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Characterization of the Caravelas River Estuary (Bahia) from a Temporal Distributional Analysis of the Foraminifera Microfauna

Caracterização do Estuário do Rio Caravelas (Bahia) a partir de Análises de Distribuição Temporal da Microfauna de Foraminíferos

Altair de Jesus Machado & Helisângela Acris Borges de Araújo

Universidade Federal da Bahia, Instituto de Geociências, Grupo de Estudo de Foraminíferos.
Rua Caetano Moura, 123, 40210-340, Salvador, Bahia, Brazil
E-mails: altair@ufba.br; hacris@gmail.com
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Abstract

The objective of this study was to evaluate the temporal distribution of the foraminifera microfauna of the Caravelas River estuary (Bahia) to determine the different stages of marine influence on this ecosystem. For this purpose, two core samples 60 cm in length were collected at different sites in the estuary. In the laboratory, subsamples were taken from the sediment columns every 2 cm. The samples were subjected to standard analysis for foraminifera. We collected, stored, and identified the first 100 samples to determine the fauna diversity. The data analysis involved calculation of relative abundances, occurrence frequencies, diversity indices, richness, dominance, and confinement. The integrated analysis of the richness and diversity indices for the TCV1A core indicated that the oscillations between the highest and lowest marine influences were not representative to the point of promoting marked events of enrichment and depletion of the fauna at this sampling site. In contrast, analysis of the TCV2A core showed a restricted marine influence during the deposition period of this sediment column, especially since the 1980s. This hypothesis can be confirmed by the richness and diversity values, which show signs of faunal impoverishment in different sections of this core.
Keywords: Bahia; Caravelas River Estuary; Foraminifera; Confinement Index

Resumo

O objetivo do presente estudo foi avaliar a distribuição temporal da microfauna de foraminíferos do estuário do Rio Caravelas (Bahia), para determinar diferentes estágios de influência marinha sobre este ecossistema. Foram analisadas amostras provenientes de dois testemunhos (TCV1A e TCV2A) de 60 cm de comprimento, coletados em pontos distintos do estuário. Em laboratório foram realizadas subamostragens a cada 2 cm, cujo sedimento foi submetido ao processo padrão para análise de framiníferos. De cada amostra foram triadas, armazenadas e identificadas as 100 primeiras testas de foraminíferos para determinação da diversidade da fauna. A análise dos dados envolveu o cálculo da abundância relativa, frequência de ocorrência, índices de diversidade, riqueza, dominância e confinamento. Considerando a análise integrada dos índices de riqueza e diversidade para o testemunho TCV1A, observou-se que as oscilações entre períodos de menor e maior influência marinha não foram representativas ao ponto de promoverem marcantes eventos de enriquecimento ou empobrecimento faunístico neste ponto de amostragem. Entretanto, a análise do testemunho TCV2A revelou, no seu ponto de amostragem, uma condição restrita de influência marinha ao logo do período de deposição desta coluna sedimentar, sobretudo a partir da década de 80. Essa hipótese pôde ser confirmada através dos valores de riqueza e diversidade, que mostram sinais de empobrecimento faunístico em diferentes trechos deste testemunho.
Palavras-chave: Bahia; Estuário do Rio Caravelas; Foraminíferos; Índice de Confinamento

1 Introduction

Paralic ecosystems (estuaries, estuarine ponds systems, open or closed lagoons, marine plains, delta regions, and mangrove ecosystems) intrinsically lead to stress for organisms because they constitute transitional environments subjected to constant fluctuations in their chemical and physical properties. In these areas, the effects of tides generate salinity, pH, and nutrient gradients that change spatially and temporally, which, in turn, alter the conditions of the environment. In the face of strong environmental heterogeneity, only organisms with adequate morphological and physiological adaptations can survive and reproduce in these areas (Bonetti, 1995). This explains the reduced number of species that generally inhabit these environments, compared with marine areas.

Among the organisms associated with estuarine environments, certain species of benthic foraminifera, generally euryhaline and eurythermic species seem well adapted to the instability of these systems. However, as salinity decreases from euhaline conditions (normal marine salinity), the diversity of foraminifera decreases, which is the main factor responsible for the distribution patterns of this group in estuarine systems, as demonstrated by several studies (Barbosa & Suguio, 1999; Debenay *et al*., 2000; Duleba & Debenay, 2003). In addition to salinity, factors such as turbidity, organic carbon, and the concentration of oxygen also influence the presence of endemic species in estuarine zones (Laut *et al.*, 2003). It is possible to define typical associations for each confinement level in an estuarine system according to the response of foraminifera species to changes in these factors. A characteristic pattern in foraminifera associations is a transition from agglutinated to calcareous forms toward the sea. Generally, forms with agglutinated walls dominate in estuarine environments, with few representatives of the Miliolida order and, in general, no members of the Rotaliida order being observed. The reduction or absence of calcareous species in paralic regions is associated with the low availability of calcium carbonate and low pH values in the water in these areas (Boltovskoy & Wright, 1976). The few calcareous species that inhabit these ecosystems exhibit thinner and more flattened shells than their ecophenotypes in adjacent coastal areas that are subjected to normal salinity (Boltovskoy *et al*., 1991).

Given the relationship maintained by foraminifera with the abiotic factors present in coastal environments, it has been possible to use these species to obtain information about estuarine systems. In this regard, numerous studies have demonstrated that this group responds efficiently to changes in the properties of water masses (Nichols, 1974), circulation patterns (Scott *et al.,* 1977), and the level of water stratification (Debenay *et al*., 1997).

In general, studies on distributional patterns in current foraminifera associations, when integrated with morphological and taphonomic data on their shells, allow a better understanding of the sediment dynamics in various types of environments, including paralic ecosystems, supporting the use of foraminiferal group in environmental and paleoenvironmental reconstruction studies.

In the Brazilian estuarine regions, foraminifera have mostly been used in environmental diagnostic studies of the hydrodynamics of paralic ecosystems (Debenay *et al.*, 2001; Eichler *et al*., 2001; Duleba & Debenay, 2003) and establish the ecological zonation of estuaries and lagoons with different degrees of salinity influences (Closs, 1964; Dias-Britto *et al.*, 1998; Barbosa, 1995; Eichler & Bonetti, 1995; Duleba *et al.*, 1999; Rodrigues *et al*., 2003).

The objective of this study was to characterize the benthic foraminifera microfauna and evaluate its temporal distribution along the Rio Caravelas estuary, in south Bahia, to determine the different stages of marine influence in this ecosystem.

2 Study Area

The Caravelas River estuary (17º43'S; 39º15'W) is located in the south coast of the state of Bahia, extends toward the continent, where it forms the second most complex mangrove system of the Brazilian northeastern region, with an area of 66 km^2 (Herz, 1991) (Figure 1). This estuary is associated with the mouth of the Peruípe River through small meandering channels and presents an entrance bar of approximately 2 km long.

The Cassumba Island that is located south of the Caravelas River, separates the internal estuary from the open sea up to the nearby city of Nova-Viçosa, comprising a coastal stretch with an extension of approximately 35 km (Figure 1). This region is characterized by an open coast protected by sand banks and coral reefs (Herz, 1991).

