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## How does a riverine setting affect the lifestyle of shellmound builders in Brazil?

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### Abstract

The contact of inland and coastal prehistoric groups in Brazil is believed to have been restricted to regions with no geographical barrier, as is the case in the Ribeira de Iguape valley. The inland osteological collection from the riverine shellmound Moraes (5800–4500 BP) represents a unique opportunity to test this assumption for this region. Despite cultural similarities between riverine and coastal shellmounds, important ecological and site distribution differences are expected to impact on lifestyle. The purpose of this study is thus to document and interpret health and lifestyle indicators in Moraes in comparison to coastal shellmound groups. Specifically we test if the rare evidence of fish and mollusk remains in the riverine shellmound led to (a) higher caries rates and (b) lower auditory exostosis frequency and (c) if the small size of the riverine shellmound translates into reduced demographic density and thus rarity of communicable infectious diseases. Of the three hypotheses, (a) was confirmed, (b) was rejected and (c) was partly rejected. Bioanthropological similarities between Moraes and coastal shellmounds include auditory exostoses with equally high frequencies; significantly more frequent osteoarthritis in upper than in lower limbs; cranial and dental morphological affinities and low frequencies of violent trauma. However, there are also important differences: Moraes subsisted on a much broader protein diet and consumed more cariogenic food, but showed a stature even shorter than coastal groups. Thus, despite the contact also suggested by treponematoses in both site types, there was enough time for the people at the riverine site to adapt to local conditions.

### Resumo

O contato de grupos pré-históricos brasileiros interioranos e costeiros é tido como restrito a regiões sem barreiras geográficas, como é o caso do vale do Ribeira de Iguape. A coleção osteológica interiorana do sambaqui fluvial Moraes (5800–4500 pYB) representa uma oportunidade única para testar tal afirmação para a região sudeste. Embora haja similaridades culturais entre sambaquis fluviais e costeiros, espera-se que as importantes diferenças ecológicas e de padrão de assentamento influenciariam a saúde. No presente estudo, objetiva-se documentar e interpretar indicadores de saúde e estilo de vida dos habitantes de Moraes, em comparação com sambaquieiros da costa. Mais especificamente investigamos se as raras evidências faunísticas de peixe e molusco no sambaqui fluvial associam-se a (a) frequências de cáries mais elevadas, e (b) proporções menores de exostose auditiva e se (c) as diminutas dimensões do sítio fluvial correspondem a baixa densidade demográfica e consequentemente baixos índices de doenças infecciosas transmissíveis. Confirmou-se (a), enquanto (b) foi inteiramente, e (c) parcialmente, rejeitada. Semelhanças bioantropológicas entre habitantes de Moraes e sambaquieiros da costa incluem exostose auditiva em frequências igualmente altas; significativamente mais osteoartrose em membros superiores que inferiores; afinidades morfológicas dentárias e cranianas, assim como baixas frequências de traumatismos violentos. Entretanto, também foram constatadas diferenças importantes: os indivíduos de Moraes, de estatura ainda inferior a de sambaquieiros da costa, alimentavam-se de uma dieta mais cariogênica, sendo o aporte proteico mais diversificado. Assim, apesar do contato, sugerido inclusive através da presença de treponematose em ambos os tipos de sítio, houve tempo suficiente para o grupo fluvial adaptar-se a condições locais.



## Introduction

### *Brazilian shellmounds*

Almost the entire 8000 km long coast of Brazil was once inhabited by shellmound (or sambaqui) builders. More than 1000 coastal sites of this type, dated to between 8000 and 800 years ago, have been recorded (Gaspar, 1998; Lima et al., 2004). They vary in size and can reach seventy meters in height and several hundreds of meters in diameter (de Blasis et al., 2007). Consisting mainly of complex sequences of layers of shells and sand, they also contain hearths, artefacts, food remains, and elaborate burials associated with bone and stone offerings as well as ochre.

