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LATITUDINAL VARIATIONS IN THE ABUNDANCE OF PLANKTIC FORAMINIFERA ALONG THE INDIAN OCEAN SECTOR OF THE SOUTHERN OCEAN

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ABSTRACT

During the 199C and 200th (also known as Pilot expedition to Southern Ocean) cruises of ORV Sagar Kanya between 9.69° N and 55.01° S latitude and 80° E and 40° E longitude, nineteen surface sediment samples were considered for present study, for which we simultaneously collected salinity data at near surface, 50 m and 100 m depths, using CTD. The planktic population is dominated by species such as *Globigerina bulloides, Globigerinoides ruber, G. sacculifer, G. conglobatus, Orbulina universa, Neogloboquadrina pachyderma, Globorotalia menardii*, etc. However, for the present purpose, the total planktic foraminiferal population was estimated in one gram dry sediments to assess the changes in their abundance along the north-south transect in the Indian Ocean Sector of Southern Ocean. Attempts are made to establish inter-relationship of planktic foraminiferal population vis-à-vis salinity and other allied factors such as nutrient (phosphate) content of the ambient water masses.

Keywords: Planktic foraminifera, abundance, latitudinal variations, Indian ocean

INTRODUCTION

Planktic Foraminifera have emerged as the prime information carriers of the environmental conditions. The global distribution of planktic foraminifera is determined through passive transport by ocean currents, coupled with their prolific productivity and sensitivity to environment variables which has led to their utilization for interpreting environmental conditions both spatially and temporally. Previous studies have established the significant role of planktic foraminifera in the illumination of ancient and modern environment and suggested that planktic foramninifera are sensitive towards salinity variations. Their abundance is supposed to be higher in areas of normal salinity (Funnell, 1967; Boltovskoy and Wright, 1976; Gibson, 1989). Hence, the recent years have witnessed a surge of interest in this line of research (Fairbanks *et al.*, 1980; Watkins *et al.*, 1998; Naidu, 2004). In spite of their utility in plaeoclimatic studies, such studies both in space and time are limited in the Indian Ocean Sector of Southern Ocean and there is an equal need to calibrate the proxies derived from planktic forminifera in higher latitude regions (Mortyn and Charles, 2003).

Therefore, in the present study we have considered the inter-relationship of planktic forminiferal population and salinity variations at different water depths in nineteen surface sediment samples in a North-South transect along the Indian Ocean sector of Southern Ocean. Here we have concentrated on whole planktic foraminiferal population and not considered the response of individual planktic species for any interpretation. Such approach has been adopted in view of earlier studies which showed taxonomic inconsistencies among authors, intraspecific variants (morpho-types) show different results, same species may show different response to different geographic province (Troelsen, 1954; Bandy, 1960; Williams *et al.*, 1988). Therefore, the utility of any parameter of species level as a tool for paleoenvironmental inferences may pose some problem in interpretation and can be overcome if broader groups of foraminifera are considered (Nigam *et al.*, 1992; Nigam and Khare, 1994).

MATERIAL AND METHODS

Site Selection

We have chosen a north - south transect from 9.69° N to 55.01° S latitude between 80° E and 40° E longitude, because it meets some of the criteria that we deem important for the abundance variations of planktic foraminifera. Stations along this transect are distributed in rather distinct latitudinal belts and can be grouped into several zoogeographic provinces which are primarily influenced by ecology and climate, namely tropical, subtropical, transitional and sub-Antarctic (Schott, 1942; Sverdrup *et al.*, 1942; Bradshaw, 1959; Fairbridge, 1966; Be and Tolderlund, 1971). Different watermasses do influence the planktic assemblages along the transect. The north ward advection of temperature and salinities of Antarctic Bottom Water (AABW), Circumpolar Deep water (CDW) and Antarctic Intermediate Water (AAIW) from the Southern Ocean to other ocean basins has a profound effect on the global ocean circulation (Matsumoto *et al.*, 2001).

Methodology

During the 199C and 200th (also known as Pilot expedition to Southern Ocean) cruises of ORV Sagar Kanya a, twenty eight surface sediment samples (comprising Peterson Grab, Gravity and Piston core top samples) were collected along with their salinity data, out of which we have considered for present study only 19 surface sediment samples. The cruise track covers a transect between 9.69° N and 55.01° S latitude and 80° E and 40° E longitude in the Indian Ocean Sector of the Southern Ocean. The locations of various stations are provided in Fig. 1 (Table 1). Since the calcium carbonate compensation depth (CCD) and lysocline in and around the study area lie below 4,400 – 4,700 m water depth (Banakar *et al.*, 1998), the dissolution effect on the samples may be ruled out. Immediately, all the sediment samples (top 1 cm. of the sediment core/grab)

Table 1: Showing details of the sampling stations.

