proximity are also used in the model as parameters. The topographical habitat features and the availability of water have also been used as restrictive factors in the present model. The present study attempts to implement habitat suitability approach for the mountain goat.

Conclusion

India has large biodiversity. However, recent population growth trends have put tremendous pressure on the habitats. The situation calls for urgent need to develop comprehensive database of the protected areas, which are temples of *in situ* conservational efforts. It is necessary to evaluate the available habitat size, quality and socioeconomic constraints. The present approach can provide information about the suitability of endangered species having very specific habitat requirements. There is need to implement such an approach for the species which are dwindling and becoming endangered due to shrinking habitat size.

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ACKNOWLEDGEMENTS. We are grateful to Prof B. L. Deekshatulu, Director, National Remote Sensing Agency, Hyderabad and Prof. S K. Bhan, Dean, Indian Institute of Remote Sensing, Dehradun for providing all the facilities required for this study We are also grateful to Dr A. J T. Johnsingh, Head, Wildlife Biology Faculty, Wildlife Institute of India, Dehradun for providing valuable suggestions and review

Received 3 July 1995, revised accepted 22 September 1995

RESEARCH COMMUNICATIONS

Carbon and oxygen isotopic records of planktonic and benthic foraminifera from a new deep-sea core of the northeast Indian Ocean

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Stable carbon and oxygen isotopic records of the planktonic foraminifera (*Globigerinoides ruber*), covering the past ~100,000 years, have been obtained from a new deep-sea core of the Bay of Bengal. High glacial-to-interglacial $\delta^{18}O$ amplitude (2.0‰) in the surface waters of this region provide evidence for the increased salinity (by ~2‰) in the glacial surface waters of this region[1,2]. In contrast, the surface water $\delta^{13}C_{TIC}$ did not change significantly during the glacial-to-interglacial transition.

Examination of the isotopic record of benthic foraminifera (*Cibicidoides* and *Uvigerina*) shows higher (1.7‰) glacial-to-interglacial $\delta^{18}O$ amplitude. This is attributed to the decrease in deep-water temperature arising from changes in source characteristics during the LGM. The glacial-to-interglacial shift in $\delta^{13}C_{TIC}$ (~0.3‰) in the deep Bay of Bengal is close to the global

$\delta^{13}C$ change, in conflict with the previous reports that suggested marked enrichment of nutrients in deep waters of the northeast Indian Ocean.

STABLE carbon and oxygen isotopic analyses in the planktonic and benthic foraminifera from the deep sea cores of the northern Indian Ocean have shown significant changes in the chemical characteristics of the surface and deep-water masses since the last glacial maximum (LGM)[1-7]. Previously published oxygen isotopic records of the planktonic foraminifera from the Northeast Indian Ocean (NEIO) are suggestive of much higher salinity as compared to today in the glacial surface waters of this region due to a reduction in riverine input[1,7]. A large influx of pollen from the Irano–Turanian Steppe and high percentage of quartz observed in the glacial sections of sediment cores also support prevalence of high aridity in the region and a weakening of the southwest monsoon during the last glaciation[8,9].

Heavy precipitation during the southwest monsoon over the Indian subcontinent is collected by the major rivers (Ganges, Brahmaputra, Salween and Irrawady) which drain into the northeast Indian Ocean. As a result, a strong north–south salinity gradient forms in the Bay of Bengal, which is reflected in the $\delta^{18}O$ distribution pattern of the Holocene planktonic foraminifera[1]. The deep Bay of Bengal is filled with water originating in the circumpolar region and transported northward by the two western boundary currents[10]. The water found at the site of the core SK-72 (water depth 3246 m) has an important component from the relatively warm North Atlantic Deep Water (NADW).

