Impact of tsunami on meiofauna of Marina beach, Chennai, India

The coastal ecosystem is characterized by frequent disturbances, which affect the structure of the ecological communities by removing established species and allowing fugitive species to colonize the disturbed area[1]. The impact of geomorphological changes on marine organisms ranging from meiofauna to large aquatic mammals has been reported earlier[2]. The marine soft-bottom experiences physical disturbances due to hurricanes[3], storms[4] and ray feeding pits[5], which affect the infauna by changing the sediment structure and food resources[6]. Meiofauna adapted to interstitial existence shows a variety of life history attributes, suggesting that these communities are capable of responding to anthropogenic and natural disturbances to establish their recolonization. Earlier investigations on the disturbances of the coastal system indicated that recolonization of the affected area might take place in about 12–23 h, months and even several years, depending on the nature of disturbance[7–9]. Nevertheless, it takes a long time to attain equilibrium with regard to the normal composition[10,11]. Further, it has been reported that there is variation in the response of different taxa to the disturbances[12,13]. Based on documented evidences, Rajendran *et. al.*[14] have reported that only two earthquakes (1881 and 1941) have caused tsunami run-up in the east coast of India. Further, they are of the view that the 26 December 2004 tsunami is unprecedented in terms of its scale and reach, and cannot be compared to its preceding historical events. It has caused extensive damage to the shore and foreshore area of the coastal system, resulting in greater physical damage. We have not come across any report indicating its impact on meiofauna.

The tsunami[14] resulted due to an earthquake on the seafloor of the Indian Ocean (3.29°N, 95.77°E) at 6.20 a.m. IST, with a magnitude M 9.0. The epicentre of the earthquake was 257 km south-southeast of Banda Aceh, Sumatra, Indonesia. This is the cause of major natural disturbances that struck the coastal line of south and South East Asian countries on 26 December 2004. Marina beach, Chennai (13°06′N. 80°18′E), which is 2028 km southeast from the epicentre was also affected by the tsunami on 26 December 2004 at 8.40 a.m. IST. The height of the wave due to the tsunami was reported to be 6 m at the Chennai coast. The present study assesses the impact of the tsunami on meiofaunal composition and distribution in the Chennai coast.

Sand sediments and water samples were collected from the intertidal region of the sandy beach of Marina, daily from 27 December 2004 to 2 January 2005, and also on 8 and 19 January 2005. Sediment samples were collected with a corer of 3.57 cm diameter and interstitial water with a lance. Physico-chemical parameters such as temperature, dissolved oxygen (DO), salinity, Eh and sand-grain composition were analysed following standard methods[15,16]. Meiofauna were extracted by decantation method[17] and preserved in 5% Rose Bengal formalin. Major taxa were identified and their composition was expressed in number of animals/10 cm^2. Data on sandgrain composition and meiofauna after tsunami were compared with those of previous investigations during November and December 2004 in the same station.

A visible change was observed in the intertidal area of the beach; instead of the usual gentle slope, the intertidal area was much flatter on 27 December 2004. However, the usual slope started to appear four days after the tsunami and normal profile was restored in about 15 days. The physico-chemical parameters of Marina beach prior to and after the tsunami are presented in Table 1. Though there are minor variations in the temperature, DO, salinity and Eh prior to and after the tsunami, these appear to be of normal occurrence rather than due to the impact of the tsunami. Nevertheless, higher oxygen content during the post-tsunami period might be due to higher wave action facilitating more dissolution of atmospheric oxygen into coastal sea water.

The sand particles of Chennai coast range in size from <63 to >2000 μm, with normal distribution showing higher percentage of particles ranging from 250 to 710 μm at a depth of 0–20 cm. However, the distribution of relative percentage of sand particles in the depths of 0–5, 5–10, 10–15 and 15–20 cm shows variations during low and high tide[18]. A day after the tsunami, higher percentage of 355 μm sand grains occurred at 0–5 cm, while distribution of sand grains at other depths appears to be normal. Thus, 2 to 4 days after the tsunami, there is distinct variation in the distribution of sand grains. Sand particles of 355 and 250 μm constituted major percentage at all depths (Figure 1). However, from the fifth day after the tsunami, normal composition of sand grains appeared to have been restored at different depths.