Sr. No.	Station No.	Location Latitude	Longitude	Water Depth (m)
1.	SK199C/10	01° 55.38'S	67° 52.85'E	2597.00
2.	SK199C/12	04° 41.18'S	67° 05.75'E	3320.00
3.	SK199C/13	07° 21.89'S	67° 10.37'E	3305.00
4.	SK199C/14	09° 10.74'S	65° 57.33'E	3373.00
5.	SK199C/15	11° 25.46'S	67° 24.16'E	3513.00
6.	SK199C/16	12° 35.56'S	67° 08.59'E	3722.00
7.	SK199C/17	15° 16.71'S	66° 00.77'E	3368.00
8.	SK199C/19	16° 16.06'S	63° 27.86'E	4003.00
9.	SK200/5	28°19.29'S	48° 43.56'E	2295.00
10.	SK200/9	30°54.85'S	44° 51.37'E	2227.00
11.	SK200/14	36° 7.30'S	44° 53.54'E	2805.00
12.	SK200/15	37° 00'S	44° 59'E	2984.00
13.	SK200/17	39° 01.71'S	44° 58.17'E	4022.00
14.	SK200/19	40° 58.88'S	45° 03.53'E	2532.00
15.	SK200/21	43° 09.00'S	44° 59.00'E	3210.00
16.	SK200/22A	43° 41.47'S	45° 4.22'E	2723.00
17.	SK200/23	44° 59.82'S	45° 00.83'E	1423.00
18.	SK200/27	49° 00.34'S	45° 13.11'E	4377.00
19.	SK200/33	55° 00.39'S	45° 00.63'E	4185.00

were stained with Rose Bengal and preserved in 10% formalin to differentiate living specimens of benthic foraminifera. The presence of living benthic foraminiferal specimen at various stations indicates modern ambient conditions. Accordingly, the surface hydrographic properties were considered for inter-comparison assuming that the modern time is representative of the time of deposition of our surface sediment samples.

All the sediment samples were processed as per standard procedures. An appropriate amount of sediments from each sample was dried overnight at 45°C. Dried sediment samples were soaked in water and subsequently treated with sodium hexametaphosphate and hydrogen peroxide in order to dissociate clay lumps and to oxidize the organic matter, respectively. The treated sediments were sieved over 63µm sieve. Over 63µm fraction was dried and transferred to plastic vials. From the dried >63µm fraction, an aliquot was taken by quartering and coning and weighed to pick 200-300 specimens of different planktic foraminifera. The total planktic individuals per gram of dry sediments were calculated. The near sea surface salinity along with salinity at 50 and 100 m water depth were measured using CTD all along the transect at designated station. The nutrient (phosphate content) data were downloaded from the annual mean climatology data set of the World Ocean Atlas along the north-south transect (Levitus *et al.*, 1994).

RESULTS AND DISCUSSION

Nineteen species of planktic foraminifera have been identified in the study area. The planktic population is dominated by species such as *Globigerina bulloides, Globigerinoides ruber, G. sacculifer, G. conglobatus, Orbulina universa, Neogloboquadrina pachyderma, Globorotalia menardii*, etc. Fig. 2a shows that the minimum value of total planktic population (33571 individuals/gram), was recorded at station SK 199C/14, whereas it reached the maximum (2042500 individuals/gram) at station SK 200/05. Similarly, the minimum near surface salinity, recorded in this transect, is 33.71‰ (at station SK 200/21), whereas maximum salinity (35.67‰) is recorded at station SK 200/14. As can be seen in Figs. 2b, c and d, the overall salinity profiles at different water depth have not varied significantly