Coastal shellmounds in Brazil are currently considered as monumental constructions intentionally built by sedentary people with high population densities (de Blasis et al., 1998; Gaspar, 1998). Zooarchaeological and stable isotope studies have shown that coastal shellmound groups were fisher-gatherers with diets based on marine resources,

especially fish (De Masi, 1999; Figuti, 1992). The shells, thus, are not interpreted as food debris, but as construction material. Probably these people used boats, since there is evidence of shellmounds on islands, and remains of deep-sea fish species amongst the faunal remains (Gaspar, 2000; Tenório, 2000). The use of plants, albeit until recently believed to have been of minor importance, was in fact quite common (Boyadjian et al., 2007; Scheel-Ybert, 1998 and Scheel-Ybert, 2001; Scheel-Ybert et al., 2003; Wesolowski, 2000). Therefore, the intense dental wear in skeletal remains associated with shellmounds is today attributed more to the admixture of plant phytoliths, than to other abrasives, such as shell fragments and sand present in the food (Reinhard et al., 2001). Although the coastal Brazilian shellmound builders were of relatively short stature, they were within the range of variation of prehistoric and extant Native Americans (Storto et al., 1999). High frequency of non-specific infections in many shellmound groups is attributed to the intense contact with animal remains and pathogens typical for tropical coastal areas (Mendonça de Souza, 1995), whereas the evidence of specific communicable infectious diseases in some of the sites suggests high population density (Okumura and Eggers, 2005). Although many neighboring sites are contemporaneous, an overall low frequency of violent trauma among shellmound dwellers indicates a relatively peaceful lifestyle and little competition for food resources (Lessa and Medeiros, 2001; Okumura and Eggers, 2005).

Although coastal shellmound builders are Mongoloids (Okumura, 2007), as are the majority of extinct and extant Amerindians, Palaeoamericans with a premongoloid morphology have first colonized the New World (Neves and Hubbe, 2005; Neves et al., 2007). However, because the most recent Palaeoamericans and the oldest shellmound builders are roughly contemporaneous (and dated to around 10,000–8000 years ago), questions arise on the origin and the contact of shellmound dwellers with other populations. This issue gained more attention with the description of a Paleoamerican morphology of the oldest shellmound builder in Brazil, dated to about 9000 years ago (Neves et al., 2005). Astonishingly, the site where this oldest shellmound dweller was found is not a coastal site. It is a riverine shellmound called Capelinha, located in the Ribeira valley, in the interior of the southeastern state of São Paulo (Figure 1).

Apart from the more than 1000 coastal shellmounds, there are also about 50 riverine shellmounds recorded in Brazil. Riverine shellmounds have been studied more systematically since the eighties, although their existence is known since the end of the fourteenth century (Barreto, 1988). They are known as riverine shellmounds because they resemble coastal shellmounds in basic construction material (mainly mollusk shells of *Anomalocardia brasiliensis* in coastal and of *Megalobulimus* sp. in riverine sites), burial distribution and pattern, habitation structures and remains giving clues about daily activities (Eggers, in press; Figuti et al., 2004). Both were used concomitantly as a place for living, dwelling, eating, as well as for the interment of the dead (Figuti et al., 2004). The inland shellmounds are circular or ovoid structures, much smaller than those at most coastal sites, and measure only about 500–2000 m<sup>2</sup>.

A region that most recently yielded new data on riverine shellmounds is the neighborhood of Capelinha, the Ribeira valley, State of São Paulo. This valley is a geographic

and ecological transition between the highlands and the seashore and was inhabited since 9000 BP. About 30 riverine sambaquis have been found in this region (Figuti et al., 2004). The cultural similarity to coastal shellmounds, and the proximity of most of the riverine sites of the Ribeira valley to the biggest river in the region, suggest that the people who built these sites arrived there coming from the coast travelling up this river. This is supported by the presence of marine vestiges found in these riverine sites, such as shark teeth (Barreto, 1988).

