraminifera in relation with the prevailing ecological factor and to develop proxies for paleoclimatic studies from this region.

6.2. Spatial distribution

As mentioned in the previous chapter, a total of 148 foraminiferal genera were reported from the study area. The abundance of these genera varied from location to location, showing a definite control of ecological parameters on the foraminiferal abundance. Majority of these genera have a rare presence. Such rarely present genera are not much useful as far as past climatic studies are concerned. Therefore, a few of
the dominant genera (with abundance >5%) are described below in detail. The
distribution of these dominant genera is shown on spatial scale as well as on kite
diagram. For the ease of presentation, the study area has been sub divided into
northern (A), central (B) and southern (C) sectors as shown in the distribution maps.

i. **Hanzawaia**: Murray (2006) described *Hanzawaia* as an epifaunal, hard
substrate preferring, marine, temperate-warm, and inner shelf genera. In the region
of central east coast of India, *Hanzawaia* is most dominant at 44 m
water depth with 14.58 % abundance, while it is absent at
several other places. *Hanzawaia* is continuously present right from
to a coastal waters up to ~200 m water
depth. Its abundance decreases and
becomes patchy in deeper waters. The geographic abundance plot of
*Hanzawaia* also shows its patchy
distribution. In northern section of
study area, the maximum abundance
of ~ 9 % is reported in a patch near
Krishna River mouth. In the central
part of the study area, two zones of
comparatively high abundance of *Hanzawaia* occur near Pennar River and off
Chennai. The samples collected off Pennar River have *Hanzawaia* abundance of ~
8%, while in the region off Chennai, abundance of *Hanzawaia* is more than 5% in
a broad area which continues in southern section of study area, under the influence
of Palar River. In the southern part, except for the region affected by Palar River,
a small patch with *Hanzawaia* abundance ~4% is also reported. *Hanzawaia*
abundance shows a decreasing trend with increasing depth (Fig. 6.1).

ii. **Quinqueloculina**: According to Murray (2006), *Quinqueloculina* is epifaunal,
marine genera preferring hypersaline to hypersaline lagoons, marine marsh and
shelf areas and is rarely bathyal. Maximum abundance (25.74 %) of
*Quinqueloculina* was reported from the depth of 36 m. Relatively higher
abundance of *Quinqueloculina* is reported from the northern part of the study area, especially the Nizamapatnam Bay. However, the abundance decreases with depth. In the central part, the contour of increased abundance (>10%) of *Quinqueloculina* runs almost parallel to the 50 m depth contour. In the southern part, abundance follows same trend as that in the central part of the study area (Fig. 6.2).

iii. **Rotalidium**: *Rotalidium* is rare in northern part of the study area with maximum abundance (~2%) near the Krishna River mouth. In the central part, this genus is present at almost all the stations, with a decreasing trend with increasing water depth. In the southern part, this genus is rare or absent except at a few stations near Ponnaiyar River. Interestingly, *Rotalidium* is generally present at station located in the vicinity of river mouths (Fig. 6.3).

iv. **Ammonia**: *Ammonia* is well represented in the sediments throughout the study area, with maximum abundance of ~21%. *Ammonia* is less abundant in deeper waters (Fig. 6.4).
v. *Asterorotalia*: *Asterorotalia* is subtropical-tropical genera with depth preference for inner shelf (Murray, 2006). In the northern part of the study area, *Asterorotalia* is dominant at stations under the influence of Krishna-Godavari Rivers with the maximum abundance of ~29%. The central and southern parts of the study area have *Asterorotalia* abundance in the range of 0-10% (Fig. 6.5).

vi. *Rosalina*: The maximum abundance of *Rosalina* (17.49 %) is reported from the depth of 25 m. *Rosalina* is present in almost every sample of the central part of the study area, while in northern and southern parts of the study area, it is present mostly in southern and northern sides, respectively, with southern sector abundance restricted in the range of 0-5 % and northern sector having 0-10 % abundance of *Rosalina* (Fig. 6.6).

vii. *Amphistegina*: In the central and southern parts, *Amphistegina* is present almost throughout, while in the northern part, its presence is restricted to the southern region. The
absence of *Amphistegina* from rest of the northern part of the study area can be attributed to the presence of two big rivers in this region, viz. Krishna and Godavari. Maximum abundance of *Amphistegina* (69.58 %) is reported from the water depth of 25.1 m (Fig. 6.7).