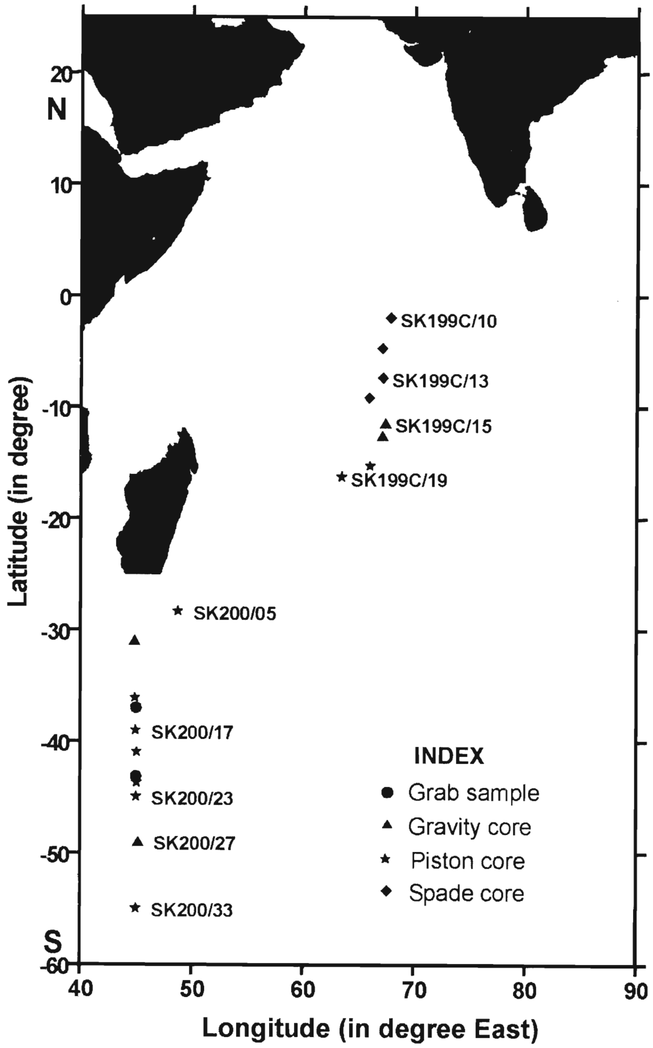

Fig. 1. Map showing the locations of grab and Piston corer samples. (o =*geographical location of the sampling stations*).

along this transect. The general salinity fluctuated between 33.71 –33.76‰ (minimum value range) and 35.67-35.75‰ (maximum value range). It is further evident from Fig. 2a-d, that all these parameters are apparently showing peculiar trends in different latitudinal regimes. From around 2° S to around 15° S latitude, it shows a relatively lower population with a small peak at station SK 199C/17 (Fig. 2a). Between around 15° S and 40° S latitude, planktic foraminiferal population is showing a relative bloom with the exception of station SK200/14 (at 36.12° S latitude). However, further south of around 40° S latitude, the planktic foraminiferal population is again showing a decrease.

Planktic foraminifera are one of the most common group of pelagic organisms in open Oceans. Earlier studies have revealed that planktic foraminiferal abundance varies by several order of magnitude across a large gradient in sea surface temperature and other hydrographic features and established a close relationship between the faunistic and hydrographic features of major oceanic water masses. Their geographical variations are particularly strong in the epipelagic rather than meso-bathypelagic zones demonstrating high sensitivity of planktic foraminiferal population to differences in water properties (Be' and Tolderlund, 1971; Mortyn and Charles, 2003). Accordingly, latitudinal or geographic restrictions of planktic assemblages as a whole are largely imposed by their