Meiofaunal composition at the Marina beach chiefly consists of turbellarians, nematodes, polychaetes, oligochaetes, and harpacticoids. Genera and species of different groups of meiofauna recorded in the present study are shown Table 2. Total meiofauna during the months of November and December 2004 was 3033 ± 372 and 2175 ± 336/10 cm^2 respectively. Quantitatively, the order of meiofaunal groups of this station during November was nematodes > harpacticoids > oligochaetes > gastrotrichs > turbellarians and during December, it was harpacticoids > nematodes > oligochaetes > gastrotrichs > polychaetes. Composition of such meiofauna in the Marina beach has been reported earlier[18]. Results of the present study indicate that a day after the tsunami, there was distinct decrease (744 ± 14/10 cm^2) in the density of meiofauna (Figure 2). Compared to the November and early December 2004 data, the density of meiofauna soon after the tsunami showed statistically significant difference at 5% level, though there might be wide fluctuation in the meiofaunal populations due to tidal action, physico-chemical parameters and predation pressure, the present results indicating low density can be exclusively attributed to the tsunami. The probable reason might be alteration of composition of sand sediments by the giant waves, leading to displacement of upper layer of coarse sand along with the meiofauna. Alternatively, in response to the giant waves, meiofauna might have migrated deeper into the soil. At Marina, the receding wave after the tsunami lasted for more than 24 h and as a consequence, the disturbance might have persisted in the soft soil for this period. The density of meiofauna two days after the tsunami increased substantially (6028 ± 932/10 cm^2). This might be due to the migration of meiofauna from displaced regions or by vertical migration from deeper to upper layer of the soil. Boaden[12] reported that increased water flow and sediment vibration had lead to immediate burrowing of many meiofaunal taxa. Grémare *et al.*[2]

Table 1. Physico-chemical parameters of intertidal region of Marina beach, Chennai

Depth	November	December	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 13	Day 24
Air	30.4	27.4	30	31.4	30.6	27.8	30.6	33	31.8	29.6	27.4
Temperature											
Sea water	29	28	27	27.4	28	27.4	28.5	28	28	28	28
0 to 5 cm	28.8	27.4	27	27.4	27.6	27.6	28	28.5	28	27.5	27.6
5 to 10 cm	28.6	27.4	27.5	27.6	27.4	27.4	27.8	28.4	28.2	27.6	27.6
10 to 15 cm	28.6	27.5	27.4	27.6	27.4	27.4	27.6	28.4	28.4	27.6	27.7
15 to 20 cm	28.6	27.6	27.4	27.6	27.4	27.4	27.5	28.6	28.4	27.8	27.7
DO											
Sea water	1.86	2.27	2.48	2.69	2.48	2.89	2.07	2.69	2.48	2.69	3.72
0 to 5 cm	1.65	1.65	2.48	2.48	2.27	2.07	1.86	1.65	2.48	1.86	3.31
5 to 10 cm	1.24	1.65	2.27	2.27	2.69	1.86	2.27	2.27	2.27	1.65	3.1
10 to 15 cm	1.24	1.45	2.27	2.07	2.07	1.86	1.86	2.07	2.07	2.07	2.48
15 to 20 cm	1.24	1.24	2.07	2.07	1.65	2.48	2.07	2.27	2.07	1.86	2.48
Salinity											
Sea water	29.09	26.04	25.86	26.4	30.53	30.35	30.17	30	26.58	26.58	32.14
0 to 5 cm	28.55	26.04	25.86	26.58	30.53	30.89	30.35	30.53	26.22	26.76	32.14
5 to 10 cm	28.55	26.04	26.94	26.22	30.89	30.71	30.53	30.89	26.58	26.76	32.86
10 to 15 cm	28.55	26.04	26.76	26.4	30.71	30.35	30.53	30.53	26.4	26.94	32.86
15 to 20 cm	28.55	25.86	26.94	26.76	30.53	30.17	30.17	30.35	26.4	26.94	33.04
Eh											
0 to 5 cm	262	262	267	261	268	270	267	266	268	265	263
5 to 10 cm	263	264	267	261	269	270	266	264	267	266	264
10 to 15 cm	264	264	266	262	269	268	266	264	268	266	264
15 to 20 cm	264	262	265	265	269	266	266	265	265	265	264