### ***The riverine shellmounds at the Ribeira valley***

The Ribeira valley shows great spatial and microenvironmental compartmentalization. This allowed a broad range of human adaptive responses, confirmed by the different cultures that developed and flourished during its 9000 years long history (Figuti et al., 2004). The signs of human occupation found in this region belong to different cultures. First, there are shellmound builders such as the Paleoamerican Capelinha man (~9000 BP; Neves et al., 2005), then the geographic expansion of riverine shellmound peoples, such as those from Moraes analyzed herein, followed (~5000 BP; Figuti et al., 2004). Third, there are also signs of Umbu lithic traditions associated with hunter-gatherers (~1200 BP) and, finally, ceramic sites and burial places associated with Itararé horticulturalists (~500 years BP) found in a more restricted area (Figuti et al., 2004). The only site of this region, which rendered a reasonable number of human remains is Moraes—the subject of the present paper.

Despite the alleged cultural similarities, there are important ecological differences between coastal and riverine shellmound site distributions. Thus, riverine shellmound builders would be expected to show differences in health in comparison to coastal dwellers.

### ***Aims***

The purpose of this study, apart from being the first site report of Moraes for the international readership, is to document and interpret health and lifestyle indicators in two settings in south-southeastern Brazil: riverine (this paper) in comparison to coastal (using already published material) shellmound groups. Specifically, we investigate whether and, if and how ecological differences of site distribution and size, influence health status. Three main hypotheses are tested. These are: the rare evidence of fish and mollusk remains in the riverine shellmound (see below) reflects on (1) oral health, and (2) on the frequency of auditory exostosis and (3) the small size of the site translates into low population density and thus rare presence of communicable infectious diseases. We hypothesize, respectively, that in comparison to coastal people, the riverine group shows: (a) a significantly higher caries rate (since there is reduced protection against caries due to little aquatic food consumption, as inferred through the rare aquatic food remains); (b) significantly lower frequency of auditory exostoses (since contact with water seems to have been rare, based on the long distance to the sea and rare evidence of aquatic food remains and implements) and (c) lower frequency of

specific communicable infectious diseases (since these diseases thrive better in larger than in smaller communities).

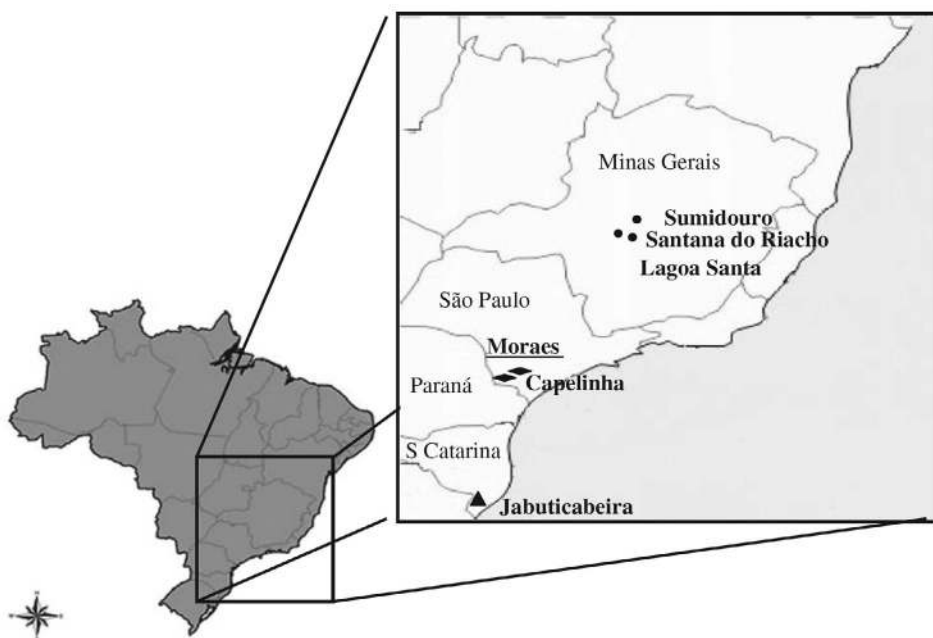
To test these hypotheses we use a classical non-destructive macroscopic approach to paleopathology, and include the major osteological markers not only to test the above-mentioned hypotheses, but also to explore other differences or similarities in health and lifestyle between these peoples. These will also include reports on biodistance.