The hydrographic structure of the deep and intermediate water in the northern Indian Ocean experienced considerable changes during the last glacial maximum[3,5]. The $^{13}C/^{12}C$ and $^{18}O/^{16}O$ ratios in shells of benthic foraminifera showed that, during the last glaciation, water column in the northern Indian Ocean was highly stratified, with a well-marked boundary between the intermediate- and deep-water masses[3], in contrast to the present conditions, when the $\delta^{13}C$ gradient is very small (0.1‰)[11]. To explain this glacial stratification, a mechanism involving the transfer of nutrients from the intermediate to deep waters was suggested[12,13]. But more recent data from intermediate-depth cores of the NEIO showed that the glacial $\delta^{13}C$ gradient was not as high as reported earlier[5,6]. The temperature of glacial intermediate- and deep-water masses in NEIO was also lower by at least 1–1.5°C compared to the present bottom water of this region[3,5,14]

The distribution of carbonates in deep-sea sediments is controlled by the depth of the lysocline, where the rate of calcite dissolution increases sharply and by the carbonate compensation depth (CCD), below which calcium carbonate does not occur. The biological productivity, water depth, chemistry and dilution by non-carbonate components are the main factors influencing carbonate content of the sediments[15]. In addition, the deep-water circulation pattern also plays an important role in determining carbonate distribution[15,16]. As a result of these changes, the depth of the lysocline varies considerably, both locally as well as globally.