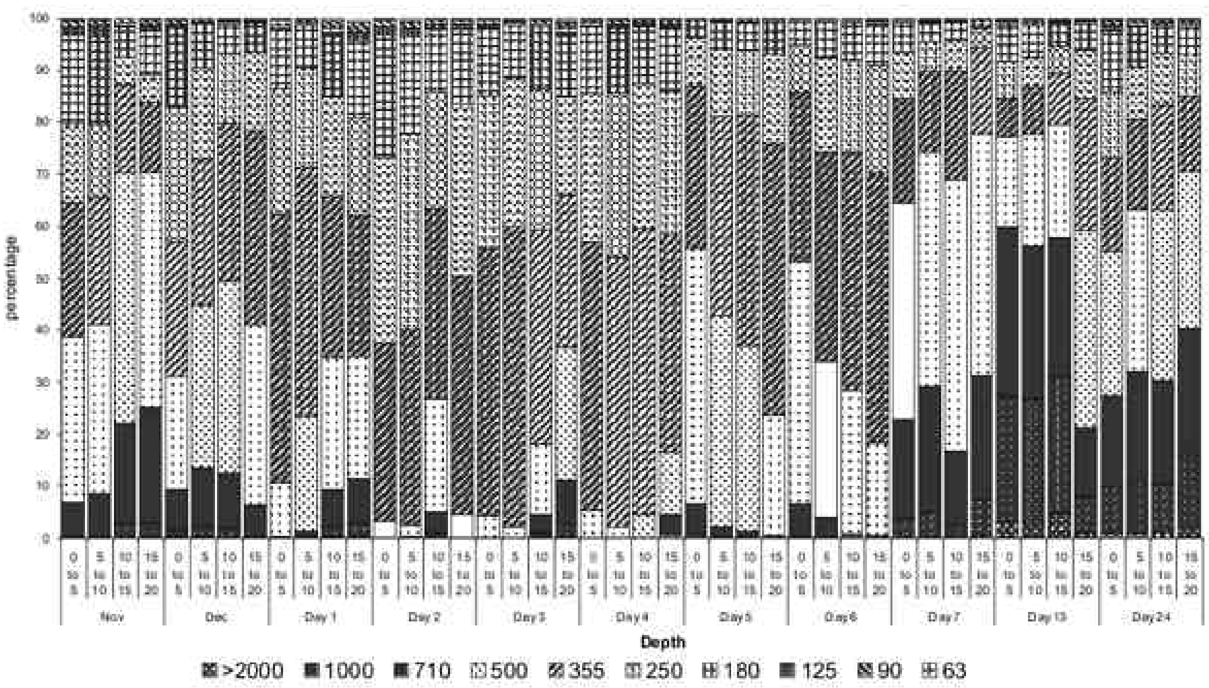

Figure 1. Percentage composition of sand grains at Marina beach prior to and after the tsunami.

are of the view that meiofauna bury themselves deep before the storm. The present study suggests that the active wave might have caused vertical and horizontal displacement of meiofauna. Such a displacement has also been reported by Warwick *et al*[19].