### *The archaeological context of the Moraes riverine shellmound*

Dates of four skeletons of the Moraes riverine shellmound, also called Jaraçatiá (Collet, 1985), located 35 km inland from the coast (24°17'S and 47°28'W; Figuti et al., 2004; Figure 1), revealed an antiquity of  $5895 \pm 45$  to  $4511 \pm 32$  years BP (KIA 15561; KIA 20844).

This small shellmound (30 m diameter and 2 m height) revealed a relatively small number of stone tools (most commonly polished quartz axes and mortars). No ceramics or projectile points were found, but some implements such as perforators and hooks made of animal teeth and bone, especially of howler monkeys (*Alouatta* sp.), deer and peccary (*Tayassu tajacu*), were discovered (Figuti et al., 2004).

The faunal remains are highly diverse, indicating that the people from Moraes hunted mainly small animals such as primates, large rodents (*Agouti paca*), peccary (*Tayassu tajacu*), and skunks (Mephitidae). Remains of deer (Cervidae) and



**Figure 1.** Approximate location of the studied site Moraes and the sites mentioned in the text: Riverine (rhombus), coastal shellmounds (triangle), and Paleoamerican inland sites (full circle).



other bigger animals are rare. This points to a diverse protein diet obtained by broad-based hunting strategies. Besides the terrestrial faunal remains, occasional marine remains were also found. These include oysters (Ostreidae) and clams (*Lucina pectinata*), shark teeth (Selachimorpha) and artifacts made of ray spines (Chondrichthyes) (Figuti et al., 2004).

## Materials and methods

During the four field trips undertaken up to 2004, 40 burials were recorded, two of them being double and the rest single. Some of them were associated with mortars probably used to process plants (Figuti et al., 2004).

Since the osteological collection from Moraes includes mainly incomplete individuals (see below), the estimation of sex and age at death, according to Buikstra and Ubelaker (1994) could only be carried out in a minority of cases. This is also the reason why, in most of the analyses, we calculated the frequency of markers according to specific bones available for examination and not per individual. The diagnoses of lesions and alterations of shape and size were carried out macroscopically in a non-destructive and non-invasive manner and followed the criteria established by Ortner and Putschar (1985) and Aufderheide and Rodríguez-Martín (1998). Only bones more than 50% complete and with good preservation were considered. The specific criteria considered for diagnosis and interpretation are as follows:

### *Markers used to test the hypotheses*

High frequencies of caries (above 10%) suggest a cariogenic diet usually associated with agriculture (Turner, 1979). In the present study, caries, defined according to criteria established by Hilson (1996), were diagnosed visually with the aid of an odontological probe. Tooth affected, size and position of caries were recorded.

One of the more robust activity indicators are auditory exostoses. In temperate climates, high frequencies of auditory exostoses suggest frequent contact with cold water, during diving, fishing, surfing, sailing (Fabiani et al., 1984) or ritual bathing with temperature shock (Lambert, 2001). In tropical and subtropical regions this marker is not sensitive enough to detect these activities among all human groups known to have been heavily dependent on aquatic resources (Okumura et al., 2007). Here, using a magnifying glass and a small flashlight, auditory exostoses are identified as bony, not pedunculated, outgrowths of variable size in the outer ear channel of fully preserved meati.

Nonspecific infections are mainly due to local trauma or systemic processes such as infections by *Staphylococcus aureus* (Ortner and Putschar, 1985), leading to periostitis and osteomyelitis. High frequencies of these non-specific infections are seen as signs of a shift to agriculture, an increase in population density, sedentism and undernutrition (Larsen, 2002). Only bones more than 50% complete and with well preserved periosteal

surfaces were assessed for periostitis and osteomyelitis. When both infectious processes were identified on one bone, only osteomyelitis was recorded.

High population density may be inferred from the presence of communicable infectious diseases, such as treponematoses. Typical lesions (*caries sicca* and saber shin tibiae) as well as distribution patterns of lesions along the skeleton were used to identify treponematoses (Aufderheide and Rodríguez-Martín, 1998; Ortner and Putschar, 1985). In this paper no attempt was made to distinguish among the three types of treponematosis that affect the bone tissue (i.e., venereal syphilis, yaws and endemic syphilis).

