Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2014 | 6(2): 5485–5491

ISSN
Online 0974–7907
Print 0974–7893

OPEN ACCESS

Short Communication

Mangrove sediment core analysis of foraminiferal assemblages - a study at two sites along the western coast of India

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Abstract: Mangroves are an unique habitat and are largely influenced by sea level changes and wave energy. Foraminifera (Protista) preserved in mangrove sediments provide an excellent proxy for deducing past conditions. One meter deep mangrove core samples at two sites on the western coast of India were collected. The foraminiferal assemblages at various depths showed significant changes in the abundance and diversity down the cores. A total of 59 species belonging to 32 genera, 24 families and five suborders were identified from the cores of these two sites. The cores showed an abundance of genus *Rotalidium* particularly the species *Rotalidium annectans*. Other species identified include *Ammonia, Elphidium, Nonion, Spiroloculina, Quinqueloculina, Globigerinoides* etc. The pH, organic matter and $CaCO_3$ also showed variations down the cores. There was a lack of correlation between sediment characteristics and the abundance of foraminifera in the cores. The low diversity and differences in distribution of foraminifera compared to surface intertidal samples may be due to intense post depositional changes or anthropogenic disturbances. The mangrove ecology thus appears disturbed by various factors.

Keywords: Diversity, ecology, Foraminifera, mangroves, sediment cores, western coast.

Mangroves are specialized ecosystems consisting of diverse groups of tropical trees and shrubs adapted to grow in intertidal regions. The ecological and economical importance of this most productive and diverse ecosystem are well explored (Blasco et al. 1996; Oakes et al. 2010). Mangroves efficiently trap sediments and the sedimentation process is influenced by various factors like sediment supply, hydrodynamics of the area, geochemical parameters etc. (Alongi 2008; Sanders 2012). The high rates of accretion make the mangrove sediments useful in palaeoclimatic studies (Kumaran et al. 2004). These sediments show presence of many organisms including Foraminifera which are unicellular protists (Lezine et al. 2002). They typically produce a test, or shell, made up of calcium carbonate or agglutinated sediment particles which are well preserved following their death. The evolutionary significance of Foraminifera and the exceptional quality of fossil records make them an excellent proxy for inferring past climatic conditions (Nigam 2005; Murray 2006). Studies around the world have shown that the shell deposits of Foraminifera in the sediments of mangroves help in palaeoclimatic reconstructions (Horton et al. 2003; Gehrels & Newman 2004; Woodroffe et al. 2005).

The diversity and distribution of foraminiferal assemblages in mangrove sediments are controlled by environmental factors (Bradshaw 1968; Murray 2001), post depositional changes (White & Walker 2011) and anthropogenic activities (Sarkar & Bhattacharya 2010). The present study was designed to understand the diversity and distribution of foraminiferal assemblages in down core mangrove sediments collected from two

DOI: http://dx.doi.org/10.11609/JoTT.o3653.5485-91 | **ZooBank:** urn:lsid:zoobank.org:pub:85FF3200-300A-4113-B815-1EC61E93A1D9

Editor: R. Ramanibai, University of Madras, Chennai, India. **Date of publication:** 26 February 2014 (online & print)

Manuscript details: Ms # o3653 | Received 04 June 2013 | Final received 07 October 2013 | Finally accepted 11 February 2014

Citation: Vidya, P. & R.K. Patil (2014). Mangrove sediment core analysis of foraminiferal assemblages - a study at two sites along the western coast of India. *Journal of Threatened Taxa* 6(2): 5485–5491; http://dx.doi.org/10.11609/JoTT.o3653.5485-91

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Funding: UGC- Special Assistance Programme (SAP).

Competing Interest: The authors declare no competing interests.

Acknowledgements: The present study was supported by UGC SAP funds. The Research Fellowship to Vidya P., through an UGC-SAP grant is gratefully acknowledged. We would like to thank people who assisted in the field during the collection of sediment cores.

areas in the western coast of India.

