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Sponge Spicules in Sediments Indicate Evolution of Coastal Freshwater Bodies.

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ABSTRACT

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Freshwater sponges siliceous spicules found in sediments have proved to be good indicators of environmental processes. Taxonomy of the present fauna, which has been shown to reach Pleistocene age, is based upon the spicules that represent printings of the different species and their habitat requirements in the sediments where they are found. Several freshwater bodies, differing in size and macrophyte covering at Taim Hydrological System, in Rio Grande do Sul coastal area (southern Brazil), were chosen for a study of spicules in their present sediments. The aim was to correlate the amount of spicules to sediment type, water characteristics and, thus, to predict the evolution of the system or to read the columns of recovered sediments. *Ephydatia facunda* Weltner, 1895, was seen to be the dominant sponge species in the area. A SEM catalogue of the spicules (gemoscleres) which cover its gemmules was produced to aid in their identification and counting in the sediments. Next, a methodology was developed in order to estimate the most confident amount of spicules to be counted in the sediments sampled. The investigation revealed that different sub-samplings had to be taken from coarse and fine sediments. Analysis of Variance (ANOVA) was applied to the spicule counting and significant differences ($p<0.0001$) were found separating the sampled sites. These differences allowed the application of multivariate analysis correlating spicule amounts to sediment type, level of organic enrichment, lake depth and water characteristic. Thus, evolution towards reduction of the free water surface was hypothesized.

ADDITIONAL INDEX WORDS: *Method, biosiliceous, enrichment..*

INTRODUCTION

Freshwater sponges siliceous spicules found in sediments have proved to be good indicators of environmental processes. (HALL and HERRMANN, 1980; HARRISON and WARNER, 1986; VOLKMER-RIBEIRO *et al*., 2001). Taxonomy of the present fauna, which has been shown to reach Pleistocene age (MATSUOKA, 1983) is based upon particularly the spicules (gemoscleres) which cover the gemmules, assexual reproduction bodies. Since spicules are not subjected to the decaying processes operating after the animal's death, they fall on the bottom sediments, and there, stand for printings of species and habitat conditions at the time of the animal's life span. Reduced lake drainage takes to accumulation of such spicules in bottom sediments, so as sometimes to produce true biogenic mineral deposits (VOLKMER-RIBEIRO, 1992). Several freshwater bodies differing in size and macrophyte covering at the Taim Hydrological System, a protected coastal area in southern Brazil were chosen for a study of the spicules in their recent sediments. *Ephydatia facunda* Weltner, 1895, was already registered as the dominant sponge species in the area (VOLKMER-RIBEIRO *et al*., 1988). The aim was to establish a procedure to count identified spicules in the sampled sediments and proceed to correlations with sediment type, the lake depth and water characteristics and, thus, to understand and predict evolution of the system or to read columns of recovered sediments.

MATERIAL AND METHODS

The freshwater bodies selected for sediment/water sampling at the Taim Hydrological System were Lagoa Flores (TAFLO, -52º 31' 08” -32º 30' 26”), Lagoa Nicola (TANI, -52º 31' 29” -32º 33' 43”), Lagoa do Jacaré (TAJA, -52º 33' 25” -32º 36' 13”), and Lagoa Mangueira (TAMA) (Fig. 1). Lagoa Mangueira, the largest one, had samples taken from its middle area, (TAMAC, -52º 53' 09” -33º 13' 01”), its swampy area (TAMAB, -52º 34' 35” -32º 46' 19”) and from the northern (TAMAN, -52º 33' 27” -32º 47' 32”) and southern (TAMAS, -53º 06' 58” -33º 30' 19”) margins. Three replicas of the sediments were taken with a