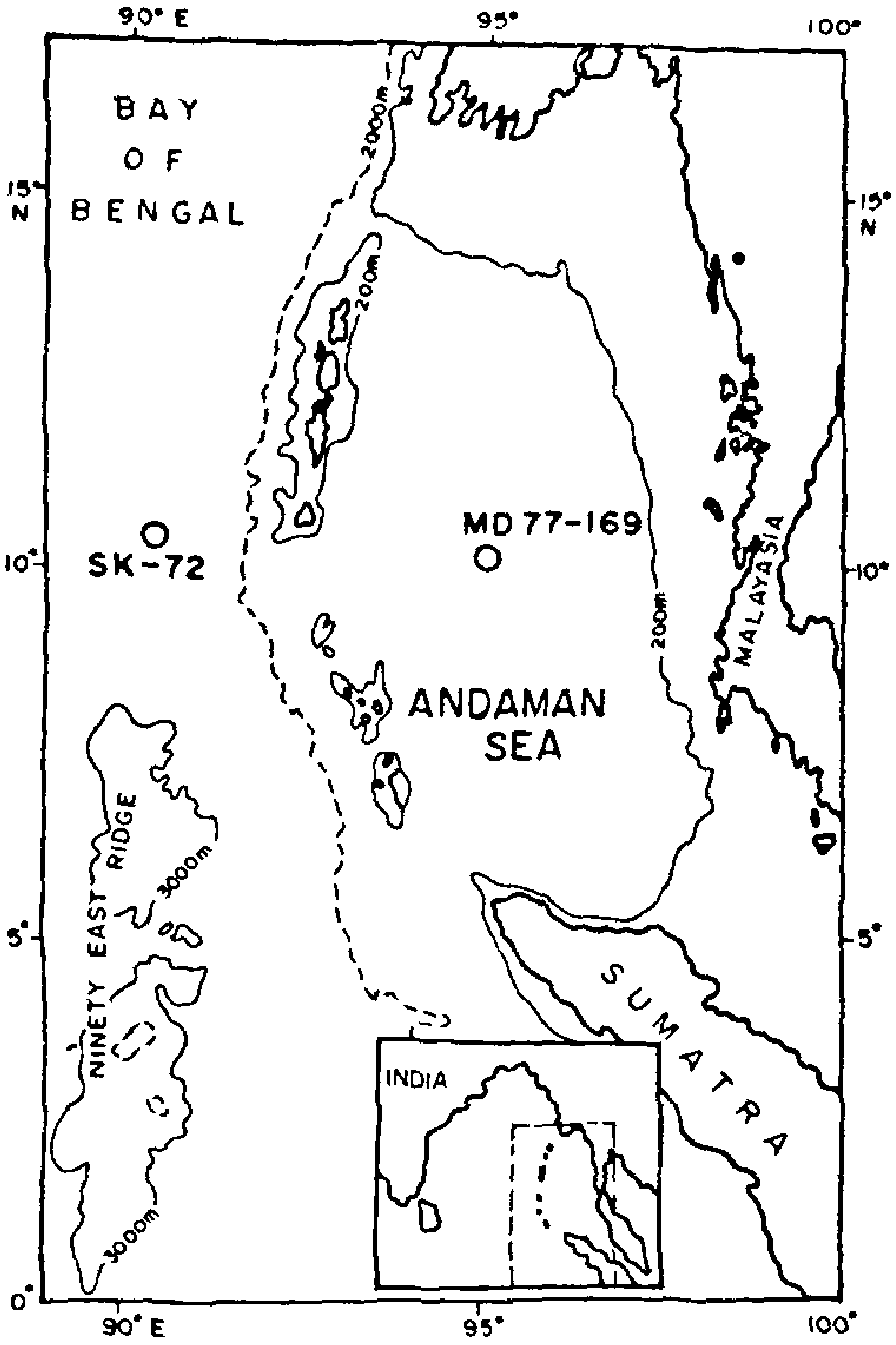

Figure 1. Location map of the cores SK-72 and MD 77-169

The box core SK-72 was retrieved from the Bay of Bengal (10°43′N and 90°27′E) during February/March 1992 at a water depth of 3246 m (Figure 1). The core was subsampled for this study at 10–20 cm intervals except within the Holocene section, where samples were taken at 5 m intervals. The sediment samples were soaked in distilled water overnight and subsequently washed through a 150 µm sieve and dried at 60°C. About 15–20 foraminiferal tests in the size range of 250–315 µm were then picked under a microscope for isotopic measurements.

The separated specimens were ultrasonically cleaned to remove adhering particles and roasted under vacuum at 400°C for 1 h. The CO_2 was extracted by the reaction of foraminiferal calcite with 100% phosphoric acid at 50°C on an on-line system and the isotopic ratios were measured using a VG Micromass 903 mass spectrometer. The precision based on the replicate measurements of the internal laboratory standard MMB for both carbon and oxygen was better than ±0.1‰. The results are expressed relative to PDB standard (Table 1). *Cibicidoides* oxygen isotopic values were converted into *Uvigerina* scale by adding 0.64‰ (ref. 17), while carbon isotopes

Table 1. Carbon and oxygen isotopic composition of planktonic (*G ruber*) and benthic (*Cibicidoides* and *Uvigerina* spp) foraminifera for core SK-72. Isotopic values are given in per mil against PDB standard

Depth (cm)	Spp	$\delta^{13}C$	$\delta^{18}O$	Depth (cm)	Spp	$\delta^{13}C$	$\delta^{18}O$
0	*Ruber*	0.79	−2.52	0	*Cibicidoides*	0.36	2.67
5	*Ruber*	0.87	−2.53	5	*Cibicidoides*	–	2.42
20	*Ruber*	1.21	−2.23	10	*Cibicidoides*	0.29	2.41
60	*Ruber*	0.97	−0.63	20	*Cibicidoides*	0.48	3.11
80	*Ruber*	1.15	−0.37	30	*Cibicidoides*	0.12	3.58
120	*Ruber*	1.14	−0.91	35	*Cibicidoides*	0.16	3.68
140	*Ruber*	1.34	−0.62	80	*Uvigerina*	−0.69	5.03
160	*Ruber*	1.21	−0.67	100	*Uvigerina*	−0.80	5.04
180	*Ruber*	1.03	−0.96				
200	*Ruber*	1.29	−1.11				
220	*Ruber*	1.13	−1.11				
240	*Ruber*	1.81	−0.78				
260	*Ruber*	1.13	−0.63				
280	*Ruber*	1.08	−1.03				
300	*Ruber*	1.23	-				
320	*Ruber*	1.26	−0.92				
340	*Ruber*	1.48	−1.31				
360	*Ruber*	1.42	−1.08				
380	*Ruber*	1.22	−1.55				
400	*Ruber*	1.15	−1.39				

Table 2. Age against depth data for core SK-72. Ages are estimated from the time scale derived for the normalized SPECMAP curve by Imbrie *et al*[19]

Event	Sub-bottom depth (m)	Age 10^3 yr
1.1	0.2	6
2.0	0.4	12
2.2	0.8	18
3.1	1.2	24
3.3	2.0	53
4.0	2.39	59
4.2	3.0	65
5.1	3.4	80
5.2	3.6	87
5.3	3.8	94

of *Uvigerina* were brought to the *Cibicidoides* scale by adding 0.83‰ (ref. 18). Carbonate contents were determined by weight loss after leaching the samples with dilute (50%) hydrochloric acid. The reproducibility of the carbonate abundance estimate is better than ±2% based on six replicate measurements.