viii. *Cibicidinella*: Maximum abundance of *Cibicidinella* (16.61 %) is reported at ~ 30 m water depth. In the northern part, *Cibicidinella* has patchy abundance which becomes more continuous and uniform, southwards from the mouth of Krishna River, and remains so till the southern sector of the study area. Contour of *Cibicidinella* abundance more than 5 % in the study area, runs parallel to the coastline from the Nizamapatnam Bay to the Pulicat Lake. General trend shows preference of *Cibicidinella* to shallow depth with decrease in its abundance with increasing water depth (Fig. 6.8).

ix. *Elphidium*: *Elphidium* is restricted to a narrow zone along the coastal belt of central east coast of India. In the northern sector, most of the stations have *Elphidium* abundance of 1-5 % or less while in the central sector, its abundance...
varies from 0 to 13.06% (at 38 m water depth). Like the central sector, in the southern sector also, the abundance varies from 0 to more than 5% and decreases southwards (Fig. 6.9).

x. **Gavelinopsis:** Maximum abundance (17.49%) of *Gavelinopsis* is reported from a station at 25 m water depth. In the northern sector, *Gavelinopsis* abundance is generally less than 5%, except at one station. In the central sector, its abundance varies from 0 to ~16%, whereas a decrease in abundance is reported with increasing water depth. Similar pattern is observed in the southern sector of the study area (Fig. 6.10).

xi. **Lenticulina:** *Lenticulina* is most abundant (8.94%) at 73 m water depth. According to Murray (2006), *Lenticulina* is an epifaunal genus and prefers outer shelf-bathyal conditions. In the study area, its presence is patchy. In the northern sector, two small zones with abundance approximately 5% or less are reported. Maximum abundance (8.94%) of *Lenticulina* is reported from the central sector, whereas in the southern sector, it reaches to a maximum abundance of 5.49% (Fig. 6.11).
xii. *Vonkleinsmidoides*: In the northern sector this genus is very rare in the vicinity of Krishna-Godavari River mouths. Its abundance starts increasing near Munneru River and continues in central sector with a preference to shallower depths. In the southern sector, *Vonkleinsmidoides* is very rare or absent (Fig. 6.12).

*Triloculina*: *Triloculina* is absent in most of samples of northern sector near Krishna-Godavari River mouths. However, Nizamapatnam Bay samples have a few *Triloculina*. Such sporadic presence of *Triloculina* continues in the central sector and in a small part of the southern sector. The maximum abundance of *Triloculina* is reported from the central sector from a water depth of ~25 m. In the southern sector, *Triloculina* is very rare or absent (Fig. 6.13).

xiii. *Textularia*: According to Murray (2006), *Textularia* prefers shelf to bathyal habitat. In the northern sector, *Textularia* are mainly restricted to the depth less than 500 m and are present all along the coastal region of the northern sector. In the central and southern
sector also, *Textularia* are restricted to a narrow zone along the coast (Fig. 6.14).

xiv. **Discorbinella**: *Discorbinella* is absent from the northern sector, probably due to the Krishna and Godavari river outlets. From the Nizamapatnam to upper half of southern sector, *Discorbinella* is present. In the central sector, *Discorbinella* is less than 5% in most of the samples while a few small patches of 5-10% abundance of *Discorbinella* are also observed. In the southern sector, only upper half has notable presence of *Discorbinella* (Fig. 6.15).

xv. **Bolivina**: According to Murray (2006), *Bolivina* is infaunal to epifaunal genus with habitat ranging from inner shelf to bathyal conditions. In the study area its maximum abundance (42.11%) is reported from the surface sample collected from 191 m depth. In the northern sector, *Bolivina* is present in high abundance (up to 30-40%) but in patches. While in the central sector, except at a few locations, *Bolivina* abundance is less than 10%. Similarly, in the southern sector,
Bolivina abundance is less than 10% (Fig. 6.16).