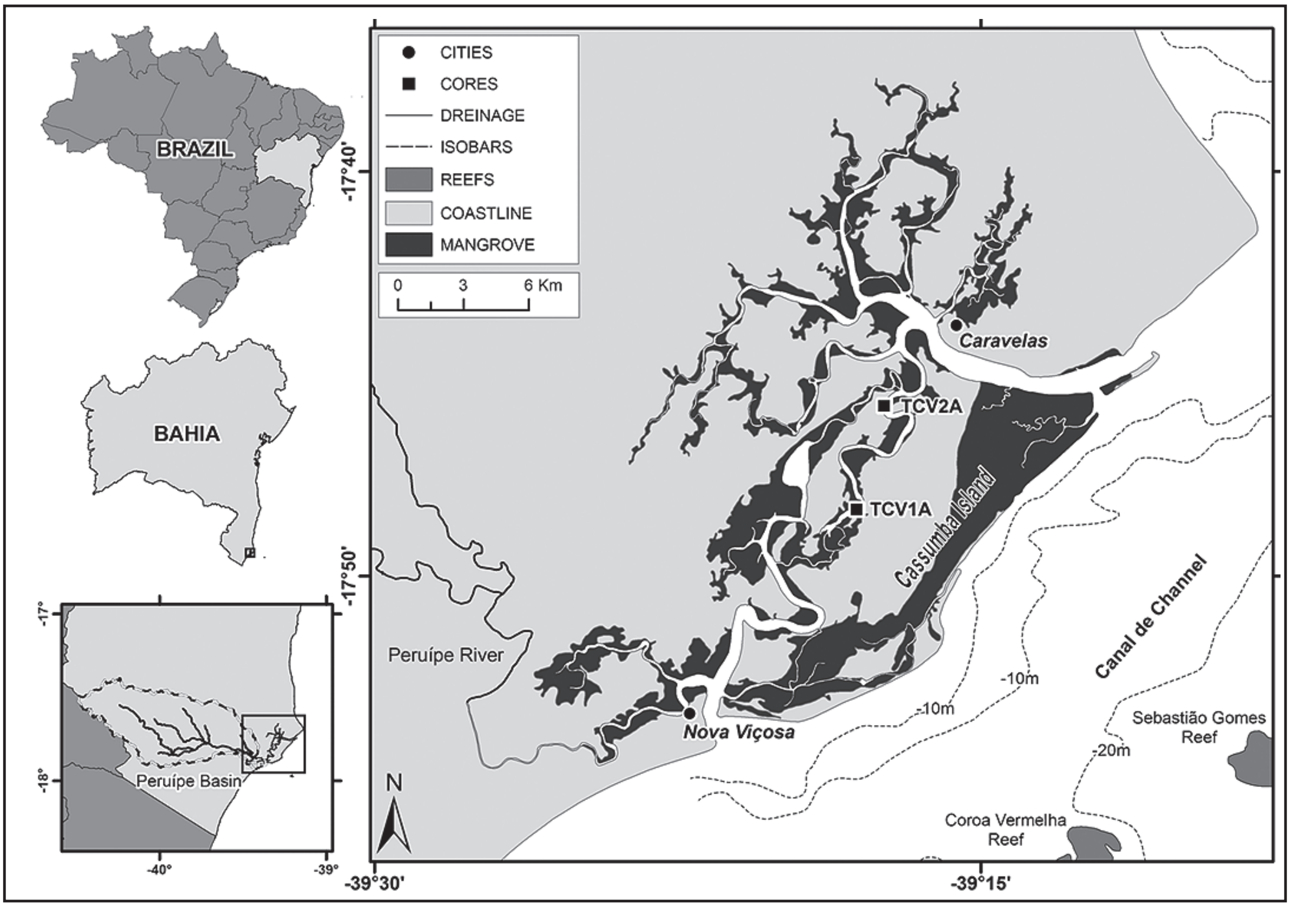

Figure 1 Map showing the location of the study area.

With respect to its geographical location, the study area is located under the Köpen's Humid Tropical Type AF climatic regime, (SEI, 1998), with mean air temperature oscillating between 28ºC and 30ºC during summer and between 20ºC and 22ºC during winter time. The mean annual precipitation is 1,750 mm, being March, April and May the rainiest months, when approximately 37% of the total annual precipitation occurs.

3 Materials and Methods

Two cores were used in this study (TCV1A and TCV2A), which were collected and provided by Prof. Ruy Kikuchi's team from the Federal University of Bahia, Brazil. They are located in two points along the Caravelas River estuary. Collection of these cores was conducted in April 2002 and April 2003, and the procedure involved a PVC tube (60 cm length and 6 cm diameter) enclosed in a gauntlet and adapted to collect unconsolidated sediment. The cores were collected by manual drilling through the sediment in the estuarine region performed by scuba divers.

Immediately after collection, the cores were frozen and kept in this condition until they were opened for description and selection of samples. During the opening of the cores, the sediment package was described based on its color and texture. Color determination was performed through comparison with a standard color guide (Goddard *et al.*, 1963). Then, subsamples were collected every 1 cm for analysis of sedimentological parameters and every 2 cm (2-3 grams of sediment) for investigation of the foraminifera specimens. A total of 29 samples from TV1A and 25 samples from TCV2A were obtained.

The samples destined for the analysis of foraminifera microfauna were washed in running water through a 0.062-mm sieve to eliminate salts, silt, and clay from the samples without losing a significant portion of the young population (Schröder *et al.*, 1987). The sediment retained in the 0.062-mm sieve was then placed in beakers and dried in an oven at 50 °C. Subsequently, the samples were placed in plastic bags previously labeled with origin data.

To determine faunal diversity, the first 100 specimens of foraminifera were retrieved and stored on Frank's slides and then identified using a stereomicroscope following specialized references. According to Patterson & Fishbein (1989) the minimum accounting for 100 individuals per sample is enough to reflect the greatest differences in relative abundance of species. Fatela & Taborba (2002) describe that the screening of 100 foraminifera per sample is statistically reliable. The systematic generic classification of the species was based on Loeblich & Tappan (1988), taking into consideration the taxonomic updates presented by Sen Gupta (1999).

Analysis of data involved the following biological descriptors:

(1) Relative Abundance (RA) expresses the percent of individuals of a given species relative to the population, which was calculated using the formula RA = n x 100/T, where "n" represents the number of individuals of a determined species, and "T" indicates the total number of individuals identified in the sample. Based on the results of this analysis, the species were classified as Principal (RA above 5%), Accessory (RA between 4.9 and 1%) or Trace (RA below 1%);

(2) Occurrence Frequency (FO) represents a measure of the constancy of species and is expressed by the equation FO = p x 100/P, where "p" symbolizes the number of samples containing the species, and "P" indicates the total number of samples analyzed. The results for this parameter allowed the species to be grouped as Constant (present in more than 50% of the samples), Accessory (occurring in 25% to 49% of the samples) or Accidental (occurring in less than 25% of the samples);

(3) Shannon-Wiener (1963) Diversity Index (H'), expressed by the equation

$$H' = \sum_{I=1}^{s}(pi.\ \log_2 pi) \text{ where } pi = ni / N$$

which relates the total number of species (s); the probability that an individual belongs to the species i (pi); the number of individuals in the species i (ni); and the total number of individuals in the sample (N).

(4) Margalef's (1958) Species Richness Index (R) relates the total number of species present (S) and the total number of individuals (N) through the formula

$$R = (S- 1)/ \log N$$

(5) Dominance Index (D), expressed as

$$D = \sum \frac{ni\ (ni-1)}{N\ (N-1)}$$

where ni represents the number of individuals in species *i*, and *N* is the total number of individuals.

(6) Confinement Index (*Ic*) reflects the degree of marine influence on the environment through the formula (Debenay, 1990)

$$Ic = \{[(C/ B + C) – (A/ A + B)] / 2\} + 1$$

where *A* represents the sum of the relative frequencies of species typical of coastal marine environments, such as *Bolivina striatula* and *Pararotalia* sp.; *B* represents the sum of the relative frequencies of species found in marine environments that are moderately confined, such as *Ammonia tepida*, *Elphidium gunteri*, and *Quinqueloculina seminulum*; and C represents the sum of the relative frequencies of species typical associated with strongly confined environments, such as *Miliammina fusca, Trochammina inflata, Arenoparrella mexicana*, and *Ammotium cassis*. Environments with values of *Ic* between 0 and 0.4 are considered marine, between 0.4 and 0.7 are considered slightly restricted from marine influence, between 0.7 and 0.9 are considered restricted from marine influence, and between 0.9 and 1 are considered confined (Semensatto & Dias-Brito, 2000).

In this study, the following species were considered for each category:

- **A:** *Pararotalia sp.* and *Quinqueloculina sp3.*

- **B:** *Ammonia beccarii f. tepida, Bigenerina sp., Elphidium gunteri, Elphidium sagrum, Elphidium sp., Textularia earlandi*, and *T. gramen.*

- **C:** *Ammobaculites dilatatus, Ammotium salsum, Ammotium sp.*, *Arenoparrella mexicana*, *Haplophragmoides wilberti*, *Jadammina macrescens*, *Miliammina fusca*, *Trochammina inflata*, and *T. salsa.*

4 Results
4.1 TCV1A Core
4.1.1 Faunal Composition

In this core, sixteen species of benthic foraminifera belonging to twelve genera, seven families, five superfamilies, and four orders were identified (Table 1).

The most representative families were Trochamminidae and Lituolidae, with 990 and 657 specimens, respectively. The families Rotaliidae and Elphidiidae were also highly represented, with 398 and 252 specimens, respectively. The least representative groups were Textulariidae (155 specimens), Rzehakinidae (147 specimens), and Haplophragmoididae (70 specimens). The representation of the identified genera in the TCV1A core revealed that agglutinated forms were more abundant (Textularia, Bigenerina, Jadammina, Arenoparrella, Trochammina, Ammotium, Ammobaculites, Haplopragmoides, and Miliammina) than calcareous forms (*Elphidium*, *Ammonia*, and *Pararotalia*) (Figure 2).

4.1.2 *Abundance* and Frequency of Occurrence

The data for the relative abundances and occurrence frequencies of the species are presented in Table 2 and show that the most abundant species were *Trochammina inflata* (representing more than 20.3% of the identified individuals) and *Ammotium salsum* (19.2%), followed by *Ammonia beccarii f. tepida* (12.5%) and *Arenoparrella mexicana* (10.1%). The other species represented less than 10% of the identified individuals.