Materials and Methods

Mangroves of Chithrapu (13^{0}04'34"N & 74^{0}46'49''E), Karnataka and Kumbla (12^{0}35'41''N & 74^{0}56'19"E), Kerala along the western coast of India were selected for the present study (Image. 1). The main species of mangroves present in these areas were *Sonneratia alba, Rhizophora mucronata, Avicennia officinalis, Bruguiera zymnorhiza, Acanthus ilicifolius* along with some associated species. Parallel sediment cores of about 1m depth were collected from each of these mangroves during periods of low tide (Image. 2). The areas cored were not much disturbed by anthropogenic activities and were minimally infused with fresh water. The cores were transported to lab, cut and sub-sampled at every inch (2.5cm intervals). The sediment samples for foraminiferal assemblage study were oven dried at 60^{0}C. The foraminiferal tests in the cores were easily susceptible to breakage and dissolution due to the long time deposition. Hence, chemical treatments were avoided and samples were repeatedly washed through 63µm sieve under low water pressure. The sand fractions were collected over whatman filter paper and oven dried at 60^{0}C. 5–10 g of dried sediment samples were used for foraminiferal assemblage studies and all the results were finally represented as per gram weight of sediment samples. Foraminiferal tests were examined, picked on to micropalaeontological slides and identified with the help of a stereo microscope. The species were identified according to Loeblich & Tappan (1987). Biodiversity indices were calculated by using Past software version 2.17 b.pH of the sediment samples down the core were measured in supernatant suspension of a 1:5 soil liquid mixture potentiometrically using pH meter (Trivedi & Goel 1986). Modified Walkley Black method (Trivedi & Goel 1986) was used for calculating the percentage organic matter present in the sediment samples down the core. An estimation of calcium carbonate was done by acid soluble weight loss method (Campillo et al. 1992) and the percentage was calculated.

Results and Discussion

Image 1. Google Earth images showing the site of collection of mangrove sediment cores

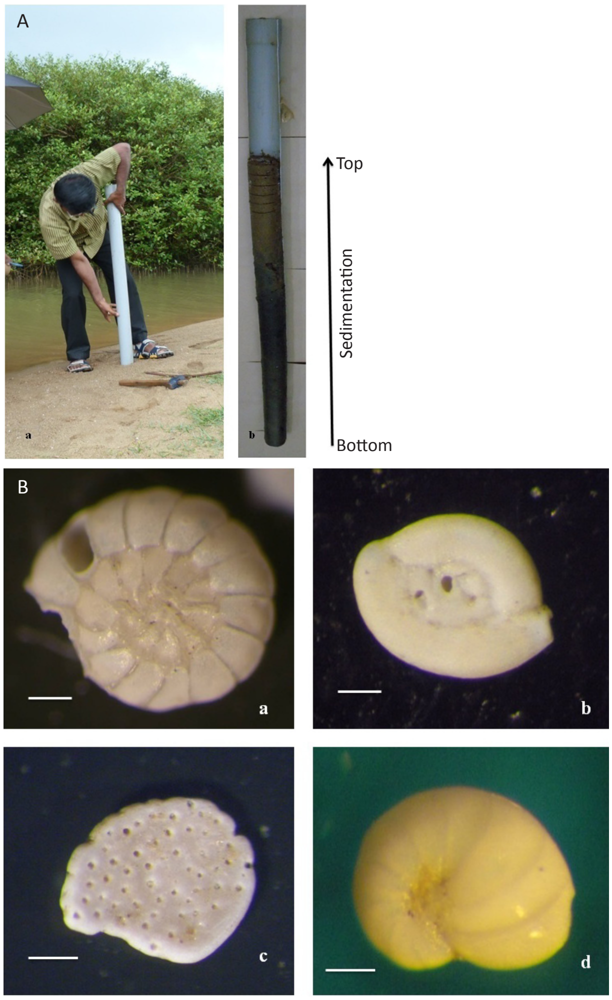


Image 2. A - (a) Collection of mangrove sediment cores (b) Image of a sediment core showing the pattern of sedimentation; B - Stereo microscopic images of some of the species of foraminifera found in sediment cores (a) *Rotalidium annectans* (b) *Spiroloculina depressa* (c) *Cibicides* sp.; (d) *Nonion incisum* (Scale bar: 500µm)