Brizalina: Brizalina is the most abundant genus in the study area with maximum abundance of ~76% at 90 m depth. According to Murray (2006), Brizalina is an infaunal genus with depth preference to marginal marine to bathyal conditions. In the northern sector, a few patches with more than 25% abundance of Brizalina are also reported, whereas in the central sector, except a few patches with more than 25% abundance, it is restricted to 0-25% of the total population. In the southern sector, abundance is less than 25%. General observation suggests maximum abundance of Brizalina around 50-100 m water depth while one patch of high abundance has also been reported from a water depth of ~2500 m (Fig. 6.17).

c. Cibicides: According to Murray (2006), Cibicides is epifaunal, with preference to the depth range of 0-2000 m and shelf to bathyal conditions. In northern sector, a patch with ~10% abundance is observed near Godavari River mouth. In Nizamapatnam Bay, Cibicides is less abundant. In the central sector, Cibicides is more abundant in
comparison to other two sectors, with abundance up to ~12%. Here it is restricted to the water depth range of 50-100 m. In the southern sector, it is comparatively less abundant and even rare (Fig. 6.18).

xvii. *Cibicidoides*: *Cibicidoides* is present in almost all of the samples. According to Murray (2006), *Cibicidoides* is infaunal to epifaunal genus with a preference for shelf-bathyal zones. In every sector *Cibicidoides* shows increase in abundance with increasing water depth. In the northern sector, its abundance varies from 0 to ~21%, whereas in the central and southern sectors, its abundance goes up to ~15% (Fig. 6.19).

xviii. *Neoeponides*: *Neoeponides* is rare to absent in most of the samples. The maximum abundance (~6%) of *Neoeponides* is reported from 37 m depth. In the northern sector, except for its small presence in a few samples in the Nizamapatnam Bay region, *Neoeponides* is completely absent from other samples. In the central sector, a few patches of comparatively high abundance of *Neoeponides* are reported, while rest of the central sector and complete
southern sector is devoid of or has very low abundance of *Neoeponides* (Fig. 6.20).

**xix. Melonis:** According to Murray (2006), *Melonis* is infaunal genera which prefers muddy and silty substrate and shelf to bathyal environments. In the study area, a few patches of high abundance of *Melonis* are present. In the northern sector, two patches of high *Melonis* abundance are reported from in front of Krishna and Godavari Rivers, while in the central sector, except for a small patch of ~1.5%, *Melonis* abundance is very low. In the southern sector, except a few samples with 3.0-3.5% abundance, *Melonis* is absent or rarely present (Fig. 6.21).

**xx. Gyroidina:** *Gyroidina* prefers shelf to bathyal environment (Murray, 2006). Increasing trend in abundance of *Gyroidina* with increasing water depth is reported throughout the study area. In the northern sector, maximum abundance (~24%) of *Gyroidina* is reported at ~2300 m depth. In the central sector, abundance of *Gyroidina* is comparatively less which continues in the southern sector. In the southern sector, an
increasing trend with depth can be observed along a transect with a maximum value of \(-16.0\%\) (Fig. 6.22).

xxi. *Epistominella*: In the northern sector, an increasing trend in abundance of *Epistominella* with increasing water depth, is observed. The maximum abundance of \(-5.0\%\) is reported from \(\sim 2800\) m depth. In the central sector, similar trend is observed with the maximum abundance of \(-5.0\%\). The southern sector has maximum abundance of \(-11.0\%\) at 1950 m water depth. Both, the northern part of this sector and southern part of central sector, share locations where *Epistominella* abundance is very low or is absent (Fig. 6.23).

xxii. *Cassidulina*: *Cassidulina* shows increase in abundance with increasing water depth. The northern sector shows maximum abundance of \(-23\%\) at \(\sim 2800\) m depth, whereas the central sector shows highest abundance of \(-27\%\) at 240 m depth. The southern sector has the maximum abundance (\(-45\%\)) at 310 m. All the sectors show increase in abundance with increase in distance from the coast (Fig. 6.24).
xxiii. **Angulogerina**: Angulogerina is almost absent in northern sector of the study area. The central sector has a few patches of Angulogerina with abundance ranging from 1-5%. In the southern sector, Angulogerina is absent or rare. The maximum abundance (~12%) of Angulogerina is reported at ~150 m depth (Fig. 6.25).