According to the classification system defined by Dajoz (1983), the tafocenosis of the TCV1A core presented 37.5% (six species) principal species, 56.2% (nine species) accessory species, and 6.2% (one species) trace species.

The species *Trochammina inflata* (20.3%), *Ammotium salsum* (19.2%), *Ammonia beccarii f. tepida* (12,5%), *Arenoparrella mexicana* (10.1%), *Elphidium gunteri* (7.3%), and *Miliammina fusca* (5.1%) were considered principal species, with abundances above 5% in the column sediment, whereas *Textularia gramen* (2.8%), *Jadammina macrescens* (2.6%), *Haplophragmoides wilberti* (2.4%), *Textularia earlandi* (2.1%), *Ammobaculites dilatatus* (2,0%), *Ammotium sp.* (1.5%), *Elphidium sp.* (1.4%), *Pararotalia sp.* (1.2%), and *Trochamminita salsa* (1.2%) represented the group of accessory species, with abundances between 4.9% and 1%. Additionally, according to these classification criteria, *Bigenerina sp2.* is considered a trace species because it exhibited an abundance below 1% (0.5%) (Table 2).

ORDERS	FAMILIES	GENERA	SPECIES NUMBER	AA	RA (%)
Lituolida	Rzehakinidae	*Miliammina*	1	147	5,1
	Haplophragmoididae	*Haplophragmoides*	1	70	2,4
	Lituolidae	*Ammobaculites*	1	58	2,0
		Ammotium	2	599	20,7
Trochamminida	Trochamminidae	*Trochammina*	2	623	21,5
		Arenoparrella	1	293	10,1
		Jadammina	1	74	2,6
Textulariida	Textulariidae	*Bigenerina*	1	14	0,5
		Textularia	2	141	4,9
Rotaliida	Rotaliidae	*Pararotalia*	1	36	1,2
		Ammonia	1	362	12,5
	Elphidiidae	*Elphidium*	2	252	8,7

Table 1 Synthesis of the faunal composition of the TCV1A core.

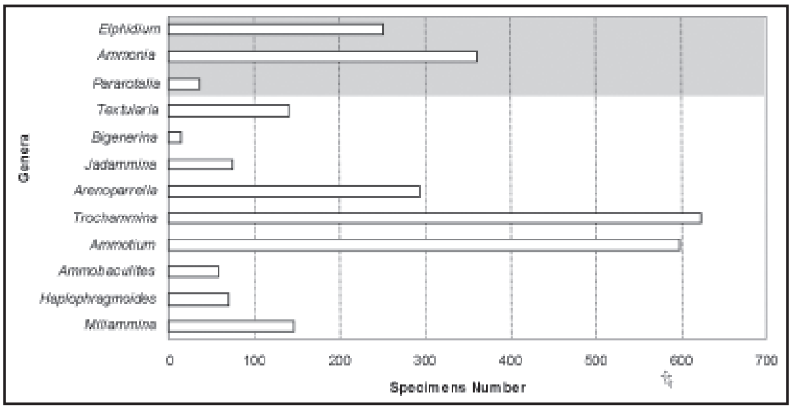

Figure 2 Representation of foraminifera genera in TCV1A core.

Considering the calculations of occurrence frequencies and the classification system adopted to evaluate these results (Dajoz 1983), 15 species (94%) were considered constant, and only one species (6%) was considered accessory. No species were recorded as exhibiting an accidental occurrence in the TCV1A core (Table 2).

The constant species were *Ammonia beccarii f. tepida* (100%), *Elphidium gunteri* (100%), *Ammotium salsum* (100%), *Arenoparrella mexicana* (100%), and *Trochammina inflata* (100%), which were present in all of the core samples; *Jadammina macrescens* (86%), present in 25 samples; *Miliammina fusca* (83%), present in 24 samples; *Haplophragmoides wilberti* (76%) and *Textularia gramen* (76%), present in 22 samples; *Ammotium sp.* (62%), present in 18 samples; *Elphidium sp.* (59%), *Pararotalia sp.* (59%), *Ammobaculites dilatatus* (59%), and *Textularia earlandi* (59%), present in 17 samples; and *Trochammina salsa* (52%), present in 15 samples (Table 2).

The species *Bigenerina sp2.* (41%) represented the only taxon in the accessory category and was represented in 12 of the 29 analyzed samples of the TCV1A core (Table 2).

4.1.3 *Vertical* Distribution

Analysis of the vertical distribution of the identified orders revealed differentiated behavior along the core. Considering the orders Lituolida and Trochamminida in particular, there was an evident alternation of dominance. The sedimentary intervals between 58 and 52 cm and between 16 and 4 cm were characterized by dominance of the order Lituolida. The interval between 52 and 16 cm, the central portion of the core, was characterized by dominance of the order Trochamminida. When analyzing the distribution of the order Rotaliida, a decreasing tendency could be observed from the base (58 cm) up to approximately 30 cm. Between 30 and 18 cm, there was a slight increasing tendency in the percentage of this order, whereas from 18 cm toward the top, a decline was observed. The order Textulariida showed a strong decreasing tendency toward the top of the core (Figure 3; Table 2).

When analyzing the most abundant species individually (present in more than 10% of the core samples) (Table 2), *Trochammina inflata* and *Ammotium salsum* showed inversely proportional distributions along the core. At the base of the core, between 58 and 52 cm, *A. salsum* was the most representative species. Between 52 and 44 cm, a decreasing tendency could be observed in the percentage of *A. salsum*, with a corresponding increase in the percentage of *Trochammina inflata*, which exhibited the highest representation in this core interval. In the portion of the core between 44 and 32 cm, the percentages of *T. inflata* and *A. salsum* were similar, with representation alternating between these species along this interval. From 30 cm toward the top, a reduction in the percentage of *T.*

TCV1A Samples (Depth in cm)	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	Total	RA	FO
CALCAREOUS																																
Ammonia beccarii f. tepida	10	10	12	12	10	10	8	10	11	16	14	14	17	18	10	13	11	10	15	10	14	11	12	14	14	10	12	14	20	362	12,5	100
Elphidium gunteri	7	7	9	7	6	11	9	8	15	12	8	9	6	10	9	8	6	7	7	8	4	6	5	3	9	5	4	5	2	212	7,3	100
Elphidium sp.	3	3	6	-	-	3		1	1	-	-	4	2	-	-	-	1	1	-	-	1	1	-	2	-	1	3	2	5	40	1,4	59
Pararotalia sp.	-	-	-	1	2	-	2	2	1	1	1	-	5	-	1	2	-	-	1	1	-	-	3	2	-	1	4	6	-	36	1,2	59
AGGLUTINATED																																
Ammobaculites dilatatus	-	-	1	-	-	-	2	7	1	6	2	-	2	4	-	5	5	7	3	-	-	-	1	-	5	-	2	1	4	58	2,0	59
Ammotium salsum	16	18	23	20	24	22	18	20	21	18	16	12	13	14	17	15	23	22	17	28	28	25	22	13	16	13	22	22	18	556	19,2	100
Ammotium sp.	2	3	-	2	3	-	2	6	3	-	1	1	2	-	1	3	-	-	4	-	-	1	-	1	-	2	-	1	5	43	1,5	62
Arenoparrella mexicana	15	12	10	10	11	8	8	13	12	10	9	12	14	9	13	12	10	10	8	7	8	8	11	7	9	7	7	8	15	293	10,1	100
Bigenerina sp2.	2	1	-	-	-	2	-	1	-	-	1	-	-	1	1	1	-	-	1	-	-	1	-	-	-	1	-	-	1	14	0,5	41
Haplophragmoides wilberti	3	-	7	4	-	9	3	2	-	-	3	2	1	-	-	4	1	1	-	1	1	3	4	3	6	5	1	2	4	70	2,4	76
Jadammina macrescens	6	2	2	2	2	-	4	3	7	-	-	5	2	3	2	1	4	2	3	2	2	1	4	3	1	1	6	4	-	74	2,6	86
Miliammina fusca	-	9	9	9	8	11	10	-	-	5	7	6	5	6	3	4	5	3	4	2	4	6	-	5	4	11	3	8	-	147	5,1	83
Textularia earlandi	1	-	-	-	2	2	-	-	-	-	-	-	-	3	6	5	4	5	-	4	3	5	2	4	-	3	4	5	3	61	2,1	59
Textularia gramen	-	1	-	1	-	-	8	3	3	2	4	-	3	-	3	2	3	-	1	3	4	2	2	8	4	5	9	2	7	80	2,8	76
Trochammina inflata	16	17	14	21	22	16	18	17	20	21	24	25	20	26	27	16	18	25	24	26	24	22	26	26	24	22	10	12	10	589	20,3	100
Trochamminita salsa	3	1		2	3	-	-	-	-	2	4	3	-	-	-	-	-	1	3	1	-	2	-	2	1	-	5	1	-	34	1,2	52
Species not identifiable	16	16	7	9	7	6	8	7	5	7	6	7	8	6	7	9	9	6	9	7	7	6	8	7	7	13	8	7	6	231	7,9	-

(black)	Species Principal (RA above 5%)
(dark grey)	Species Accessory (RA between 4.9 and 1%)
(light grey)	Species Trace (RA below 1%)

Table 2 Data on the absolute frequency (AR), abundance and occurrence of species along the TCV1A core.