Age assignments and correlation of cores are based on the planktonic oxygen isotopic stratigraphy by using graphic correlation of the SPECMAP $\delta^{18}O$ record (Table 2)[19]. The average sedimentation rate in SK-72 is about 4.1 cm/ka. The planktonic record of SK-72 correlates well with another core (MD 77-169) of the northeast Indian Ocean[7].

The results of the oxygen isotopic analyses of the surface-dwelling planktonic foraminifera *Globigerinoides ruber* in SK-72 are plotted against time in Figure 2. The observed glacial-to-interglacial $\delta^{18}O$ amplitude exceeds the ice volume effect of ~1.2‰ (ref. 20) by 0.8‰. This could arise from either a cooling of surface waters by about 3°C (ref. 21) or from an increase in salinity by ~2‰ (ref. 22), or from a combination of both the factors. However, earlier studies have shown that the glacial surface temperature in the Bay of Bengal did not differ by more than 1°C from the present SST[1,22]. Therefore, the glacial enrichment in $\delta^{18}O$ could be attributed mainly to the increased salinity. Comparison of the $\delta^{18}O$ records between SK-72 and the Andaman Sea core MD77-169 indicates generally lower ^{18}O in the Andaman Sea, because core MD77-169 comes from a region which is greatly influenced by runoff from the rivers Irrawady and Salween.

The LGM to core top change in $\delta^{18}O$ for the benthic foraminifera (~1.7‰; Figure 3) is also considerably higher than the ice volume effect[20]. Since there is no evidence for any local deep water formation in NEIO during the last glaciation, the higher glacial–Holocene shift in benthic $\delta^{18}O$ in this region should be due to a decrease in deep-water temperature as a result of the changes in source waters[14,23]. It is quite likely that the glacial deep water in the Bay of Bengal had a greater contribution from the Antarctic Bottom Water (AABW) at the expense of warmer NADW as production of the latter was greatly reduced during the glacial times. The additional $\delta^{18}O$ enrichment (~0.5‰) in SK-72 implies a cooling by about 2°C; this is somewhat higher than the previous estimate (1.5°C)[3]. However, it must be noted that these computations assume no local salinity change in excess of that included in the global ice volume effect. If there was a local increase in salinity as well (which is likely given the dramatic increase in surface salinity during the LGM and the consequent downward diffusion of salt through the water column), the magnitude of cooling would be smaller.

The present geographic distribution of $\delta^{13}C$ in the deep sea is related to the oxygen and nutrient contents