### ***Markers used to explore further differences and similarities between riverine and coastal shellmound builders***

To countercheck caries frequency and make inferences about paleodiet, we included dental wear analyses in our study. A higher frequency of posterior than anterior dental wear suggests a diet rich in plant foods, usually also associated with agriculture (Brothwell, 1963; Larsen, 1997; Molnar, 1971; Smith, 1984). Here we used Smith's (1984) and Brothwell's (1963) criteria for anterior and posterior dental wear respectively. Maxillary and mandibular teeth belonging to the left and the right side were considered in one category. Only individuals with well preserved incisors or canines and first molars were included in the analysis.

Other markers critical for oral health and indirectly for paleodiet estimation are periapical abscesses and *antemortem* tooth loss. Abscesses are identified in this study by the presence of a drainage channel through the alveolar bone (Buikstra and Ubelaker, 1994). When the abscess persists or grows, the loss of teeth is the final consequence, leading to difficulties in mastication, speech and the loss of the ability to use teeth as tools to produce artefacts. *antemortem* tooth loss is diagnosed herein as any degree of alveolar resorption.

Related to paleodietary issues is the nutritional status. The growth of a child reflects nutritional status better than any other single marker (Eveleth and Tanner, 1990), whereas the final result of the interaction of heredity, diet, adaptation to climate and altitude as well as chronic diseases (especially infections) is adult stature (Ulijaszek, 1997). Adult stature was calculated here on all available complete long bone measurements and using the regression formula developed by Sciulli and Giesen (1993).

*Cribra orbitalia*, formerly interpreted as a sign of anemia (Stuart-Macadam and Kent, 1992), is seen today as a consequence of a broad range of physiological stressors such as malnutrition, diarrhea, gastrointestinal parasites, genetic diseases and/or low level of iron absorption during growth due to specific dietary components (Wapler et al., 2004). Pitting and porosity, with or without thickening and confluence of pores, remodeled or not, are considered here as indicative of *cribra orbitalia* in orbital roofs more than 50% intact. Porotic hyperostosis presents similar aetiology and diagnostic criteria as *cribra orbitalia*. Only occipitals and parietals more than 50% complete and with good preservation were considered.

To aid interpretation of activity we also included the evaluation of articular degeneration (or osteoarthritis). This is a multifactorial disease where sex, age, body build, nutrition, hormones and heredity play a role, but physical activity and mechanical stress are the most important contributing factors (Jurmain, 1999; Larsen, 1997). More frequent or severe osteoarthritis in upper than in lower limbs suggests activities such as swimming, diving and sailing among others (Bridges, 1991). Articular degeneration is identified here as porosity, osteophytes, lipping and/or eburnation on articular surfaces (Buikstra and Ubelaker, 1994) of upper limbs (shoulder, elbow, hand and wrist) and lower limbs (hip, knee, ankle and foot) more than 75% preserved, and is scored as present or absent.

Interpersonal conflicts as well as accidental trauma can shed light on the lifestyle of past populations. Fractures and trauma are mainly due to accidents and interpersonal violence (Aufderheide and Rodríguez-Martín, 1998; Ortner and Putschar, 1985). Therefore, fractures were included in this survey. All bones more than 50% complete were analyzed macroscopically for *antemortem* fractures with signs of healing. Their localization was used to distinguish between accidental fractures and interpersonal violence (such as Parry fractures or blunt fractures on the occipital).

Statistical analyses (Fisher's and chi-squared tests, adopting  $p < 0,05$ ) were only carried out for features present in anatomical units with a good sample size (caries per tooth, *antemortem* tooth loss, abscesses per alveolus, unspecific infections per bone and articular degeneration per joint). The frequencies of osteological markers from Moraes were discussed in relation to frequencies obtained from published reports on coastal shellmounds located in the South–Southeast of Brazil.

## Results

### *Burial types, minimum number of individuals, age at death and sex in Moraes*

At the end of three field seasons, 40 burials had been recorded (Figuti et al., 2004). Among these, 14 burials were reported to contain individuals in undetermined positions, and three were collected only partially. From the 42 individuals recorded, seven were not collected at all and at least four were not sent to our laboratory for curation processes and analyses.