A total of 59 species belonging to 32 genera, 24 families and five suborders were identified collectively from mangrove cores of Chithrapu and Kumbla (Table 1). Chithrapu cores showed the presence of 55 species of Foraminifera belonging to all the 32 genera 24 families and five suborders while in Kumbla cores there were 33 species of 20 genera 12 families and three suborders (Fig. 1). The cores of both the sites showed abundance of *Rotalidium* species mainly *Rotalidium annectans* which are the abundant species found in the western coast of India (Nigam & Chathurvedi 2000; Gadi & Rajashekhar 2009). 77% and 72% of the foraminiferal tests in Chithrapu and Kumbla cores respectively were that of *Rotalidium annectans*. *Ammonia beccarii* was the next abundant species (11% in Chithrapu and 9% in Kumbla) while most of the other species were found in fewer numbers. The occurrence of many species like *Pseudononion japanicum, Donsissonia florae, Hastigerinella riedieli* etc., were restricted to a single test per gram of sediment in the cores. The most predominant suborder in the cores studied here were Rotalina followed by Miliolina, Globigerinina, Textularrina and Legenina. The foraminiferal diversity and distribution (Shannon (H'), Evenness (J')) was low in both Chithrapu cores (H'=1.056, J'=0.2634) and Kumbla cores (H'=1.205, J'=0.3445) (Table 2). There

Table 1. List of species of Foraminifera found in sediment cores of Chithrapu and Kumbla

	Species	Chithrapu	Kumbla
1	*Rotalidium annectans* (Parker & Jones, 1865)	+	+
2	*Rotallinoides papppilosus* (Brady, 1884)	+	+
3	*Asterorotalia dentata* (Parker & Jones, 1865)	+	+
4	*Pararotalia calcar* (d'Orbigny, 1826)	+	+
5	*Porosorotalia* sp. (Voloshinova, 1958)	+	+
6	*Ammonia beccarii* (Linne, 1758)	+	+
7	*Ammonia dentata* (Parker & Jones, 1865)	+	+
8	*Ammonia tepida* (Cushman, 1924)	+	+
9	*Asteroammonia* sp. (Voloshinova, 1970)	+	+
10	*Elphidium craticulatum* (Fitchel & Moll, 1798)	+	-
11	*Elphidium crispum* (Linne, 1758)	+	-
12	*Elphidium discoidale* (d'Orbigny, 1826)	+	+
13	*Elphidium discoidale multioculatum* (Cushman & Ellisor, 1945)	+	+
14	*Elphidium indicum* (Cushman, 1936)	-	+
15	*Elphidium poeyanum* (d'Orbigny, 1826)	+	+
16	*Elphidium simplex* (Cushman, 1931)	+	+
17	*Nautilus macellus* (Fitchel & Moll, 1798)	+	-
18	*Nonionina heteropora* (Egger, 1857)	+	+
19	*Nonion asterizens* (Fitchel & Moll, 1798)	+	+
20	*Nonion elongatum* (d'Orbigny, 1846)	+	+
21	*Nonion gratulopi* (d'Orbigny, 1826)	+	-
22	*Nonion incisum* (Cushman, 1926)	+	+
23	*Nonion scaphum* (Fitchel & Moll, 1798)	+	+
24	*Nonionella parri* (Cushman, 1936)	+	+
25	*Nonionella stella* (Cushman & Edwards, 1937)	+	+
26	*Pseudononion japanicum* (Asano, 1936)	+	-
27	*Bolovina striatula* (Cushman, 1911)	+	+
28	*Cibicides* sp. (de Montfort, 1808)	+	+
29	*Discorbis rimosa* (Parker & Jones, 1862)	+	-
30	*Discorbites vesicularis* (Lamarck, 1804)	+	+
31	*Donsissonia florae* (Mc Culloh, 1977)	+	-
32	*Gyrodina neosoldanii* (Brotzen, 1942)	+	-
33	*Heterolepa simplex* (Frenzenau, 1884)	+	-
34	*Nautilus balthicus* (Schröter, 1783)	+	+
35	*Quasirotalia* sp. (Hanzawa, 1967)	+	+
36	*Rosalina brady* (Cushman, 1948)	+	+
37	*Rotamorphina cushmani* (Finlay, 1939)	+	-
38	*Globigerina bulloides* (d'Orbigny, 1826)	+	+
39	*Globigerinoides ruber* (d'Orbigny, 1839)	+	+
40	*Globamalina ovalis* (Haques, 1956)	+	-
41	*Globorotalia multioculata* (Morrow, 1934)	+	-
42	*Hastigerinella riedeli* (Rögl and Bolli, 1973)	+	-
43	*Duplella apexadina* (Patterson & Richardson, 1987)	+	-
44	*Fissurina laevigata* (Reuss, 1850)	+	-
45	*Paravulvulina* sp. (Ciche & Zapletalova, 1965)	+	-
46	*Trochamina inflata* (Montagu, 1808)	+	-
47	*Sorites* sp. (Ehrenberg, 1839)	+	-
48	*Spiroloculina aequa* (Cushman, 1917)	+	-
49	*Spiroloculina communis* (Cushman & Todd, 1927)	+	-
50	*Spiroloculina depressa* (d'Orbigny, 1826)	+	+
51	*Spiroloculina excavata* (d'Orbigny, 1826)	+	-
52	*Spiroloculina nobilis* (Reuss, 1850)	+	-
53	*Spiroloculina orbis* (Cushman, 1917)	+	-
54	*Quinqueloculina ludwigi* (Reuss, 1850)	+	-
55	*Quinqueloculina laevigata* (d'Orbigny, 1846)	-	+
56	*Quinqueloculina seminulum* (Linne, 1759)		-
57	*Triloculina insignis* (Brady, 1879)	-	+
58	*Triloculina terquimiana* (Brady, 1879)	-	+
59	*Triloculina trigonula* (Lamarck, 1804)		-