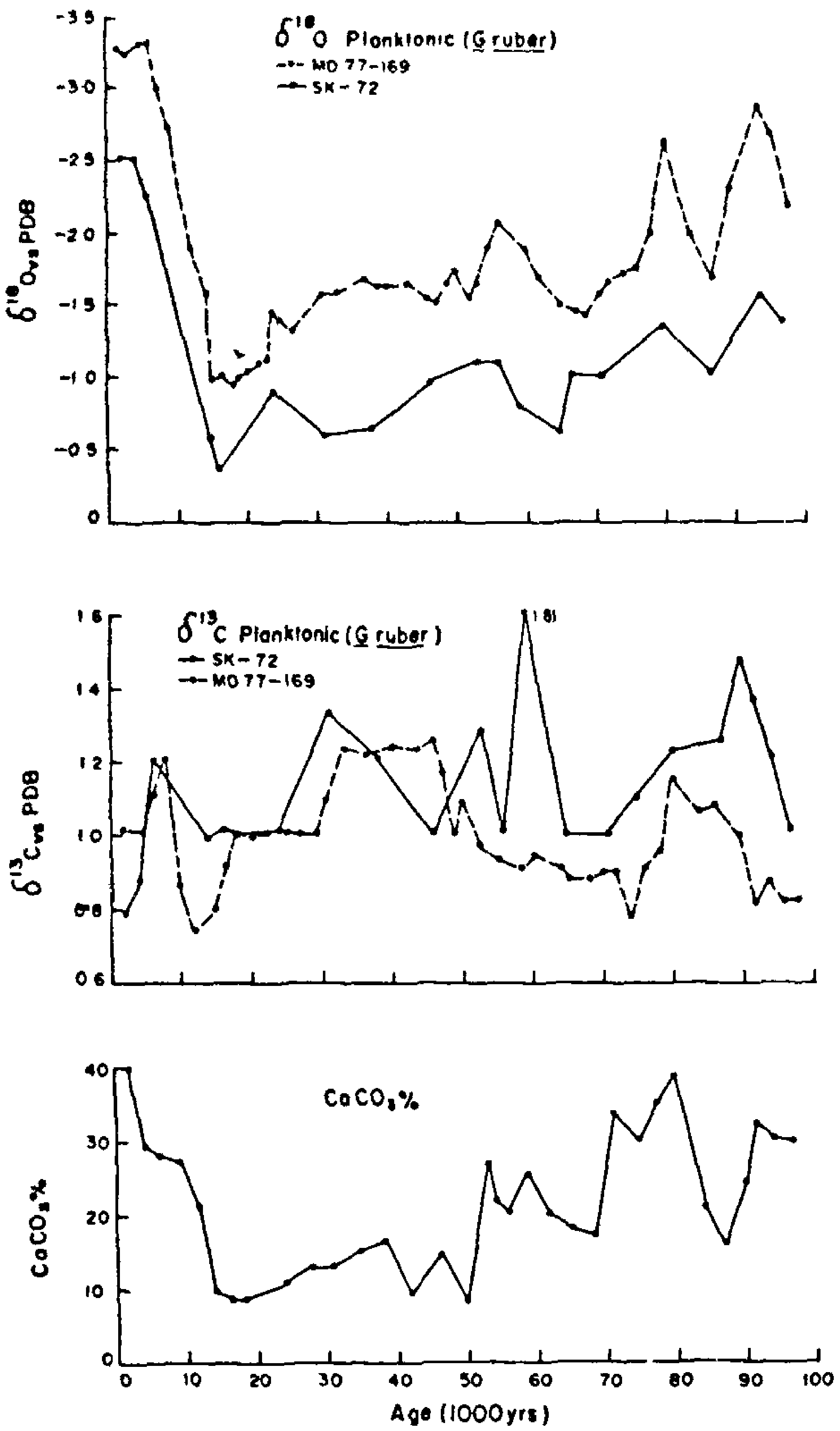

Figure 2. Carbon and oxygen isotopes in planktonic foraminifera (*Globigerinoides ruber*) and CaCO$_3$ percent in the cores SK-72 and MD 77-169 plotted against age.