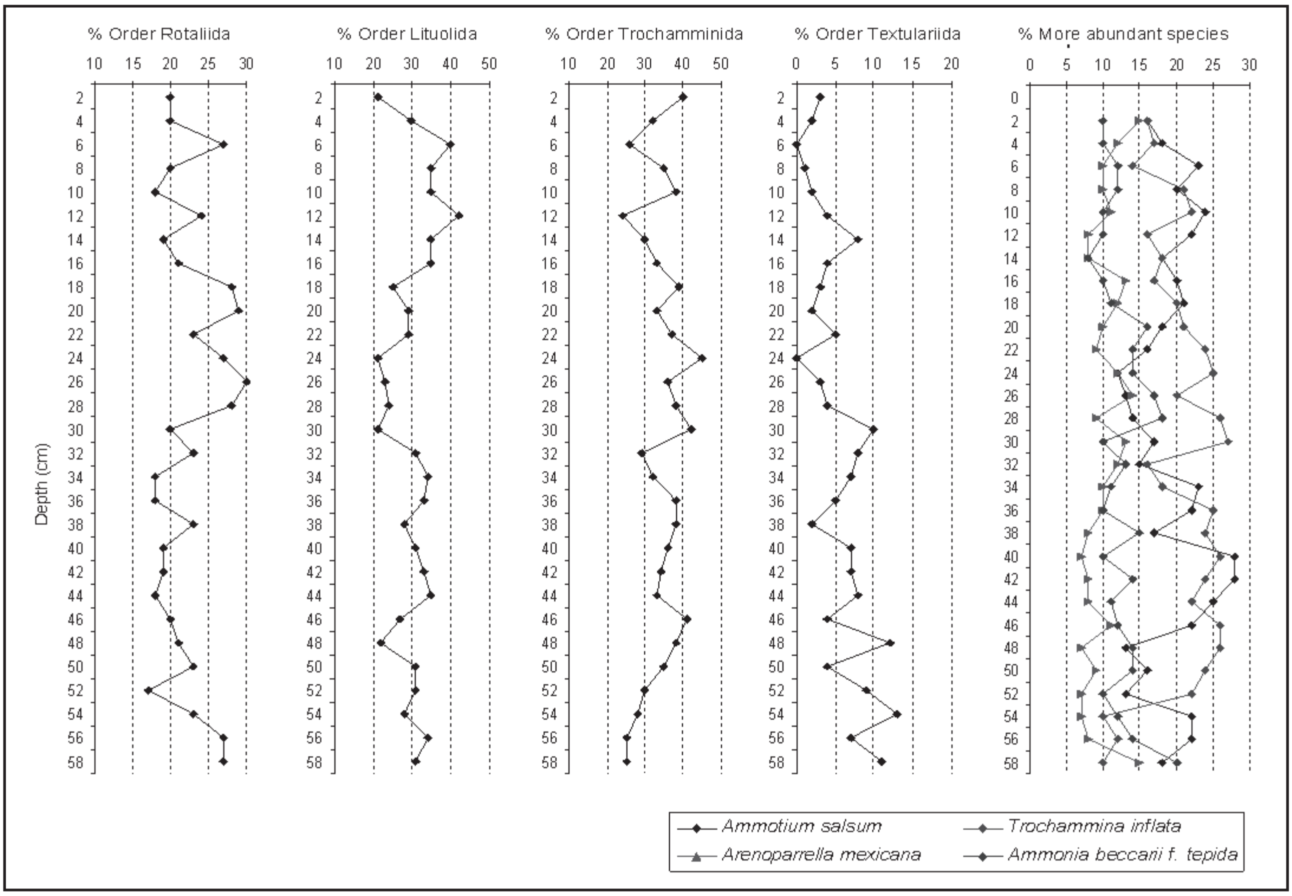

Figure 3 Vertical distribution of the identified orders and most abundant species along the TCV1A core.

inflata was found, with an increase in the percentage of *A. salsum*, followed by a decreasing between 6 cm and the core top (Figure 3; Table 2).

Regarding the distribution of the species *Ammonia beccarii f. tepida*, a decreasing tendency in its percentage was observed between 58 and 52 cm. From 52 cm toward the top, homogeneous behavior was observed in this species' vertical distribution, presenting only two peaks of abundance (in 28 and 20 cm), with a slight decreasing in the most superficial samples. The same pattern of homogeneous distribution recorded for *A. beccarii f. tepida* was shown for the species *Arenoparrella mexicana*, which exhibited some stability in its vertical distribution, with punctuated increases in representation at depths of 46, 60, 26, and 16 cm (Figure 3; Table 2).

With respect to the least abundant species, *Elphidium gunteri* presented increasing representation up to 18 cm, followed by a reduction toward to the top of the core. In the analysis of the vertical distribution of the species *Miliammina fusca*, an increasing tendency was observed from 50 cm toward the top of the core. The species *Textularia earlandi* and *Textularia gramen* exhibited an irregular distribution from the base to the median portion of the core and practically disappeared in the upper portion of the core. Regarding the distribution of the other species, no pattern was seen. It was possible to note small increasing or decreasing intervals intercalated with intervals presenting absences in some of the core samples (Table 2).

4.1.4 Richness, Diversity and Dominance

Analyses of the ecological descriptors, Margalef's richness (R), Shannon's diversity (H'), evenness (J), and dominance (D) were conducted based on the values calculated and presented in Table 3 and in Figure 4. The values of richness varied between 2.2 (in samples collected a depths of 6, 12, 20. and 28 cm) and 3.0 (in samples collected at depths of 32, 44, 48, 54, and 54 cm). The samples presenting the lowest richness values were located in the mid-upper portion of the core, whereas the samples with highest richness values were located

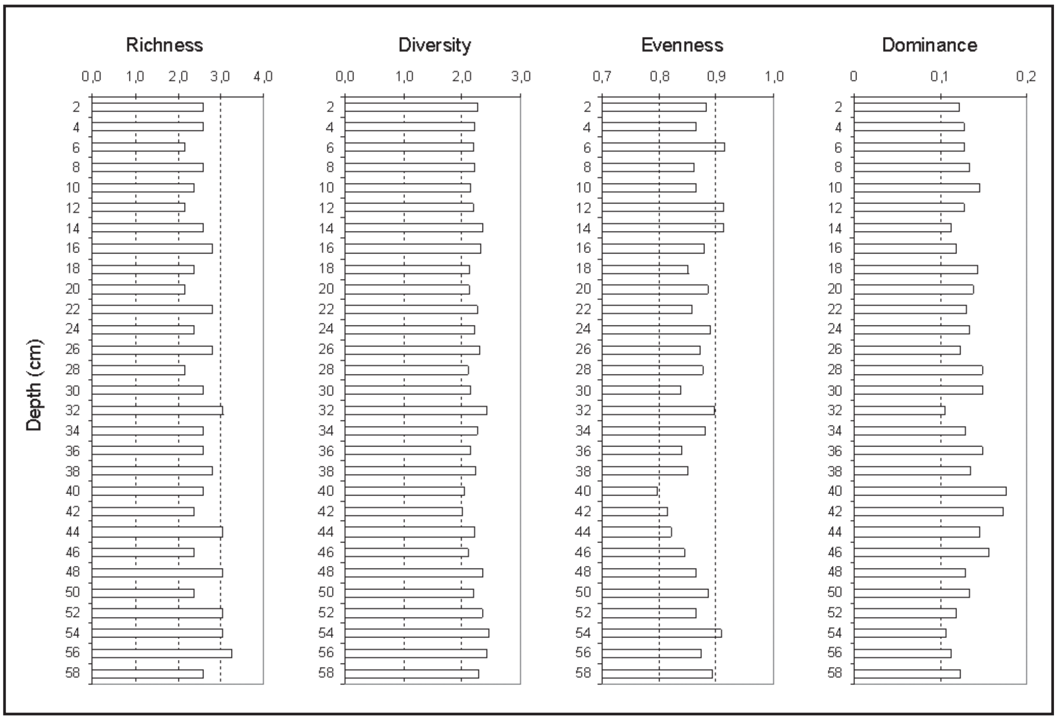

Figure 4 Vertical distribution of the richness, diversity, evenness and dominance indices along the TCV1A core.

in the mid-lower portion (Figure 4; Table 3). The diversity oscillated between 2.0 (in samples collected at depths of 40 and 42 cm) and 2.5 (in the sample collected at 54 cm). The samples with the lowest diversity index values presented only 12 (40 cm) and 11 species (42 cm), whereas the sample with the highest diversity index included 14 species (54 cm) (Figure 4; Table 3).