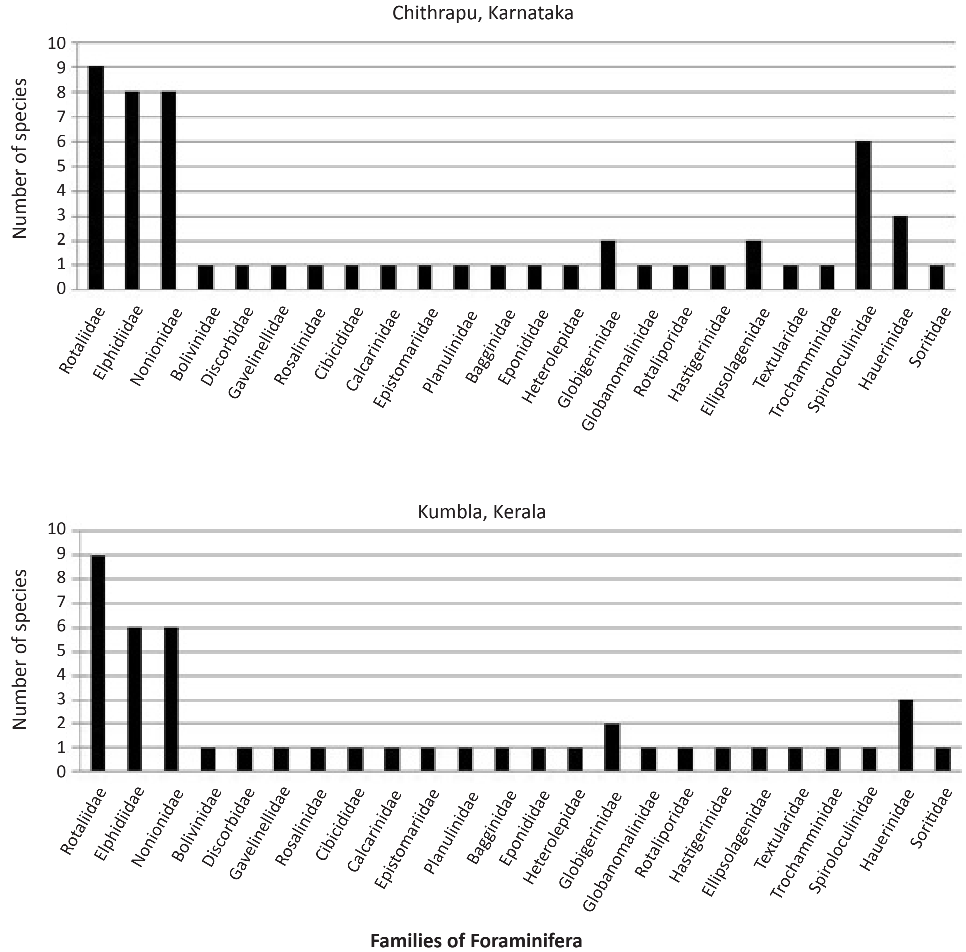


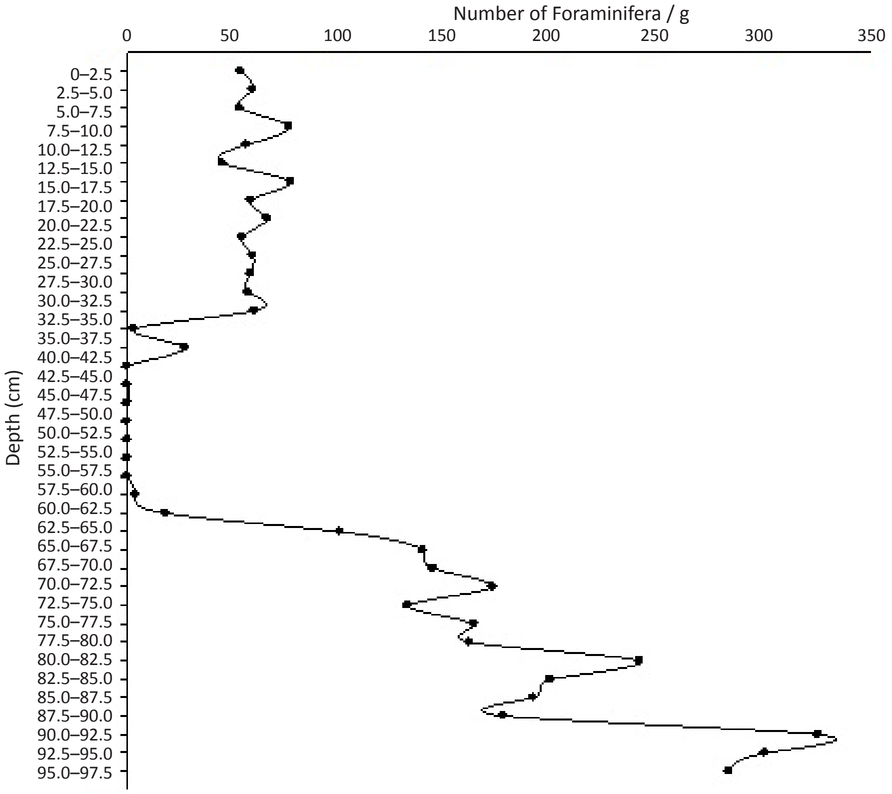
Figure 1. Graph showing the distribution of families of Foraminifera in sediment cores

were considerably wide variations in the diversity and distribution of tests at every depth down the core. The comparatively lower diversity in mangrove cores might be due to the poor preservation of tests in the deposited sediments which resulted in the loss or change in the relative abundance of particular species, or a loss in species diversity (Smith 1987). The distribution of the tests in the down core samples could have been affected by the dominance of some particular species which could resist the post depositional and other destructive changes (Hayward et al. 2004; Husain et al. 2007). Both the cores showed a complete absence of foraminiferal tests at some continuous depths (40–57.5 cm depth in Chithrapu, 90–97.5 cm depth in Kumbla), which might be indications of past climatic changes such as sea level regression, increased atmospheric CO_2 etc or due to post depositional taphonomic changes etc. (Fig. 2).