xxiv. **Uvigerina**: In the study area, Uvigerina is present in all three sectors. In the northern sector, maximum abundance is ~48% at ~1850 m water depth. In the central sector, the maximum abundance is ~12% at ~200 m, whereas in the southern sector, maximum abundance (~17%) is reported at ~2100 m water depth. Except these high abundance patches of more than 10%, all three sectors have a common abundance range (1-10%) of Uvigerina (Fig. 6.26).

xxv. **Suggrunda**: Suggrunda is present mostly in the northern sector with a maximum abundance of ~17% at ~1950 m depth. Most of the samples containing Suggrunda are from relatively deeper depths. In the central sector, Suggrunda was
reported in two samples with depth more than 200 m, while it is absent in southern sector (Fig. 6.27).

xxvi. **Stainforthia:** Maximum abundance (~35%) *Stainforthia* is reported from ~185 m. In the northern sector, this genus is present mostly in the 1-10% abundance range. In the central sector, this genus is present all along the coast, with abundance range of 0 to ~35%. In the southern sector also, this genus is present along the coast and abundance range is 0 to ~20% (Fig. 6.28).

xxvii. **Nonion:** According to Murray (2006), *Nonion* is infaunal genus and prefers depth range of 0-180 m. In the northern sector, the maximum abundance (50%) is reported at 90 m water depth. Areas near Krishna-Godavari Rivers have more abundance of *Nonion*. In the central and southern sectors *Nonion* abundance ranges between 0 to 10% (Fig. 6.29).

xxviii. **Miliolina:** Except a few stations, *Miliolina* is absent from the study area. Its maximum abundance (~11%) is reported from ~250 m water depth (Fig. 6.30).
Fig. 6.26: Surface distribution of genus *Uvigerina* in study area.

Fig. 6.27: Surface distribution of genus *Suggrunda* in study area.

Fig. 6.28: Surface distribution of genus *Stainforthia* in study area.

Fig. 6.29: Surface distribution of genus *Nonion* in study area.
6.3. Depth Distribution

Water depth is one of the important ecological factors that control the distribution of benthic foraminiferal genera. Therefore, in order to understand the changes in abundance of benthic foraminiferal genera with changing water depth, abundance of different genera, with abundance more than 5.0%, is plotted on a depth profile (Fig. 6.31 a-f). The plots show that a few genera, including Hanzawaia, Quinqueloculina, Rotalidium, Ammonia, Asterorotalia, Amphistegina, Elphidium, Gavelinopsis, Rosalina, Cibicidinella, Triloculina, Nonion and Gavelinopsis show higher abundance in relatively shallower depths, while Bulimina, Miliolina, Suggrunda, Epistominella, Melonis, Gyroidina, Cassidulina, Uvigerina and Stainforthia are more abundant in deeper waters. In addition to these, a few genera e.g. Brizalina, Bolivina, Cibicides and Cibicidoides are present at almost all depths, thus showing no particular depth preference. Some genera namely, Angulogerina, Neoeponides and Lenticulina are restricted to the intermediate depth zones in the region off central east coast of India. On the basis of this distribution, a composite generic distribution is presented in Fig. 6.32.

Though, changes in relative abundance of individual taxa are quite helpful to understand past ecological changes, an assemblage of taxa with similar ecological preferences is more useful to understand past climatic changes. Therefore, in order to draw meaningful assemblages from this depth related preference of genera, cluster analysis, was carried out and is discussed in the next section.
Fig. 6.31a: Relative abundance of *Hanzawaia, Quinqueloculina, Rotalidium, Ammonia, Asterorotalia* in surface sediments.
Fig. 6.31b: Relative abundance of *Rosalina, Amphistegina, Cibicidinella, Elphidium, Gavelinopsis* in surface sediments.
Fig. 6.31c: Relative abundance of *Lenticulina*, *Vonkleinsmidoide*, *Triloculina*, *Textularia*, *Discorbinella* in surface sediments.
Fig. 6.31d: Relative abundance of *Bolivina, Brizalina, Cibicides, Cibicidoides, Neoeponides* in surface sediments.
Fig. 6.31e: Relative abundance of *Melonis, Gyroidina, Epistominella, Cassidulina, Angulogerina* in surface sediments.
Fig. 6.31f: Relative abundance of *Uvigerina, Suggrunda, Stainforthia, Nonion, Miliolina* in surface sediments.
Fig. 6.32: Composite diagram of relative depth distribution of some important genera in the region off central east coast of India.