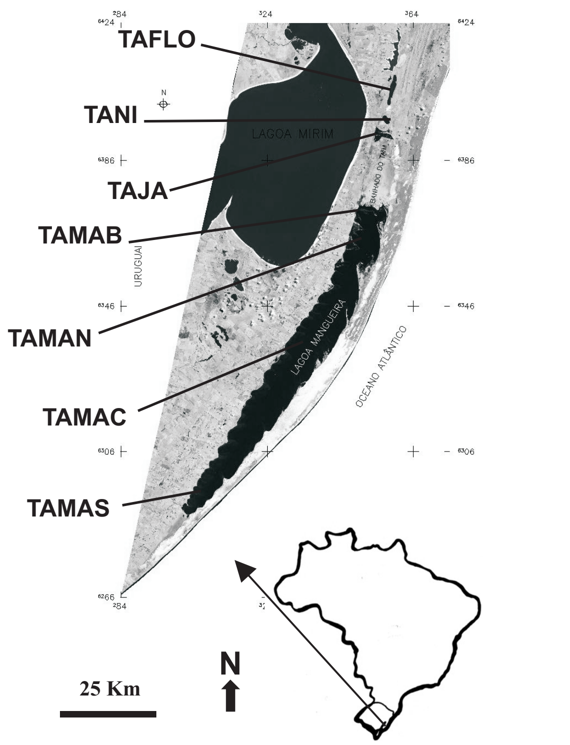

Figure 1. The Taim Hydrological System bearing indication to the sampled freshwater bodies (lagoas).TAFLO:Lagoa Flores; TANI:Lagoa Nicola,; TAJA; Lagoa do Jacaré; TAMAB: Lagoa Mangueira banhado (swamp); TAMAN: Lagoa Mangueira, North,; TAMAC: Lagoa Mangueira, center; TAMAS: Lagoa Mangueira South.

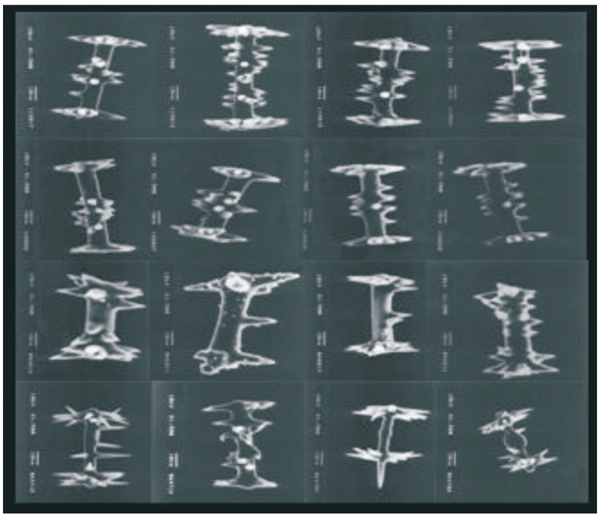

Figure 2. SEM ilustration of variations presented by the gemmoscleres of specimens of *Ephydatia facunda* collected from different habitats at Rio Grande do Sul coastal área. Top line- Man-made ditch along the National Road 471 at the Taim Ecological Station (MCN nº 1198); Second line- Canal at Lagoa do Jacaré, Taim Ecological Station (MCN nº 1268); Third line- Patos Lagoon, close to the town of São Lourenço do Sul (MCN nº 468); Bottom line- Lagoa do Jacaré , Taim Ecological Station (MCN nº 647).

piston corer. They were then boiled in nitric acid and washed several times in distilled water. The suspended siliceous material, spicules included, was dropped on a slide and after completely dried, it was covered with Entelan and glass cover slips. Taxonomic identification of the spicules and counting of the gemmoscleres was next processed under a light microscope. *Ephydatia facunda* Weltner, 1895, was confirmed as the dominant species in the sediments.

The same method was used to prepare SEM stubs of gemmoscleres of *E. facunda* from different habitats at this coastal area, in order to build a photographic plate (Fig. 2) for their identification and counting on the slides of sediments. No spicules were found in the very coarse sediments from the central area of Lagoa Mangueira and very different amounts were present in the sediments from the other sampled lakes, depending on the coarseness. To establish the minimum significant number of slides to be counted for spicules, slides were prepared using all the sediment in aliquots of 0,35cm3 from each one of the three replicas taken from one fine (Lagoa do Jacaré) and one coarse grained sample (Lagoa das Flores). This resulted in 51 slides for fine grained sediment and 9 slides for coarse grained sediment. However the aliquot had to be diluted to allow for the perception and counting of all gemmoscleres in each slide. That resulted in a total of 75 slides of fine grained sediment and 15 slides of coarse grained sediment counted for each sampling place. Upon that counting, the minimum number of slides to be counted (WETZEL and LIKENS, 2000) was established as 9 slides from 0,35cm3 of fine grained sediment and 4 slides from 0,35cm3 of coarse grained sediments.

These minimum numbers were, however, doubled aiming maximal confidence of results, so that 19 slides were finally counted for the fine grained sediments and 5 slides each of two 0,35cm3 aliquots for the coarse grained sediments.

Length of water column and water samples were taken at the same sampling stations.

Suspended solids, hardness, silica and chlorophyll a were the water quality variables chosen for analyses, carried according to A.P.H.A. (1992). A multisensor YSI 6920 was used in field to measure water pH, conductivity, and salinity. Lake depth was taken using a HONDEX portable depth sounder.

The granulometric analysis of the sediments was performed on the mixed three replicas according to KRUMBEIN and PETTIJOHN, 1922 and the organic matter in the sediments was determined after WETZEL and LIKENS (2000).