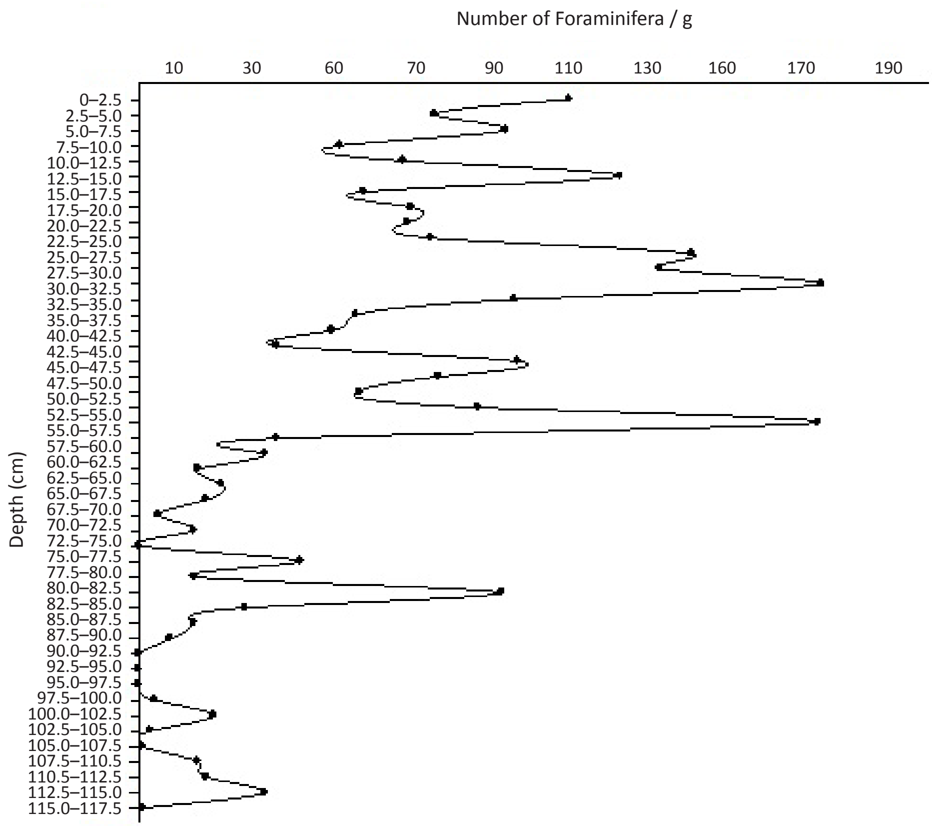
The pH, organic matter (%) and $CaCO_3$ (%) down the cores varied from 7.3–8.6, 0.1–2.7 %, 2–13 % respectively in Chithrapu cores and 7.7–8.0, 0.2–3.5 %, 1–14 % respectively in Kumbla cores (Fig. 3). Hydrogen ion concentration (pH) significantly affects the existence of foraminiferal tests. Lower pH (<7.0) accompanied by lower temperatures can cause dissolution of calcium carbonate in sediments (Bradshaw 1968). In Chithrapu cores, the calcium carbonate showed a slightly decreasing trend towards depth while there was a slight increase in bottom segments. According to Sundararajan & Srinivasalu (2010), high sedimentation might be the reason for the high value of calcium carbonate in the

Table 2. Diversity attributes of Foraminifera in sediment cores

Attributes	Chithrapu cores	Kumbla cores
Foraminiferal Number/g	3577	2362
Species Richness/g	55	33
Shannon Diversity (H’)	1.056	1.205
Simpson’s Dominance	0.392	0.474
Evenness (J’)	0.263	0.345