Integrated analysis of the richness and diversity indices revealed that TCV1A did not show sudden tendencies for faunal enrichment or impoverishment. The richness and diversity revealed a weak decreasing tendency in the sediment column between 58 and 40 cm, as the samples with the highest richness values were grouped in that sampling interval. In the upper portion, between 40 cm and the top of the core, equilibrium was observed in the species richness, with small decreases in the samples collected at 28, 20, 12, and 6 cm (Figure 4; Table 3). The evenness varied between 0.8 and 0.9, with a marked reduction in the interval between 44 and 40 cm.

Dominance exhibited an opposite pattern to that of the richness and diversity indices, with an increasing from the base up to 40 cm in the core. In the upper portion of the core, from 40 cm to its surface, a more homogeneous dominance was observed, with a slight decreasing in the samples collected at 32, 16, and 14 cm. This result was confirmed by observing that the highest dominance value (0.2) only occurred in the samples located in the lower portion of the core (samples at 46, 42 and 40 cm). The other samples showed dominance values of 0.1 (Figure 4; Table 3).

Despite having followed the same pattern as richness, diversity and dominance presented smoother curves as a product of the mathematical properties embedded in the calculation of these indices to filter variations of numerically low significance. Thus, the calculations of diversity and dominance assigned very low weights to species represented by few individuals. Therefore, the presence or absence of the rare species in the samples did not significantly alter the final values obtained for these indices.

4.1.5 Confinement Index (*Ic*)

According to the confinement index (*Ic*), the TCV1A core alternated between restricted marine influences and complete confinement stages. From the base (58 cm) up to 52 cm, the *Ic* value was 0.8, revealing the existence of environments restricted from the marine influence. Between 50 and 14 cm, the *Ic* varied between 0.8 (environments restricted from marine influence) and 0.9 (confined environments). In the portion of the core between 12 and 0 cm, the *Ic* value was maintained at 0.9, which reveals the stability of the confinement condition at the top of the sediment column (Table 3).

When analyzing the composition of the identified foraminifera tests, a predominance of forms with agglutinated shells over individuals with calcareous shells could be observed. The number of agglutinated specimens per sample varied between 76 (in samples 44 and 36) and 62 (in sample 26), whereas the number of calcareous specimens varied between 30 (sample 26) and 17 (sample 52). These data allowed us to confirm that calcareous forms presented higher representation in the samples obtained at the base of the core (58 and 56 cm) and in the samples collected in the portion between the 28 and 18 cm depth in the core column. In the rest of the core intervals, including the top, the representation of the calcareous forms decreased, which confirmed the results obtained through the confinement Index, indicating to a confined condition at the top of the core.

Some of the specimens collected could not be identified, mostly because of their small size or the preservation their shells. The number of unidentified individuals per sample varied from five (sample collected at 18 cm) to 16 (samples at 4 and 2 cm) (Table 3).

4.2 TCV2A Core

4.2.1 Faunal composition

In the TCV2A core, eighteen species were identified, all benthic, belonging to thirteen genera, eighteen families, seven superfamilies, and five orders. The order Lituolida was represented by three families, four genera, and five species; the order Trochamminida by one family, three genera, and four species; the order Textulariida by one family, two genera, and three species; the order Miliolida by one family, one genus, and one species; and the order Rotaliida by two families, three genera, and five species (Table 4).

The order Trochamminida was the most representative, including 28.8% of the identified specimens, followed by the orders Lituolida (28.2%), Rotaliida (24.5%), Textulariida (5.8%), and Miliolida (0.9%). Among the recorded superfamilies (Rzehakinacea, Lituolacea, Trochamminacea, Textulariacea, Miliolacea, and Rotaliacea), Trochamminacea was represented by 747 specimens, followed by the superfamilies Rotaliacea (614 specimens), Lituolacea (542 specimens), Rzehakinacea (165 specimens), Textulariacea (145 specimens), and Miliolacea (23 specimens) (Table 4).

Analyses/Samples	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58
Richness (R)	2,6	2,6	2,2	2,6	2,4	2,2	2,6	2,8	2,4	2,2	2,8	2,4	2,8	2,2	2,6	3,0	2,6	2,6	2,8	2,6	2,4	3,0	2,4	3,0	2,4	3,0	3,0	3,3	2,6
Diversity (H')	2,3	2,2	2,2	2,2	2,2	2,2	2,3	2,3	2,1	2,1	2,3	2,2	2,3	2,1	2,1	2,4	2,3	2,2	2,2	2,0	2,0	2,2	2,1	2,3	2,2	2,3	2,5	2,4	2,3
Evenness (J)	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,8	0,9	0,9	0,8	0,9	0,8	0,8	0,8	0,8	0,9	0,9	0,9	0,9	0,9	0,9
Dominance (D)	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,2	0,2	0,1	0,2	0,1	0,1	0,1	0,1	0,1	0,1
confinement index (Ic)	0,9	0,9	0,9	0,9	0,9	0,9	0,8	0,8	0,8	0,8	0,8	0,9	0,8	0,8	0,8	0,8	0,9	0,9	0,8	0,8	0,9	0,9	0,8	0,8	0,9	0,8	0,8	0,8	0,8
% Calcareous tests	20	20	27	20	18	24	19	21	28	29	23	27	30	28	20	23	18	18	23	19	19	18	20	21	23	17	23	27	27
% Agglutinated tests	64	64	66	71	75	70	73	72	67	64	71	66	62	66	73	66	73	76	68	74	74	76	72	72	70	70	69	66	67
Species not identifiable	16	16	7	9	7	6	8	7	5	7	6	7	8	6	7	9	9	6	9	7	7	6	8	7	7	13	8	7	6

Table 3 Richness, diversity, evenness, dominance, and confinement index data for samples of the TCV1A core.

ORDERS	FAMILIES	GENERA	SPECIES NUMBER	AA	RA (%)
Lituolida	Rzehakinidae	*Miliammina*	1	165	6,6
	Haplophragmoididae	*Haplophragmoides*	1	63	2,5
	Lituolidae	*Ammobaculites*	1	48	1,9
		Ammotium	2	431	17,2
Trochamminida	Trochamminidae	*Trochammina*	2	361	14,4
		Arenoparrella	1	326	13,0
		Jadammina	1	60	2,4
Textulariida	Textulariidae	*Bigenerina*	1	28	1,1
		Textularia	2	117	4,7
Miliolida	Hauerinidae	*Quinqueloculina*	1	23	0,9
Rotaliida	Rotaliidae	*Pararotalia*	1	27	1,1
		Ammonia	1	281	11,2
	Elphidiidae	*Elphidium*	3	306	12,2

Table 4 Synthesis of the faunal composition of the TCV2A core.

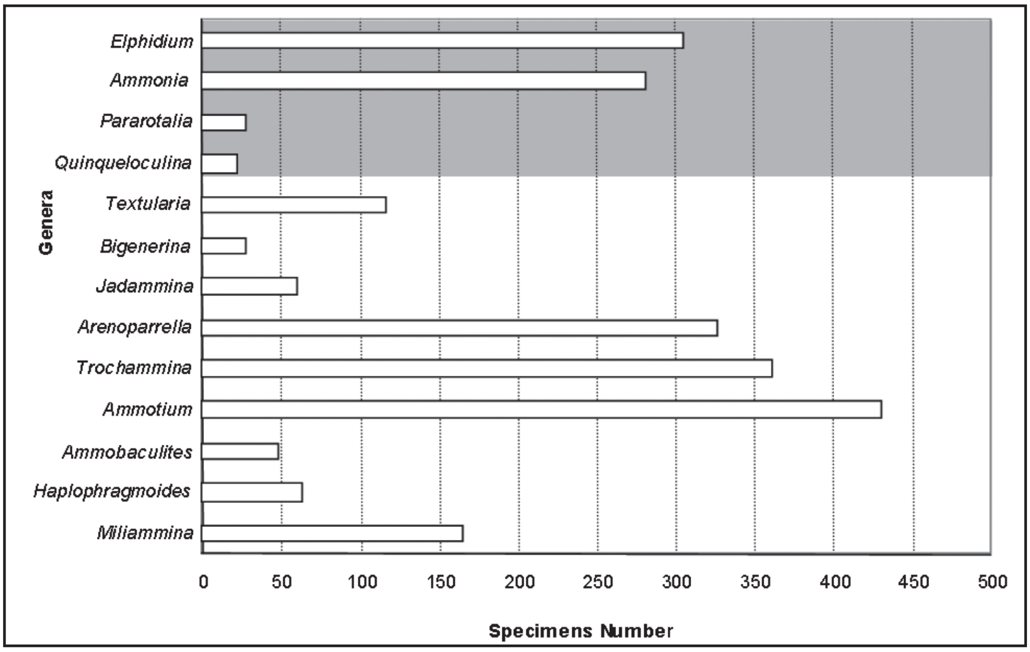

Figure 5 Representation of the foraminifera genera of the TCV2A core.