Multivariate analyses of the data were performed using the software PC-ORD 4.0 for Windows (MCCUNE and MEFFORD, 1999) (Table 3). Sampling units were grouped by their physical and chemical characteristics, after a log transformation [log(x)], using Euclidean Distance as a dissimilarity measure, and the Minimum Variance method was used as a clustering criterion (WARDS, in ROMESBURG, 1984). In order to verify the variability of the main limnological characteristics responsible for the clustering, a Correlation Principal Components Analysis (MCCUNE and MEFFORD, *op. cit.*) was applied to the data.

RESULTS

Values of the granulometric analysis of the sediments, including their content of organic matter, are presented in Table 1. The mean values of the physical and chemical data for the water samples are given in Table 2. Cluster analysis is presented in fig. 3 and the results of the Principal Components Analysis are shown in tables 3 and 4 and in Figure 4.

DISCUSSION

Cluster analysis divided Lagoa Flores from the remaining sampling units, which, in turn, were divided in three groups: Group 1, formed by Lagoa Nicola and Jacaré, Group 2 comprising Banhado and Lagoa Mangueira Northern Region and Group 3 formed by Lagoa Mangueira Central area and Southern Region (Figure 3). On the first axis of the Principal

Table 1. *Classification of the sediments and % of the organic matter .*

Samples	Textural classification	% of organic matter
TANI	Mud with sand	27,70%
TAMAB	Sand with mud	22,70%
TAFLO	Sand with mud	9,95%
TAJA	Mud	40,90%
TAMAC	Sand	0
TAMAS	Sand	0
TAMAN	Sand	12,90%

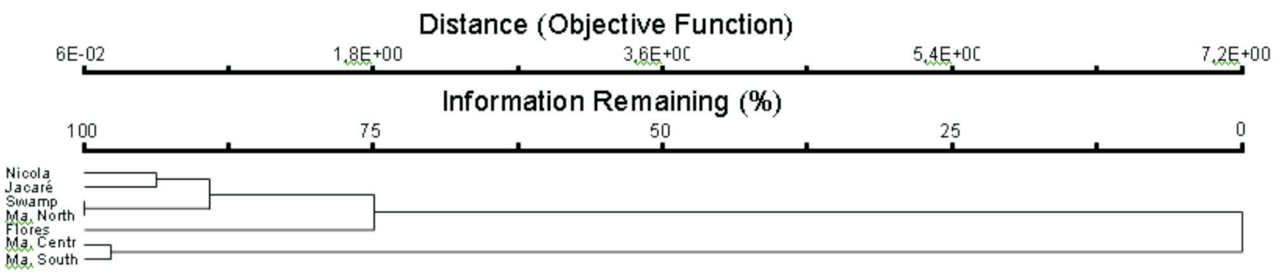

Figure 3. Cluster analysis (Euclidian distance; Ward´s method) of the sampling units based on physical and chemical variables.

Table 2. *Mean values of the spicules counting in the sediments and of the physical and chemical data of the water samples: Espic.: Spicules; Cond.: Conductivity; pH: Hydrogen potential; Sal.: salinity; Depth: deepness; STV: Total Volatile Solids; SSV: Volatile Suspended Solids; Hard.: Hardness; Sil: Dissolved Silica,; Acl: A chlorophyl.*

	TANI	TAMAB	TAFLO	TAJA	TAMAC	TAMAS	TAMAN
Espic	3,18	3	2,91	11,20	0,16	0,2	4,03
Cond.	0,23	0,32	0,07	0,30	0,31	0,29	0,33
pH	7,59	7,84	7,60	7,57	8,27	8,39	8,11
Sal.	0,11	0,18	0,03	0,16	0,17	0,16	0,18
Depth	2,09	2,25	3,22	2,37	2,40	2,31	2,83
STV	73,06	90,16	51,00	80,84	73,22	69,44	101,75
SSV	18,19	17,67	20,69	17,82	25,71	14,56	19,07
Hard.	63,16	91,92	26,77	80,00	83,74	83,57	88,76
Sil.	2,28	1,67	2,45	2,97	1,70	1,82	1,61
ACL.	4,71	13,00	22,31	11,97	37,41	11,97	19,25

Table 3. *Correlation of environmental characteristics (spicular abundancy, organic matter in the sediments, physical and chemical characteristics of the waters) with axis 1 e 2.*

Environmental Characteristics	Axis 1	Axis 2
Spicular abundancy	0,2335	0,3891
Conductivity	-0,4175	0,1623
pH	-0,3334	-0,3301
Salinity	-0,4211	0,1452
Depth	0,2585	-0,2702
Total Volatile Solids	-0,3249	0,2514
Volatile Suspended Solids	0,0651	-0,2813
Hardness	-0,4225	0,1542
Dissolved Silica	0,3096	0,2290
Chlorophyl a	-0,0258	-0,4365
Organic matter in sediments	0,1764	0,4584

Table 4. *Summary of the Principal Component Analysis (ACP). *= significant axis*