Composition of sand particles, which form interstices, constitutes one of the important factors in the colonization of meio-

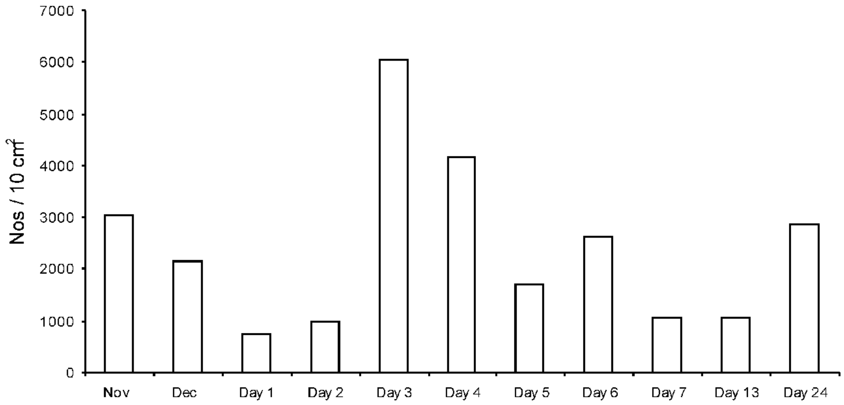

Figure 2. Meiofauna density prior to and after the tsunami.