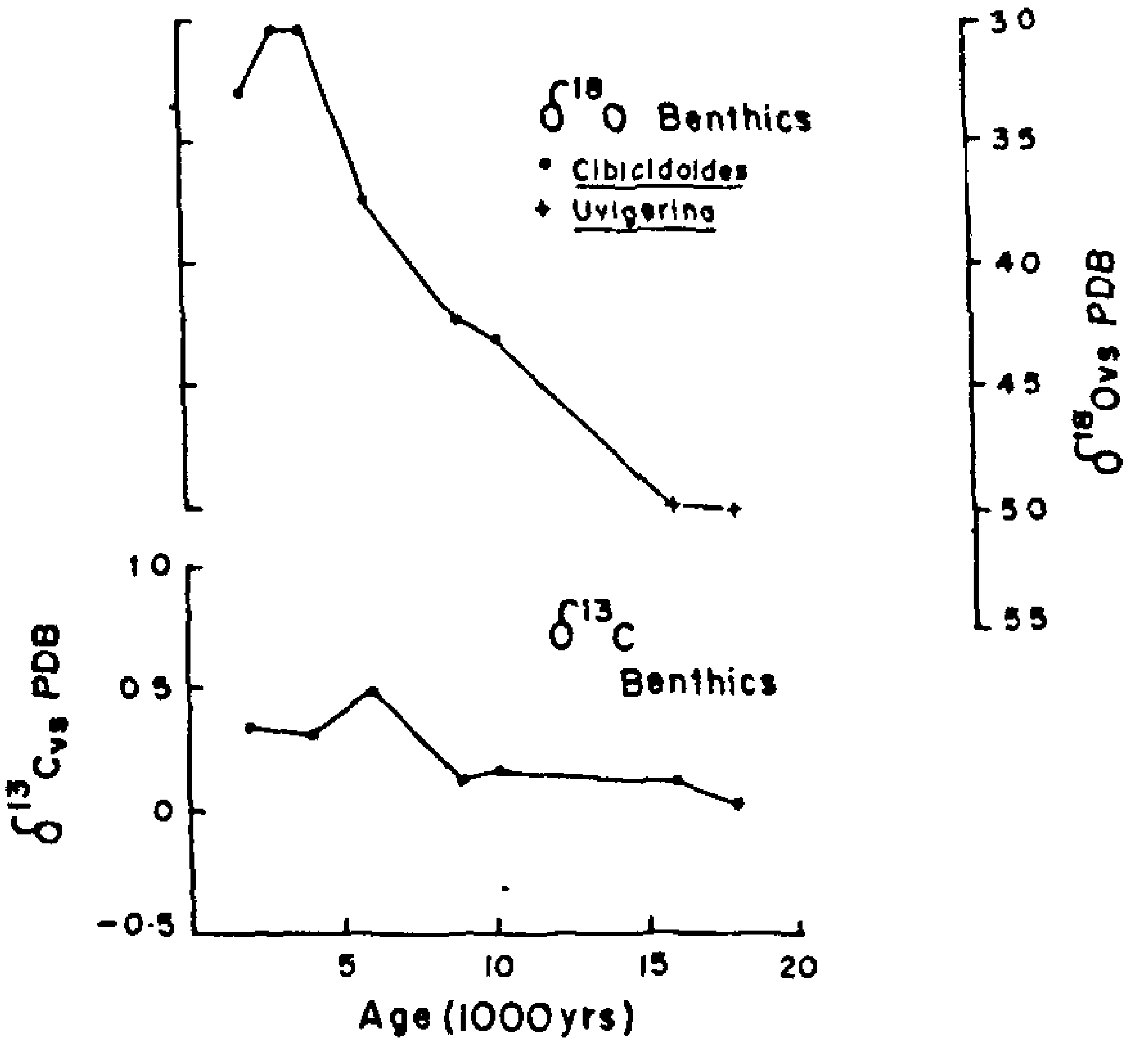

Figure 3. Stable isotopic record of the benthic foraminiferal genus *Cibicidoides* and *Uvigerina*. Oxygen isotopes of *Cibicidoides* corrected by adding 0.64‰ and carbon isotopes of *Uvigerina* corrected by adding 0 83‰

and circulation pattern of the water masses[11]. However, during the last glaciation the deep-water circulation probably experienced considerable changes because of the decreased production of NADW[24,25]. Carbon isotopic data on benthic foraminifera belonging to the genera *Cibicidoides* and *Uvigerina* have shown that during the LGM deep-ocean $\delta^{13}C$ was lower by 0.32–0.46‰ compared to the late Holocene[4,18]. In SK-72 the maximum $\delta^{13}C$ difference (0.45‰) was observed between 20 and 100 cm levels. However, the mean glacial–interglacial $\delta^{13}C$ shift is only ~0.3‰ (Figure 3), which is very close to the global deep-water $\delta^{13}C$ shift. Recent studies from the intermediate-depth water cores from the North Indian Ocean have clearly demonstrated that the glacial mid-depth water masses in NEIO are also similarly depleted in ^{13}C by 0.3–0.4‰, compared to the Holocene[5,6]. Hence, the $\delta^{13}C$ gradient between the intermediate and deep waters was very similar to that observed today. It can, therefore, be concluded that the glacial NEIO did not experience a dramatic change in the vertical chemical structure (acute oxygen depletion and nutrient enrichment in the deep waters) as reported previously[3].