The most representative families were Trochamminidade and Lituolidae, with 747 and 479 specimens, respectively. The families Rotaliidae and Elphidiidae also exhibited high representation, with 308 and 306 specimens, respectively. The least representative families were Rzehakinidade (165 specimens), Textulariidae (145 specimens), Haplophragmoididae (70 specimens), and Hauerinidade (23 specimens) (Table 4).

The representation of the identified genera in the TCV2A core samples revealed that agglutinated forms were more abundant (Textularia, Bigenerina, Jadammina, Arenoparrella, Trochammina, Ammotium, Ammobaculites, Haplopragmoides, and Miliammina) than calcareous forms (Elphidium, Ammonia, Quinqueloculina, and Pararotalia) (Figure 26). The most representative genera were *Ammotium* (431 specimens, 17.2%), *Trochammina* (361 specimens, 14.4%), *Arenoparrella* (326 specimens, 20.7%), *Elphidium* (306 specimens, 12.2 %), *Ammonia* (281 specimens, 11.2%), *Miliammina* (165 specimens, 6.6%), and *Textularia* (117 specimens, 4.7%) (Figure 5).

4.2.2 Abundance and Frequency of Occurrence

The data regarding the relative abundance and frequency of occurrence of the identified species are presented in Table 5. According to these data, the most abundant species were *Ammotium salsum* (representing 15.9% of the total identified individuals), *Trochammina inflata* (13.7%), *Arenoparrella mexicana* (13.0%), and *Ammonia beccarii f. tepida* (11.2%). Other identified species presented percentages below 10%.

Considering the classification system defined by Dajoz (1983), six species were considered principal species, representing 33.3% of the identified *taxa*, while 10 (55.5%) were identified as accessory and 2 (11.1%) as trace species (Table 5).

The species *Ammotium salsum* (15.9%), *Trochammina inflata* (13.7%), *Arenoparrella mexicana* (13.0%), *Ammonia beccarii f. tepida* (11.2%) *Elphidium gunteri* (9.0%), and *Miliammina fusca* (6.6%) were considered principal species, with abundances above 5% in the sediment column, whereas *Haplophragmoides wilberti* (2.5%), *Jadammina macrescens* (2.4%), *Elphidium sp.* (2.1%), *Ammobaculites dilatatus* (1.9%), *Ammotium sp.* (1.3%), *Elphidium sagrum* (1.1%), *Pararotalia sp.* (1.1%), and *Bigenerina sp2.* (1.1%), represented accessory species, with relative abundances between 4.9% and 1%. Only *Quinqueloculina* sp^3 (0.9%) and *Trochammina salsa* (0.8%) were considered trace species, presenting abundances below 1% (Table 5).

With respect to the frequency of occurrence, based on the classification system adopted to evaluate these results (Dajoz 1983), 15 *taxa* (83.3% of the total species) were considered constant, and only three *taxa* (16.7%) were classified as accessory species. No species was recorded as exhibiting an accidental occurrence in the TCV2A core (Table 5).

The constant species were as follows: *Ammonia beccarii f. tepida* (100%), *Elphidium gunteri* (100%)*, Ammotium salsum* (100%)*, Arenoparrella mexicana* (100%)*, Miliammina fusca* (100%), and *Trochammina inflata* (100%)*,* which were present in all of the samples of the core; *Jadammina macrescens* (92%), present in 23 samples; *Elphidium sp.* (80%) and *Haplophragmoides wilberti* (80%), in 20 samples; *Textularia gramen* (68%), in 18 samples; *Ammotium sp.* (64%) and *Textularia earlandi* (64%), in 16 samples; *Elphidium sagrum* (56%) and *Ammobaculites dilatatus* (56%), in 14 samples; and *Quinqueloculina sp*^{3} (52%), present in 13 samples (Table 5). *Bigenerina sp2.* (48%), *Pararotalia sp.* (44%), and *Trocahammina salsa* (44%) represent the group of accessory species (Table 5).

4.2.3 Vertical Distribution

The vertical distribution of the calcareous and agglutinated orders, as presented in Figure 6, showed a decreasing tendency regarding the abundance of the Rotaliida order toward the top of the core. The highest representation of this order occurred at the base of the core at depths of 50 and 46 cm (31% of the total of identified specimens). The lowest values were found in samples collected from depths of 32, 30, 18, and 10 cm (19% of the total of identified specimens). The order Miliolida showed heterogeneous behavior along the core, being absent or showing low representation at the base and in the upper portion of the sediment column. At the base of the core, between depths of 50 and 32 cm, this order was rarely recorded, with one *taxon* being found per sample at depths of 40 and 36 cm. In the upper portion of the core, between 12 and 2 cm, the order was recorded with a frequency of only one *taxon* per sample at the depths of 6 and 4 cm. In the interval of the core between depths of 30 and 14 cm, there was a slight increase in the representation of Miliolida (Figure 6; Table 5).

Regarding the agglutinated orders, an increase in the representation of the order Lituolida was observed from the base to the top of the core. In the sample collected at 10 cm, the specimens of this order represented 40% of the total of identified forms. The smallest contribution of the order was observed at the 48 cm depth, where its representation corresponded to 19% of the identified forms. The order Trochamminida presented more homogeneous behavior along most of the core (between 50 and 18 cm in depth), with a decreasing in abundance toward the top of the core from the 16 cm depth. The order Textulariida showed a decreasing tendency at the base of the core between depths of 48 and 3 cm, with a significant increase in representation between 36 and 30 cm. In the 28 to 14 cm interval, the order was poorly represented and even absent (samples collected between 26 and 22 cm). From the 22 cm depth toward the top of the core, there was an increasing tendency observed in the representation of this order (Figure 6; Table 5).

TCV2A Samples (Depth in cm)	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	Total	RA	FO
CALCAREOUS																												
Ammonia beccarii f. tepida	8	11	13	12	10	11	7	9	4	9	9	9	10	11	10	9	12	13	14	13	16	14	15	15	17	281	11,2	100
Elphidium gunteri	9	6	12	6	7	6	10	11	12	9	15	9	10	11	7	6	10	9	11	9	10	7	6	8	9	225	9,0	100
Elphidium sagrum	-	-	-	-	-	-	1	3	2	2	3	1	3	3	2	1	2	-	-	-	-	1	2	2	-	28	1,1	56
Elphidium sp.	1	1	-	-	-	3	3	2	1	3	2	2	4	2	-	-	3	3	4	3	4	1	4	2	5	53	2,1	80
Pararotalia sp.	3	4	3	1	2	3	-	-	-	-	-	-	-	-	-	3	-	-	1	1	-	-	4	2	-	27	1,1	44
Quinqueloculina sp3.	-	1	1	-	-	-	2	1	3	2	1	1	4	3	2	-	-	1	-	1	-	-	-	-	-	23	0,9	52
AGGLUTINATED																												
Ammobaculites dilatatus	2	7	4	5	1	-	1	3	-	-	-	2	-	-	-	3	3	6	4	-	-	-	2	-	5	48	1,9	56
Ammotium salsum	15	17	22	18	22	21	20	17	13	17	15	21	18	10	14	13	11	16	12	17	17	15	12	10	15	398	15,9	100
Ammotium sp.	2	-	-	1	2	-	-	5	2	4	2	2	1	-	1	3	-	1	4	1	-	1	-	1	-	33	1,3	64
Arenoparrella mexicana	9	9	10	12	10	8	15	13	19	15	11	12	15	18	22	12	10	11	12	14	17	17	12	12	11	326	13,0	100
Bigenerina sp2.	5	4	3	4	4	2	-	-	-	-	-	-	-	-	1	1	-	1	1	1	-	1	-	-	-	28	1,1	48
Haplophragmoides wilberti	3	6	3	3	5	9	2	1	1	-	2	1	-	-	-	4	2	1	-	2	1	3	5	3	6	63	2,5	80
Jadammina macrescens	3	1	-	1	1	-	3	2	6	4	5	3	1	2	1	2	5	2	3	3	2	1	5	3	1	60	2,4	92
Miliammina fusca	5	4	7	6	10	9	8	3	9	10	10	8	8	11	10	6	7	3	4	3	4	6	4	5	5	165	6,6	100
Textularia earlandi	7	3	2	5	1	7	-	-	-	-	-	-	-	2	5	6	5	5	-	4	3	5	3	4	-	67	2,7	64
Textularia gramen	4	3	2	1	-	-	2	1	2	1	-	-	-	-	2	3	4	-	1	3	4	2	3	8	4	50	2,0	68
Trochammina inflata	11	13	7	10	10	10	11	12	12	11	13	18	13	12	15	18	16	18	21	16	15	16	16	15	13	342	13,7	100
Trochamminita salsa	3	1	-	2	2	-	-	-	-	-	1	-	-	-	-	-	-	1	3	1	-	2	-	2	1	19	0,8	44
Species not identifiable	10	9	11	13	13	11	15	17	14	13	11	11	13	15	8	10	10	9	5	8	7	8	7	8	8	264	10,6	-

(black)	Species Principal (RA above 5%)
(dark grey)	Species Accessory (RA between 4.9 and 1%)
(light grey)	Species Trace (RA below 1%)

Table 5 Data for the absolute frequency, abundance, and occurrence of the species in the TCV2A core.