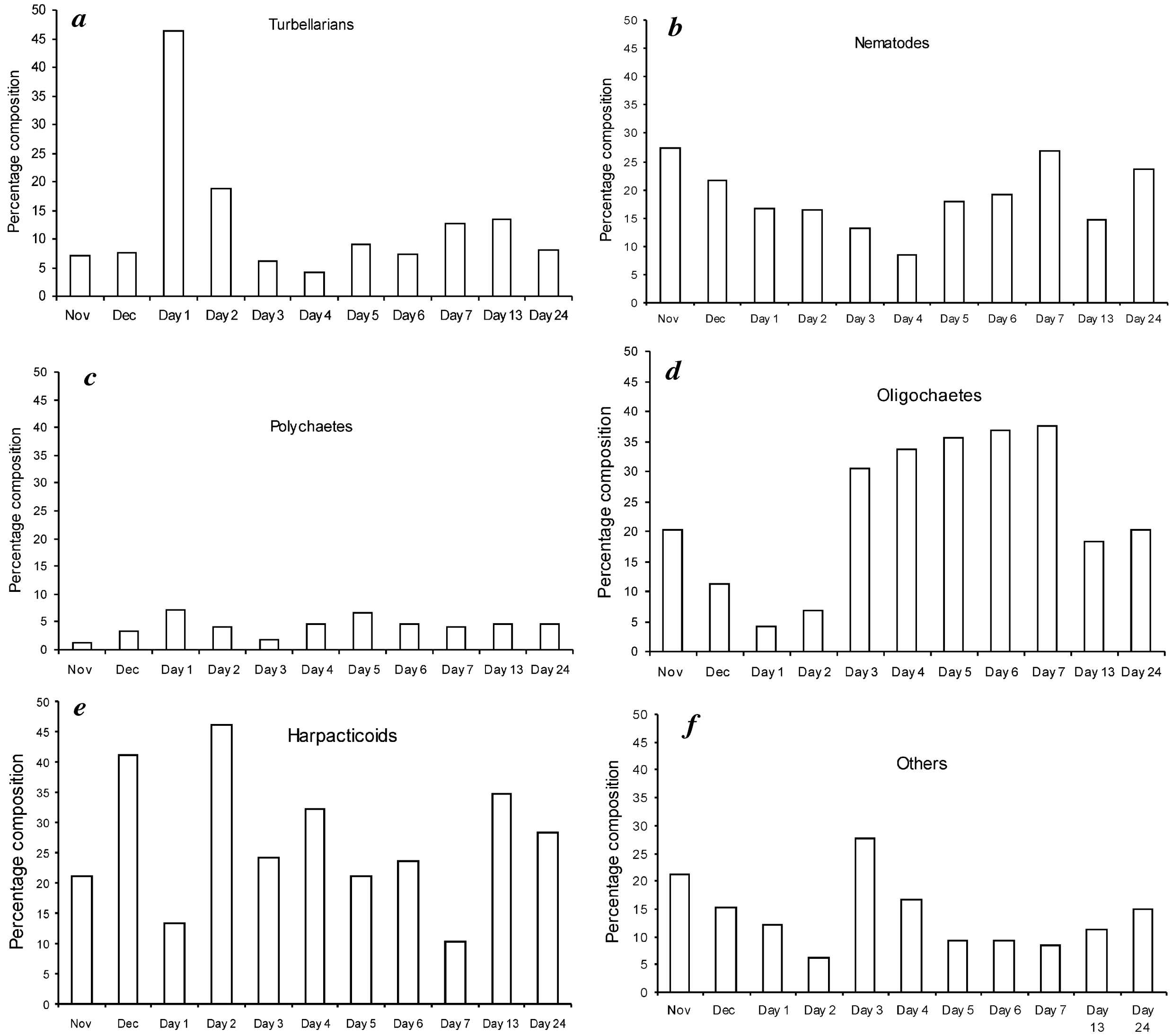

Figure 3. Percentage composition of major groups of meiofauna prior to and after the tsunami.

fauna. Maximum number of meiofauna has been reported where the sand-grain diameter[20] ranges between 0.175 and 0.275 mm. Two days after the tsunami, the composition of sand particles at a depth of 0–20 cm in the intertidal region of Marina beach, showed higher percentage ranging from 250 to 355 μm. This size range was reported to be highly suitable