The carbonate content of SK-72 varies from ~8% to ~40% by weight (Figure 2). The carbonate content is high (39.4%) in the top portion of the core (0–5 cm), decreases rapidly to 8.5% at 100–105 cm and remains low down to 200 cm depth. Thereafter, the variation was relatively small. High carbonate contents correspond to interglacials (oxygen isotope stages 1 and 5), whereas low values are seen during the glacial stages 2 and 4. The carbonate content during isotopic stage 3 is also low. This CaCO$_3$ abundance pattern is consistent with the carbonate data of other cores in the North Indian Ocean[26,27]. The low CaCO$_3$ abundance during the glacial times could be attributed to the decrease in lysocline as well as dilution by terrigenous matter. As stated earlier, the glacial deep waters probably received a greater contribution of cooler AABW. The decrease in sea water temperature favours carbonate dissolution and this would have contributed to the observed decrease in sedimentary CaCO$_3$ content during glacial times.

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ACKNOWLEDGEMENTS I express my sincere thanks to R. Ramesh for his assistance in the isotopic measurements at PRL, Ahmedabad, and K. Gopalan for his encouragement and support to carry out this work The support and help provided by P. K. Banerjee in obtaining the core samples is thankfully acknowledged. I thank the referees of *Current Science* for their valuable comments. Thanks are also due to S Ramaswamy for providing me the samples of the core SK-72.

Received 15 February 1995, revised accepted 15 September 1995

Resistance to *Bacillus sphaericus* in *Culex quinquefasciatus* Say 1823

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Biological control of *Culex quinquefasciatus* using *Bacillus sphaericus* was considered a practical solution because of its specific and prolonged killing action against mosquito larvae. To study the feasibility of *B. sphaericus* ('Spherix') in mosquito control, multicentric trials were undertaken. Initially, *B. sphaericus* was very effective but within a year, after 20–25 rounds of application, field populations of *Cx. quinquefasciatus* developed resistance up to 150-fold. Genetic studies revealed that resistance was recessive, autosomal and controlled by more than one gene. This is the first report on nature and mode of inheritance of resistance against *B. sphaericus* in mosquitoes.

CULEX *quinquefasciatus* Say, 1823, is the major vector in the transmission of lymphatic filariasis caused by the nematode *Wuchereria bancrofti* in the tropics. To control *Cx quinquefasciatus*, *Bacillus sphaericus* is emerging as a promising larvicide[1,2]. Extensive multicentric field trials carried out by Malaria Research Centre in India showed that the spraying of 'Spherix' (a commercial preparation of *B. sphaericus* Russian strain B-101, Serotype H5a 5b;) at the rate of 1 g/m^2 provides control of *Cx. quinquefasciatus* breeding for 2–4 weeks[3,4]. After 20–25 rounds of continuous field application of *B. sphaericus* within a year, reduction in its efficacy against *Cx. quinquefasciatus* was noticed. In this communication we report the development of resistance against *B. sphaericus* in field populations of *Cx. quinquefasciatus* and its mode of inheritance in this species.

Adult mosquitoes from *B. sphaericus* sprayed and unsprayed areas of Farrukhabad and Ghaziabad (Uttar Pradesh), Madras (Tamil Nadu) and Panaji (Goa) were collected and transported to MRC laboratories in Delhi for colonization[5] and further studies. In addition to these field populations, two laboratory strains maintained since 1988, one each from Delhi state and Sonepat (Haryana) were also used in bioassay and genetic crosses. Bioassays were performed following the method of WHO[1] with necessary modifications[6]. One per cent stock suspension of Spherix in dechlorinated water was prepared fresh and was used immediately for the bioassays. Twenty-five late III/early IV instar larvae were placed in 250 ml of water containing the required dose of *B. sphaericus* for 24 h and scored for mortality. All the tests were carried out in two replicates at 27± 1°C. Dose–mortality responses of treated lines were analysed using probit regression method of Finney[7].

Dose–mortality regression of the field populations and two laboratory strains are given in Figure 1 and Table 1.