Axis	Eigenvalue	Variation %	% of Accumulated Variation	Broken-stick eigenvalue
1*	5,018	45,6	45,6	3,020
2*	3,357	30,5	76,1	2,020
3	1,410	12,8	88,9	1,520

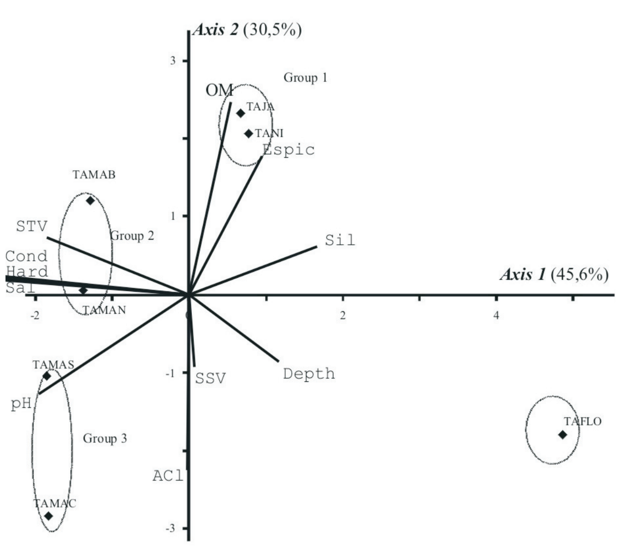

Figure 4. Distribution of the sampling units upon their environmental characteristics following Principal Component Analysis (axes 1 and 2) **Cond:** conductivity; **ACl:** clorophila**;** **Hard:** hardness; **Espic:** spicular abundance; **OM:** organic matter; **pH:** Hydrogen potential; **Depth:** depth; **Sal:** salinity; **Sil:** Dissolved Silica; **SSV:** Volatile Suspended Solids; **STV:** Total Volatile Solids.

Components Analysis, the eigenvectors revealed the strong positive contribution of silica and depth, opposed to low values of hardness, salinity, conductivity and total solids (Table 3, figure 4). The second axis showed the strong influence of chlorophyll *a*, pH and depth on its negative end, positioned oppositely to organic matter and spicule abundance, which contributed strongly to the ordination of sampling units on the positive end of this axis (Table 3, figure 4). Therefore, it is possible, from figure 4, to point out the environmental variables related to higher abundances of spicules, indicating greater production of gemmules, if not of sponges. To Group 1 belong Lagoa do Jacare and Lagoa Nicola, which presented the greatest values of accumulation of gemmoscleres and thus of gemmular/sponge production. These environments are characterised by high organic matter and silica values, and low pH, chlorophyll-a and depth. Group 2, which comprised Banhado da Lagoa Mangueira and Lagoa Mangueira Northern Region, had mid-range amounts of spicules, and is characterised by high values of conductivity, hardness and salinity for Mangueira Northern, and greater quantity of total solids for Banhado. It can be pointed out that Banhado also shows high values of organic matter, since it is evolving towards the positive end of axis two, which is correlated to this variable. Group three, composed of Lagoa Mangueira Southern Region and Central Region, was characterised by the lowest spicules counts, the lowest organic matter values, lower silica, high pH, high hardness, low total solids, high chlorophyll-a and great depth. Lagoa das Flores was separated from the remaining sampling stations due to its greater depth, great quantities of chlorophyll-a and silica, high pH and low organic matter concentration, with a mid-range spicules count, indicating also a mid-range sponge productivity. A marked preference of the sponges for organic matter concentration in sediments of shallow lakes was also found by HALL and HERRMANN (1980) in sediment cores of a lake in Colorado, USA, and by HARRISON and WARNER (1986) in sediments recovered from a bog lake at British Columbia, Canada. The fact that the spicular counting in the present sediments was carried upon the gemmoscleres takes to the demonstration of a continued gemmular production. Gemmules are produced in these latitudes at autumn, triggered by the reduced level of the waters at this period. The macrophytes are the first to suffer the water reduction because of their prefered localization along the marginal areas of the lakes. Since they are the substrates available to support the sponges a relation may be stablished between their exposition to the drought and that of the sponges in terms of their gemmullar production. So a final link may be drawn out of this macrophyte-sponge association signaling to the registration of the local hydroperiods.

CONCLUSIONS

Spicule content analysis in sediments could be related to environmental characteristics, indicating higher sponge production in environments evolving towards a swamp system, however still containing considerable amounts of free water and presence of marginal macrophytes, sources of organic matter and providers of the substrata necessary for fixation of such fauna in sandy environments. Since gemmular spicules were the sole ones counted their presence/abundance is evidence of a regular sucession of seasonal drier periods registered in the recent sediments of the sampled coastal freshwater bodies.

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