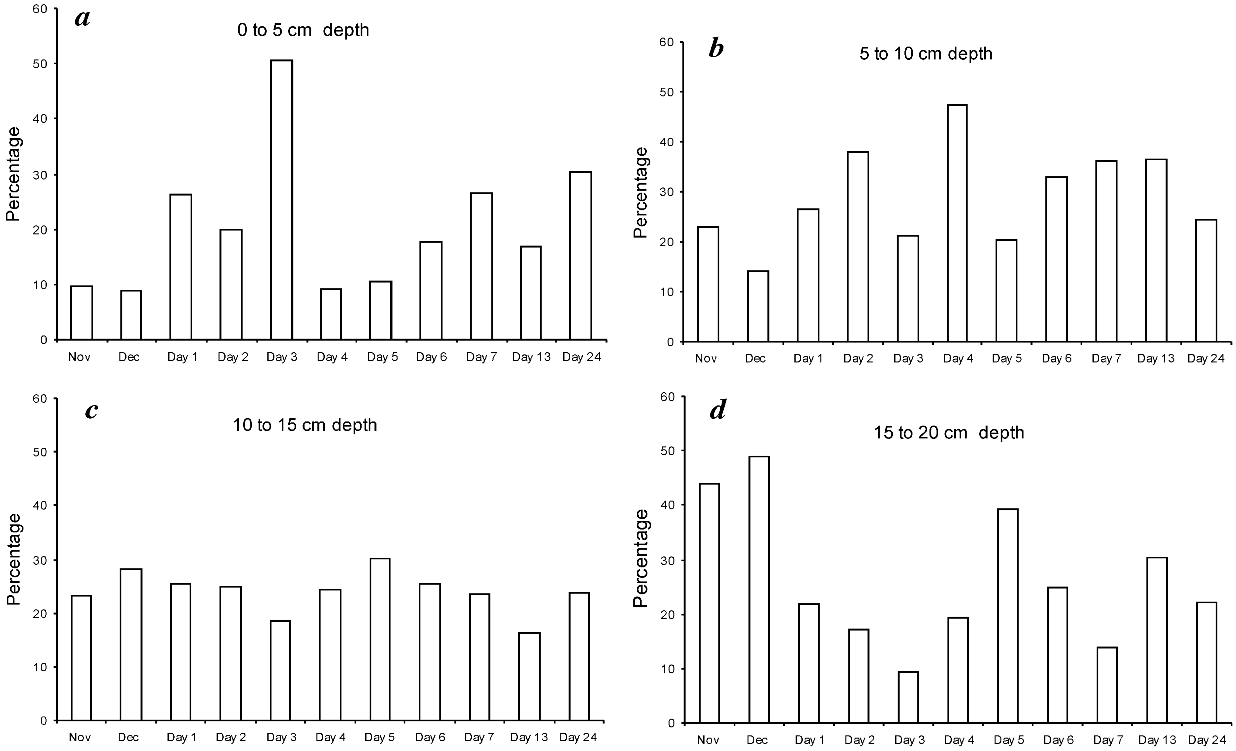

Figure 4. Vertical distribution of meiofauna at different depths (0 to 20 cm) prior to and after the tsunami.

Table 2. Meiofauna of Chennai coast after tsunami

Foraminiferans	*Elphidium* sp.
Cnidarians	*Halammohydra* sp.
	Psammohydra sp.
Turbellarians	*Otoplana* sp.
	Macrostomum sp.
Nemertines	
Nematodes	*Halalaimus setosus*
	Desmodora sp.
	Chromadora sp.
	Sabatieria sp.
	Steineria sp.
	Metapselionema sp.
Gastrotrichs	*Chaetonotus* sp.
	Thaumastoderma sp.
Rotifers	
Kinorhynchs	*Cateria* sp.
Polychaetes	*Hesionides* sp.
Archiannelids	*Polygordius madrasensis*
	Saccocirrus minor
Oligochaetes	*Marionina* sp.
Harpacticiod copepods	*Arenosetella indica*
	Psammastacus acuticaudatus
	Leptastacus euryhalinus
	Emertonia minuta
	Sewellina reductus
Ostracods	*Polycope* sp.
Isopods	*Angeliera phreaticola*
Halacarids	*Halacarus* sp.
Insects	
Miscellaneous	

for the abundance of meiofauna on the Indian coast[18]; occurrence of such a favourable grain composition as well as other physico-chemical parameters might have favoured recolonization of meiofauna at a very high density, as evidenced on the third day after the tsunami. The present results suggest that there is a quick response to the physical disturbance by meiofauna as well as recolonization to a higher density, when favourable conditions prevail. Favourable granulometric conditions prevailed on the third and fourth day after the tsunami, and the higher density of meiofauna coincided with it. Five days after the tsunami, the sand grain was restored to normal composition at the Marina, leading to normal density of meiofauna. Seven, 13 and 24 days after the tsunami, meiofaunal composition, physico-chemical parameters as well as sand grain composition were restored to the typical beach values. Thus the duration taken for recolonization of depleted meiofauna is about a week.

Due to the impact of the tsunami, oligochaetes, nematodes and harpacticoids showed reduced populations, while polychaetes and turbellarians occurred at higher density (Figure 3), suggesting that these groups can withstand the impact of disturbance better than the other groups. While studying meiofauna during deep-sea disturbance in the Indian Ocean, Ingole *et al.*[21] also reported a decrease in the density of copepods and nematodes resulting from their mortality or migration to undisturbed areas. In the recolonization process, most of the major groups of meiofauna as well as other groups (foraminiferans, cnidarians, nemertines, gastrotrichs, rotifers, kinorhynchs, ostracods, isopods, halacarids, insects and miscellaneous) showed high response, as evidenced by their higher number on the third and fourth day after the tsunami. Compared to the pre-disturbance period, with the exception of turbellarians, all other groups showed variation in their vertical distribution (Figure 4). Even those species, which were earlier reported[16] to occupy 10–15 cm depth, have now occupied the upper layers mostly due to the favourable sand grain and interstices produced by the impact of the tsunami.