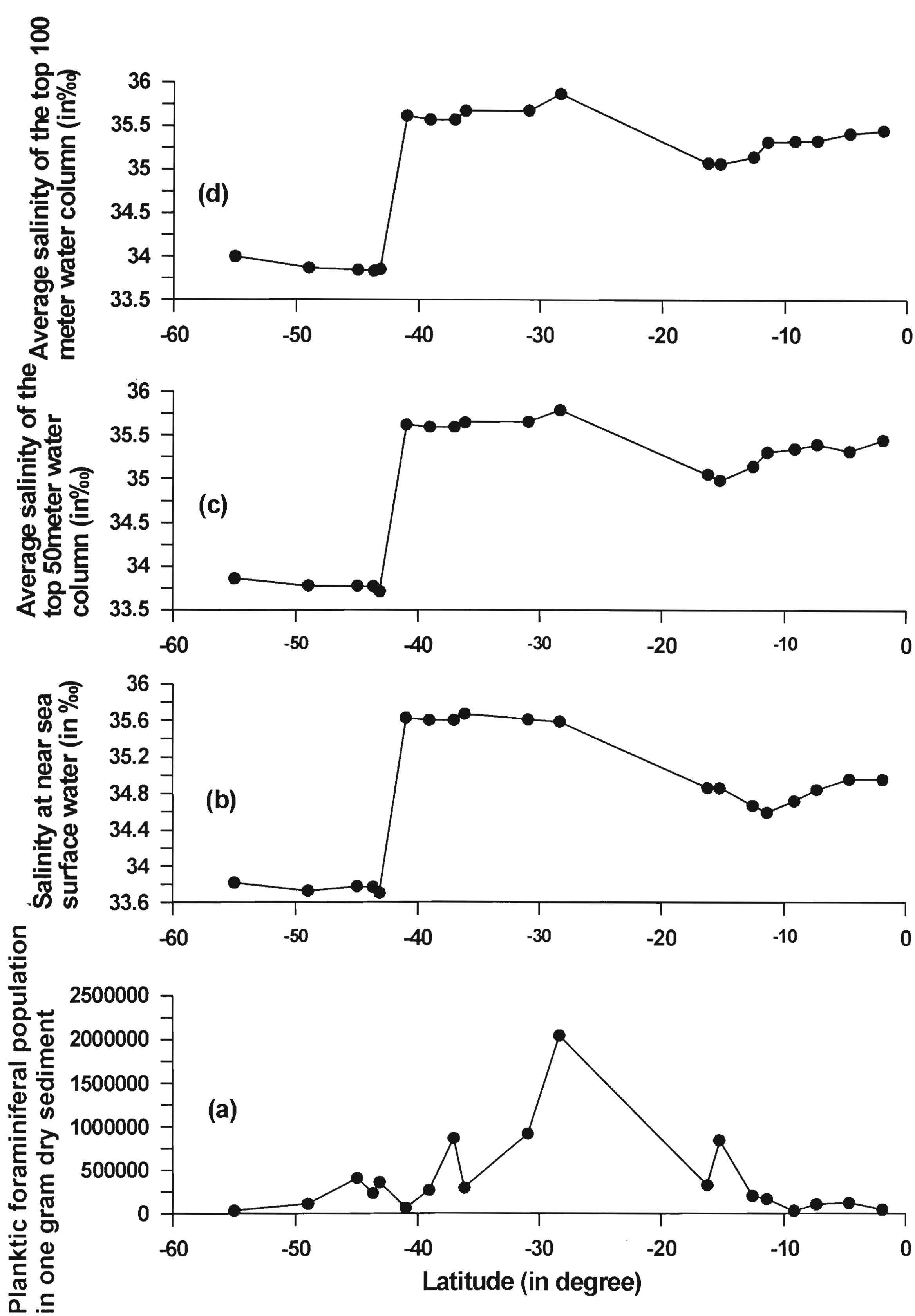

Fig. 2a. Latitudinal changes in abundance of planktonic foraminiferal population in one gram dry sediments.
Fig. 2b. Latitudinal changes of salinity (in %o) of near sea surface water.
Fig. 2c. Latitudinal changes of average salinity (in %o) of the top 50 m water column.
Fig. 2d. Latitudinal changes of average salinity (in %o) of the top 100 m water column.

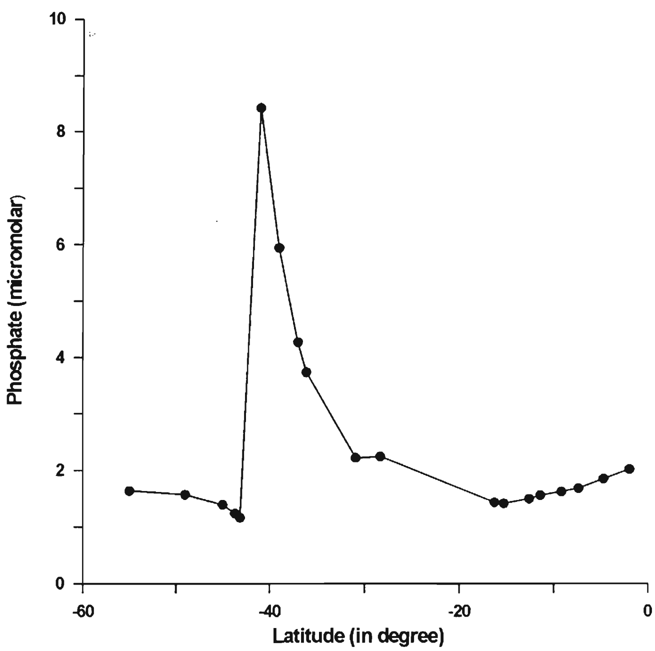

Fig. 3. Latitudinal changes of nutrient (phosphates) content (in micromolar) at near surface water mass.

dependence on particular water masses. It is an established fact that planktic foraminiferal population of the Recent sediments in general represents photic zone conditions of water masses. Accordingly, the near surface salinity along with the average salinity at 50 and 100m water depth have been considered for inter-comparison. As stated earlier, the planktic foramninifera are extremely sensitive towards salinity variations and their abundance is supposed to be higher in the areas of normal salinity (Funnel, 1967; Boltovskoy and Wright, 1976; Gibson, 1989).