Chithrapu cores



Kumbla cores

Figure 2. Down core depth profile of abundance of Foraminifera in sediment cores

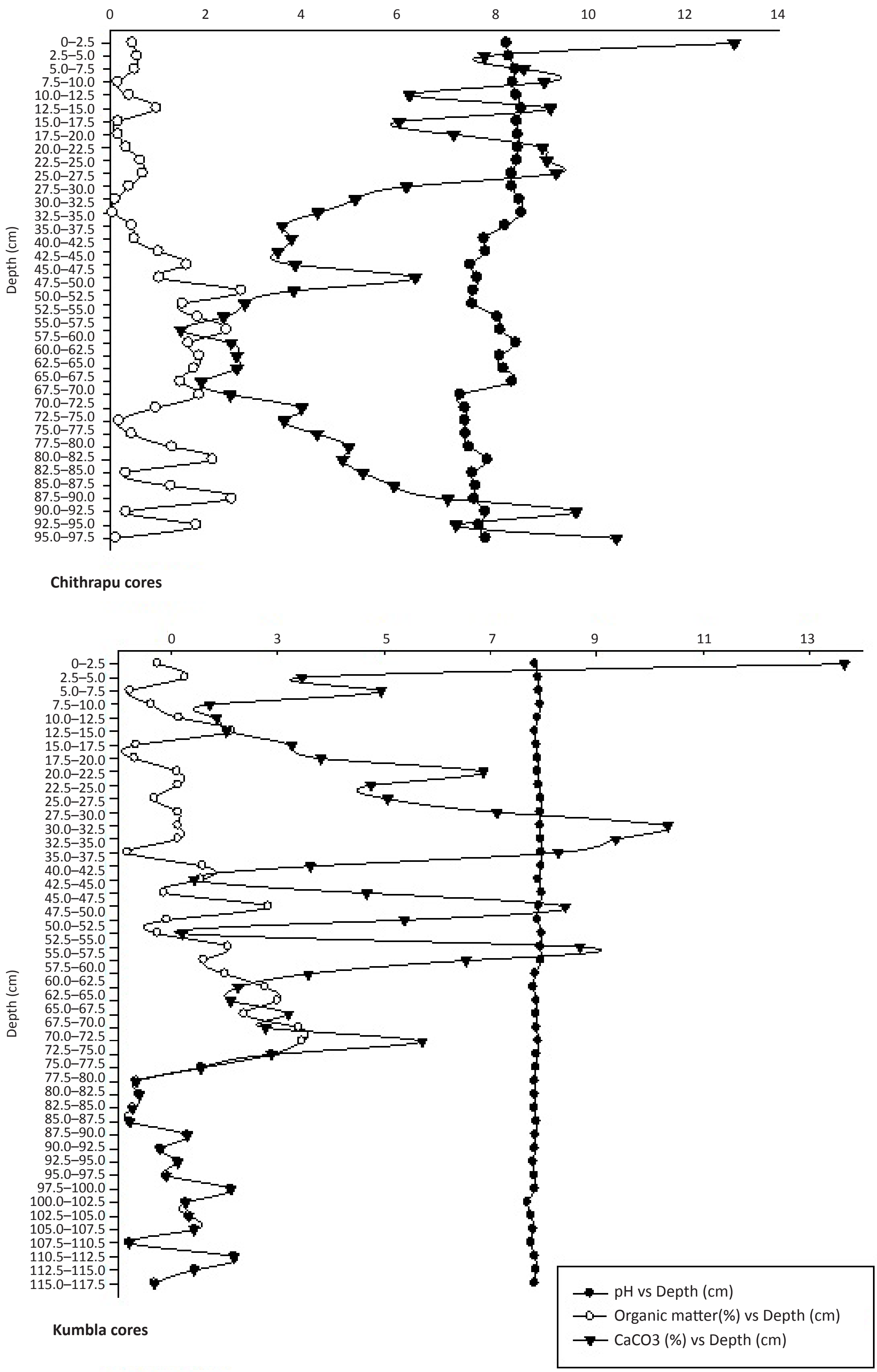


Figure 3. Down core depth profile of pH, organic matter and calcium carbonate in sediment cores

bottom segments and active detritus dilution might have caused the lower concentration in the middle depths. The lower values of organic matter at certain depths could be due to higher decomposition rates. Studies have shown that surface sediments from intertidal zones show a significant correlation between these sediment characteristics and the abundance of Foraminifera (Gadi & Rajashekhar 2007; Gandhi et al. 2007). But in core samples especially those from mangroves, such correlations may not be found due to the interference of many other factors (Sanders et al. 2010; Sundararajan & Srinivasalu 2010). In the present study also, such correlations between sediment characteristics and foraminiferal assemblages were not significant. This may be due to intense post depositional changes including post-mortem taphonomical changes (Berkeley et al. 2007) or the past environmental conditions which the mangroves experienced (Ellison & Zouh 2012). In addition to this, anthropogenic activities can also disturb the post-sedimentation process and alter the physico-chemical and biotic components of core samples to a greater extent (Qiu et al. 2011; Lezine et al. 2002).

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