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Phylogeography and origin of Indian domestic cattle

Cattle had played a pivotal role in the upliftment of human culture and civilization. Besides being used mainly as a beast of burden and ceremonial animal in prehistoric and historic time, cattle were also used as a rich source of protein and fat. The present-day domestic cattle are broadly classified into two groups: zebu (humped) and taurine (humpless), which are scientifically referred as *Bos indicus* and *Bos taurus* respectively. A clear dichotomy has been described for zebu and taurine mitochondrial DNA (mtDNA)[1,2]. This dichotomy can only be explained by the presence of two subspecies of wild aurochs before domestication. The Indian subcontinent harbours a variety of cattle. There are evidences that the ~5000 yr old ancient Indus civilization had made marked progress in the field of animal husbandry[3]. Besides many non-descript breeds, there are 30 well-recognized cattle breeds in India[4]. Majority of these breeds are low producers of milk; hence they are primarily used for the production of castrated bulls, which are used in agriculture, carting and transport. Previous studies on Indian cattle have proved independent domestication centre for Indian zebu. No attempt has been made to measure the time depth for this important event. In view of the above data, we attempted to undertake a pilot study using long-range mtDNA marker to obtain vital insights into the domestication of zebu cattle.

Fresh blood samples from 25 local cattle were collected from three geographical regions (Figure 1). The local cattle fall under the non-descript category is considered as the founder population for the breed[5]. According to the information provided by farmers, precaution was taken to collect samples from unrelated individuals from countryside villages. DNA was isolated from leucocytes by standard phenol chloroform extraction methods[6].

Using polymerase chain reaction, partial mtDNA D-loop regions were amplified. Primers were designed to amplify a 375-bp fragment from the hypervariable region 1 (HVR-1), AN4-bio (L15960; 5′-GGTA-ATGTACATAACATTAATG-3′) and AN3 (H16334; 5′-CGAGATGTCTTATTTA-AGAGG-3′). Primer AN4-bio was biotinylated for subsequent product purification. Reactions were performed using 10 ng of template mtDNA in a 50 μl reaction volume, 2.5 units of *Taq* DNA polymerase, 10X reaction buffer (50 mM KCl; 10 mM Tris-HCl pH 9.0; 1% Triton X-100, 1.5 mM$MgCl_2$), with concentrations of 200 mM for each dNTP and 2 ng μl^{-1} of both the forward and reverse primers. Before amplification a 20 μl oil overlay was added to each sample. Amplification was done using a 4 min denaturation step followed by 40 cycles of 40 s at 94°C, 40 s at 55°C, 40 s at 72°C and a final extension at 72°C for 4 min. Reaction products were purified using Dynabeads (DYNAL), according to the manufacturer's instructions. Sequencing of a 240-bp fragment (16023–16262) for both strands was performed using the dideoxy chain termination method. The sequences were deposited in GenBank (accession no. AY972130-AY972154).

Using Clustal X[7], 240-bp sequences were aligned with Anderson reference sequence[8]. These 25 sequences were analysed in conjunction with previously published sequences of cattle from North and South India[1,9] (Table 1). In order to broaden the study, published sequences

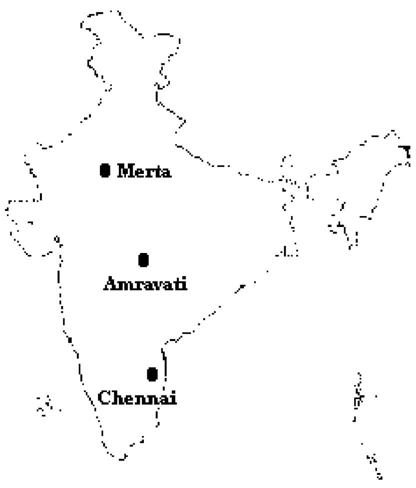

Figure 1. Map of India showing sampling locations.