Analyzing the most abundant species individually (percentages above 10% in the core) (Table 5), it was observed that *Ammotium salsum* exhibited irregularities in abundance among the samples, with a slight increasing toward the core top. The species *Trochammina inflata* showed the opposite behavior, alternating intervals of high representation with *Ammotium salsum* and showing a slight decreasing toward the top of the core (Figure 6).

The species *Arenoparrella mexicana* exhibited irregular abundance between samples from the 50 and 32 cm of the core depth. From the 30 cm toward the top, a decreasing was observed in the abundance of this species. The species *Ammonia beccarii f. tepida* and *Elphidium gunteri* presented heterogeneous behavior along the entire sediment column, precluding the identification of any tendency in the distributional pattern of these *taxa*, which alternated among small increases and decreases in representation (Figure 6; Table 5).

With respect to the species with percent abundances below 10% along the core, it was observed that *Miliammina fusca* presented the highest representation in samples collected from the depth of 34 cm toward the top. The vertical distribution of other species did not show any pattern of distribution. Only small intervals of increases and decreases in the representation of certain forms could be observed, and some species were found in some samples but not in other core samples (Table 5).

4.2.4 Richness, Diversity and Dominance

The results for the ecological descriptors (Richness, Diversity, Evenness, and Dominance) are presented in Table 6 and Figure 7. The values for richness from the TCV2A core varied between 2.2 (samples collected at depths of 42, 26, and 12 cm) and 3.3 (samples collected at 42, 4, and 2 cm depths). In general, the lower richness values were located in the interval between the 28 and 12 cm depths. At the base (between depths of 48 and 30 cm) and the top of the core column (between depths of 10 and 2 cm), there was an increase in the richness values (Figure 7).

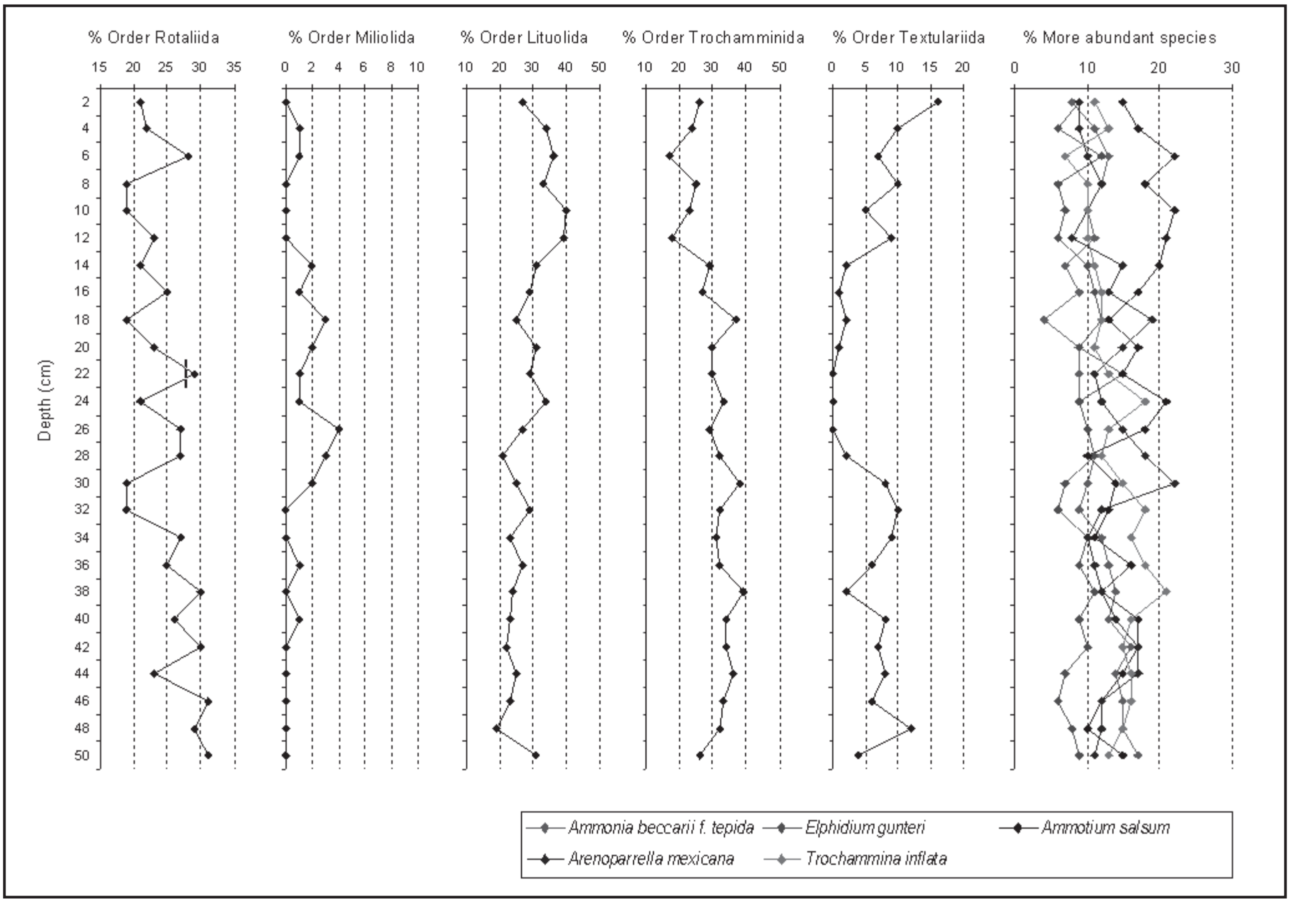

Figure 6 Vertical distribution of the identified orders e most abundant species along the TCV2A core.

The diversity values varied between 2.1 (samples collected at 42, 26, and 24 cm depths) and 2.6 (in the sample collected at the 2 cm depth). It was observed that the samples located at the base of the core, between 50 and 32 cm depth (except for the sample collected at 42 cm), presented values of diversity equal to or above the mean (2.3) recorded for the core. From 30 cm toward the top, an increasing was observed in the diversity of species (Figure 7).

When comparing the richness and diversity values, it was possible to observe a slight impoverishment of the fauna between 30 and 12 cm depth, with a tendency for enrichment from 8 cm toward the core top. In the upper portion, between 40 cm and the top of the core, an equilibrium was observed in the species richness, with slight decreases in the samples collected at depths of 28, 20, 12, and 6 cm (Figure 7). Evenness varied from 0.8 to 0.9, with a marked reduction in the interval between 44 and 40 cm.

Dominance showed the opposite pattern compared to richness and diversity, with high values in the middle portion of the core between depths of 30 and 6 cm. In the lower portion of the sediment column, there were samples presenting low values of dominance (0.11), specifically the samples collected at 48, 46, 34, and 32 cm. This could also be observed at the top of the sediment column, with the samples collected at 4 and 2 cm exhibiting dominance values of 0.10 and 0.9, respectively (Figure 7).

4.2.5 Confinement Index (Ic)

The values obtained for the confinement Index (*Ic*) revealed that the TCV2A core was characterized by 96% of samples presenting conditions of restricted marine influence (*Ic* value of 0.8). A *Ic* value of 0.9 was found only for the sample collected at the 24 cm depth, indicating a condition of confinement for that interval (Table 6).