The geographical variations in absolute abundance (total planktic population in one gram sediments) of the total planktic foraminiferal population in surface sediment samples is shown in Fig. 2a. It is worth noting that the latitudinal region between around 15^0 S and 40^0 S latitude shows an abundance of population with an overall decrease in the both (northern and southern) sides of this latitudinal regime. On mutual examination of salinity vis-à-vis population profiles, the variations in the planktic foraminiferal population are in tandem with the salinity profiles of near surface, average salinity of top 50m and average salinity of top 100m water depth. This suggests the role of salinity along this transect in determining planktic foraminiferal abundance.

Our findings are in agreement with earlier studies (Be' and Tolderlund, 1971, figure 6.27). The pattern of total absolute abundance of planktic foraminifera along the present transect appears to be basically the same as those generally cited as depicting the primary organic productivity and average standing crop of zooplankton in the world's oceans (Fairbridge, 1966). The organic matter flux (OMF) can be closely correlated with the export production from the upper ocean (Deuser and Ross, 1980) and is primarily controlled by phytoplankton production (Honzo, 1996). Changes in the production of phytoplankton affect the planktic foraminifera's nutrition (Eguchi *et al.*, 1999) and thus their abundance. Perhaps the food availability appears to be one of the controlling factors of the production of planktic foraminifera in the upper ocean. It is interesting to note that the nutrients (phosphate) are the substances controlling productivity. It has also been noticed that the marine regions with abundant nutrients (like phosphates) would witness greater phytoplankton development. As stated earlier, planktic foraminifera depend on phytoplankton for nutrition and phytoplanktons depend upon nutrients (such as phosphates); therefore, the foraminiferal abundance may also be controlled by the nutrients (phosphates) (Boltovskoy and Wright, 1976). By and large, similar relationship is also evident in our results where the planktic foraminiferal abundance profile correlates well with phosphate (Fig. 3). Our results are in agreement with the inferences drawn in earlier studies (Schott, 1935; Bradshaw, 1959; Parker, 1960; Berger, 1969).

In terms of general circulation pattern in the study area, the annual mean flow in the northern Indian Ocean is almost featureless and weaker than 10 sv, whereas the subtropical gyre dominates the southern hemisphere (Tomczak and Godfrey, 2003). The central water masses are typically the regions of low phyto and zooplankton densities, whereas the areas of major current systems and upwellings are known for their rich standing crop. Thus, we find that the central waters of around 2^0 S to 15^0 S latitude, which are characterized by relatively weak circulations (Tomczak and Godfrey, 2003) and reveal lower salinity, are distinguished by low foraminiferal abundance. This may also be attributed to the influence of the subtropical water mass, marked by an oligotrophic condition (Longhurst *et al.*, 1995). It is interesting to mention here that the sediment trap studies carried out along the central North Pacific Ocean exhibited that in the subtropical watermass planktic population was low due to lower productivity under oligotrophic conditions (Eguchi *et al.*, 1999).

Higher foraminiferal abundances are recorded in the regions between around 15^0 S and 40^0 S latitude; having increased salinity, nutrients (phosphates) and major current gyres (Tomczak and Godfrey 2003). The reduction in the foraminiferal population further south of around 40^0 S latitude could perhaps be ascribed to the possible reduction in the phytoplankton in the regions close to higher latitude. As the solar radiation is much more limited during winter time due to relatively low light intensity (Lalli and Parsons, 1997) the photosynthesis retards in the regions of higher latitudes. Since phytoplankton is the main food source for planktic foraminifera, low food availability prohibits foraminiferal productions resulting in low planktic population (Eguchi *et al.*, 1999). Our results show basic agreement with the investigations of Bradshaw (1959) and Belyaeva (1964), indicating that low concentrations are to be found in the central water masses and that the high population densities characterize the major current systems of the world's oceans.

To conclude, it is important to mention that the salinity and nutrient values must have been altered with the advancement/retreat of the ice sheets in the geological past. Although salinity changes in the past cannot be directly measured (Henderson, 2002), they definitely must have left imprints on the planktic population of the marine sedimentary record in a measurable way. Therefore, the evident relationship among salinity, nutrient (phosphates) content and planktic foraminiferal population established in the present study could be a useful proxy for assessing palaeosalinity variations linked with ice-sheet movement in this area (if studied in the subsurface sediments). It is proposed that a number of transects for similar investigations in geographically distinct regions could be advantageous to further strengthen the observations of the present study and help arrive at a comprehensive conclusions.

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