6.4 Q-mode cluster analysis
In view of growing emphasis and better reliability of assemblage of species rather than individual species for paleoclimatic reconstruction, continuous efforts have been made to devise means to classify foraminiferal population into groups with similar
ecological preferences. Such grouping has often been made based on morphology. However, development of statistical software has made the work of grouping of foraminiferal population easier. The cluster analysis is one such technique which has been used by various workers to divide total foraminiferal population into more effective smaller groups of a few taxa, from different parts of the world oceans (Parker and Berger, 1971; Thunell, 1978; Lutze and Coulbourn, 1984; Jorissen, 1987; Van Marle, 1988; Martin and Liddell, 1989; Bergsten et al., 1996; Haunold et al., 1997; Horton, 1999; Annin, 2001; Samir et al., 2003; Mendes et al., 2004; Hromic et al., 2006; Hayward et al., 2007; Frezza and Carboni, 2009; Kemp et al., 2009). From the Indian Ocean region, cluster analysis of benthic foraminiferal population in surface sediments have been carried out by Nigam, 1986; 1987; Bhalla and Nigam, 1988; Kathal et al., 2000, etc.

Therefore, to study the interrelationship between benthic foraminiferal taxa, and to develop meaningful assemblages out of total benthic foraminiferal population, Q mode cluster analysis was done. From all the genera (146) reported from 79 stations, genus with 1 or more than 1% abundance at least at one station were chosen for the analysis. The genera not fulfilling the criteria were considered as “Others” in analysis. Cluster analysis was performed on Primer 5 software with Bray-Curtis similarity index. The result is plotted in the form of a two-dimensional binary dendrogram (Fig. 6.33). At similarity level 25, all the stations can be grouped into cluster A (deepwater) and B+C (shallow and intermediate water). However, at higher level of similarity (35), clusters B and C separate out. At further higher level of similarity (45), cluster C can be subdivided into Cl and C2. Stations based on their clusters are plotted on the study area map for distribution on spatial scale. Details of each cluster with their constituent genera and ecological characters are discussed below.

**Cluster A**

Cluster A is composed of 23 samples ranging in depth from 170 to 2841 m, representing deepwater assemblages. The dominant genera of this cluster are *Brizalina, Bolivina, Bulimina, Cassidulina, Gyroidina, Melonis, Stainforthia, Suggrunda, Uvigerina* and *Hyalinea balthica.*
Fig. 6.33: Results of Q mode cluster analysis showing three main clusters, A, B, and C (with two subclusters, C1 and C2). X axis = Stations; Y axis = Linkage distance
Cluster B
Cluster B is composed of 10 samples, ranging in depth from 25 to 44 m, representing the shallow water assemblages. The dominant genera from this cluster are Ammonia, Amphistegina, Cibicidinella, Quinqueloculina, Rotalidium and Hanzawaia.

Cluster C
Cluster C is composed of two clusters, C1 and C2. Subcluster C1 is composed of 21 samples and represents shallow water assemblage with depth ranging from 20-77 m, except one station of 976 m. The dominant genera from this cluster are, Ammonia, Amphistegina, Bolivina, Brizalina, Cibicidinella, Gavelinopsis, Hanzawaia, Nonion, Quinqueloculina, Rosalina, Uvigerina and Asterorotalia trispinosa. Subcluster C2 is composed of 21 samples and represents intermediate depth assemblages with depth ranging from 48 to 154 m. The dominant genera of this cluster are Ammonia, Amphistegina, Brizalina, Cassidulina, Elphidium, Uvigerina, Quinqueloculina, Cibicidoides, Cibicides, Bolivina, and Angulogerina.

Fig. 6.34: Surface distribution of Clusters in Study area.

Fig. 6.35: Diagrammatic representation of Depth preference of Clusters observed in study area.
The cluster analysis grades benthic foraminiferal genera into depth related assemblages thus showing the dominant control of parameters related with water depth on the benthic foraminiferal distribution. Figure 6.34 shows the surface distribution of clusters, while the following diagrams show the depth preference of clusters observed in study area (Fig. 6.35). These clusters can be used to infer changes in water depth from the region off central east coast of India, during the geologic past.