When analyzing the composition of the identified foraminifera shells, a predominance of individuals with agglutinant shells over individuals with calcareous shells was observed. The number of agglutinant specimens per sample oscillated between samples 71 (samples collected at 32 and 30 cm depths) and 55 (samples collected at 28 cm), whereas the number of calcareous specimens varied between 31 (samples collected at 50 and 4 cm) and 19 (samples collected at 32, 10, and 8 cm). Analysis of the vertical distribution of the calcareous forms showed a lower representation of specimens with this type of shell from 20 cm toward the top, with a consequent increase in the representation of agglutinated forms (Table 6). An integrated analysis of these data with the values of the confinement index confirmed the influence of restricted marine conditions during the deposition of the sediment comprising the TCV2A core, particularly in its upper portion.

Given the precarious state of preservation of a portion of the collected shells, it was not possible to identify some specimens. The number of unidentified individuals per sample varied between 5 (sample collected at 38 cm) and 17 (sample collected at 16 cm) (Table 6). It is important to highlight the increase in the number of unidentified specimens from the base to the 16 cm core depth. From 14 cm toward the top, there was a decreasing tendency in the number of specimens not identified (Table 6).

5 Discussion and Conclusions

Our analysis of the estuarine cores (TCV1A and TCV2A) revealed the faunal composition of locations characterized by the penetration of saline water and subjected to a polyhaline hydric regime. We suggest that the sediments in these cores were deposited under conditions similar to the present. The recorded associations of foraminifers in both sediment columns indicated the predominance of agglutinant over calcareous forms, which allowed confirmation of the salinity conditions in the area. According to Murray (1971), polyhaline zones are

Descritores/estações	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50
Richness (R)	3,3	3,3	2,7	3,1	2,9	2,2	2,7	2,9	2,7	2,5	2,7	2,7	2,2	2,3	2,7	3,1	2,7	3,1	2,9	3,3	2,2	3,1	2,9	3,1	2,4
Diversity (H')	2,6	2,5	2,2	2,4	2,3	2,2	2,2	2,3	2,2	2,2	2,3	2,1	2,1	2,2	2,2	2,4	2,4	2,3	2,3	2,3	2,1	2,3	2,4	2,4	2,3
Evenness (J)	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,8	0,9	0,9	0,8	0,9	0,9	0,8	0,9	0,8	0,9	0,8	0,9	0,9	0,9
Dominance (D)	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
Confinement Index (Ic)	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,9	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8
% Calcareous tests	21	23	29	19	19	23	23	26	22	25	30	22	31	30	21	19	27	26	30	27	30	23	31	29	31
% Agglutinated tests	69	68	60	68	68	66	62	57	64	62	59	67	56	55	71	71	63	65	65	65	63	69	62	63	61
Species not identifiable	10	9	11	13	13	11	15	17	14	13	11	11	13	15	8	10	10	9	5	8	7	8	7	8	8

Table 6 Richness, diversity, evenness, dominance, and confinement index data for the samples and species of the TCV2A core.

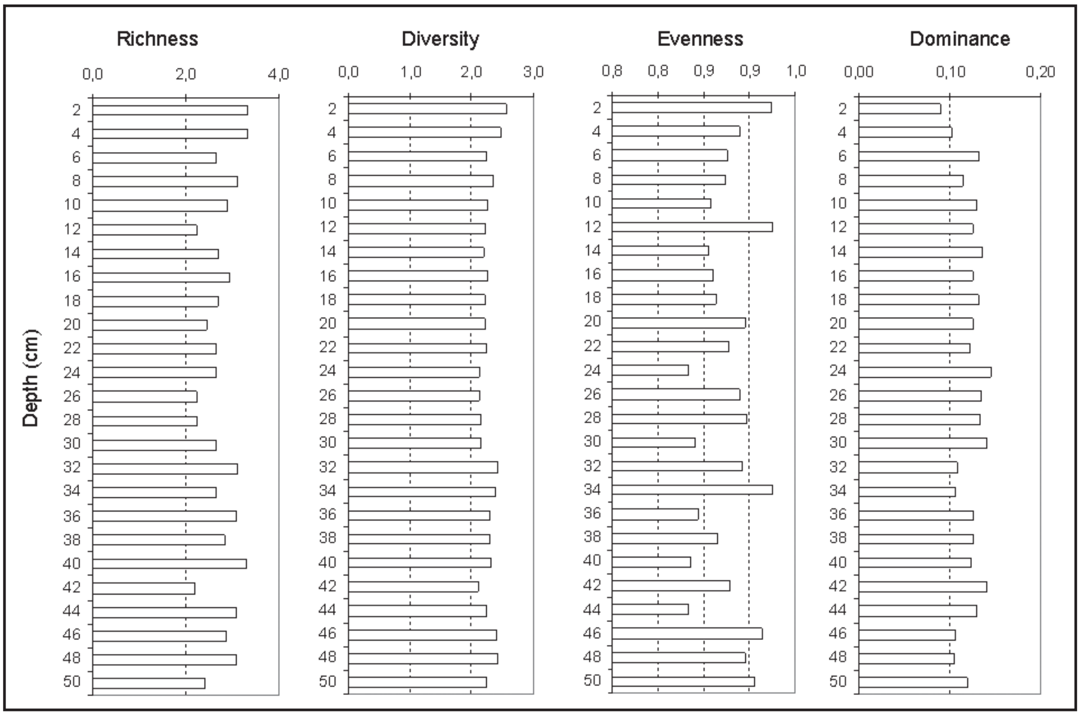

Figure 7 Vertical distribution of the richness, diversity, evenness, and dominance indices along the TCV2A core.

characterized by the predominance of agglutinant forms, with few representatives of the order Rotaliida and, in general, an absence of Miliolidea. Boltovskoy & Wright (1976) explained the low content of calcareous forms in estuarine environments as a result of excess of organic matter in these areas and consequent bacterial activity, which reduces the pH of the sediment, thus dissolving the calcium carbonate shells.

At the base of the TCV1A column (between 50 and 52 cm), the significant reduction of calcareous species and the dominance of the Lituolida order, represented by species of the genera *Miliammina, Haplophragmoides, Ammobaculites*, and *Ammotium*, revealed low salinity conditions at the time of the deposition of this sediment interval. A similar association was reported in temperate (Jennings *et al*., 1995) and tropical (Debenay, *et al*., 2001; Duleba & Debenay, 2003) mangrove zones, which is indicative of environments that are significantly influenced by fresh water. The high abundance of *Ammotium salsum* in the same interval indicates that the base of the core may have been deposited under conditions with a high concentration of suspended material (Scott & Medioli, 1980). According to Barbosa (1991) and Barbosa *et al.* (2005), associations with large quantities of *Ammotium salsum* occur in areas with high turbidity and high fluxes of organic material in the sediment.

The same pattern described for the interval between 52 and 50 cm in the TCV1A column was repeated for the upper part of the core between 16 and 4 cm in depth, which is evidence of a return to the conditions described above. In the interval between 52 and 16 cm, the opposite condition was observed, with an increase in the representation of calcareous species (*Ammonia beccarii f. tepida* e *Elphidium sp.*) being found, especially in the interval between 30 and 18 cm, dominated by the order Trochamminida and represented by the genera *Trochammina*, *Arenoparrella*, and *Jadammina*. The first two genera are characteristic of mangrove zones, with their presence having been recorded in these environments by several authors (Scott *et al.,* 1990; Debenay *et al.,* 2000 ; Duleba & Debenay, 2003). Thus, it can be conclude that at the moment of the deposition of this interval of the TCV1A core, the environment was subjected to stronger marine influence, which can be supported by the increase in the contribution of calcareous forms.

Subdivision of the TCV1A core into three intervals characterized by, from the base to the top, low, high, and low marine influence, respectively, is supported by the results for the confinement index (*Ic*), which revealed the restriction of marine influence at the base of the core (between 58 and 52 cm) and in the upper portion. In the intermediate portion of the column, the *Ic* values confirmed stronger marine influence at the time of sediment deposition. Considering the integrated analysis of the richness and diversity indices, the oscillations between periods of higher and lower marine influence were not representative to the point of promoting marked events of enrichment or impoverishment of the fauna.

The TCV2A core presented a reduction in the contribution of species from the order Rotaliida. In this column, one species of the order Miliolida was present and exhibited slight representation in the interval between 30 and 14 cm in depth. These data, associated with increased representation of the order Lituolida and reduced representation of the order Trochamminida from the base to the top of the sediment column, indicate a gradual reduction of marine influence in the location where this core was collected. This situation can be explained as a result of the deforestation of the estuarine area and the influx of large quantities of particles into the estuary, contributing to its siltation and obstructing the entrance of marine water to this location. Data presented by Minervino Netto (2008) show the high rate of occupation and soil use in the Caravelas plains beginning in the early 1980s, which would provide support for this hypothesis.

The association of the vertical distribution data for the identified orders and species and the results from the confinement index confirms a condition of restricted marine influence during the deposition period of the TCV2A core. This hypothesis can be confirmed by the diversity and richness values, which show signals of impoverishment of the fauna in several segments of the sediment column.

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