A detailed study of the human remains at the laboratory revealed a minimum number of individuals (MNI) of 61 associated with 30 distinct burials. The high percentage of undetermined position (14/33 or 42.4%) and various post-depositional factors, such as erosion, animal, root and anthropogenic factors, could explain the discrepancy between the number of individuals recorded at the excavation and then estimated in the laboratory.

More than 40% (13/30) of the burials contained only one individual, whereas the rest contained remains of two (8/30), three (5/30) or four (4/30) individuals. Furthermore, most "multiple" burials contained only a small quantity of bones from each individual, due to the bad preservation and incompleteness of the majority of

skeletons. Of the 61 individuals, 40 presented with less than 25% of the anatomical units, 11 with 25–50%, six with 50–75%, whereas only four among them were more than 75% complete.

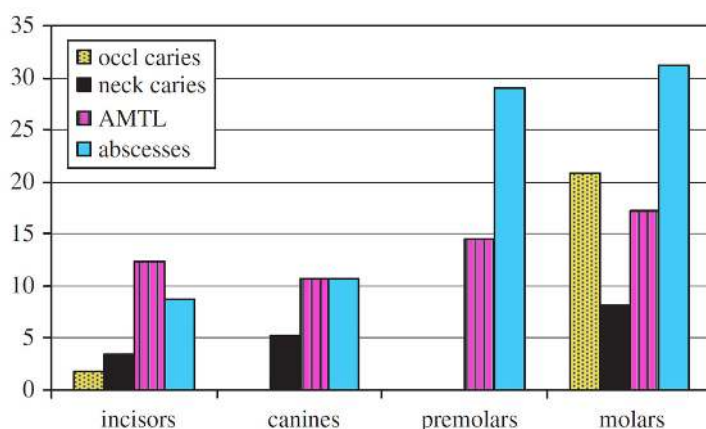
From the 61 individuals analyzed in the laboratory, at least four adults and five juveniles exhibited traces of ochre. Unfortunately, the study using Raman spectroscopy similar to that carried out on the thick ochre layer covering a bone from the coastal shellmound Jaboticabeira II (Edwards et al., 2001), was inconclusive for Moraes.

Due to the incompleteness of most individuals, age at death could be determined only in two-thirds of them. Accordingly, 36.1% (22/61) were assigned as adults, 44.3% (27/61) were juveniles, 11.5% (7/61) young adults, 6.5% (4/61) middle adults and finally 1.6% (1/61) old adults. Similarly, sex could be estimated in only half of the adults, with a higher but non-significant ( $\chi^2 = 0.69$ ,  $p = 0.405$ ) proportion of males (10/36, 27.8%) than females (7/36, 19.4%).

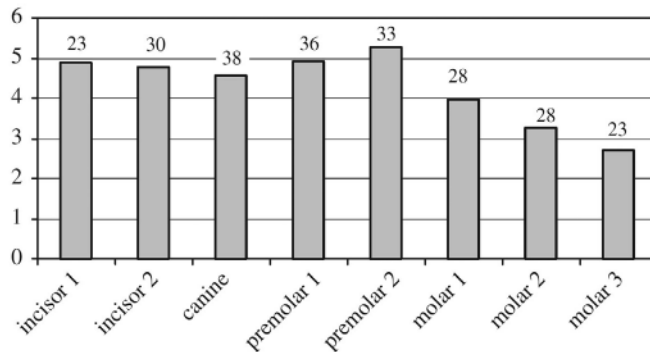
### Oral pathology

Among the 247 permanent teeth studied, 30 (or 12.2%) showed caries. Nineteen of them (63.3%) were occlusal and 11 (36.7%) were neck caries. Molars showed significantly more ( $\chi^2 = 18.5$   $p = 0.000$ ) occlusal as well as neck caries (7/86 and 18/86), than canines (2/38; 0/38) and incisors (2/57; 1/57) (Figure 2). Among carious teeth, anterior teeth (incisors and canines) showed significantly more neck caries, while molars presented more occlusal caries (Fisher  $p = 0.047$ ). No caries whatsoever were observed in premolars, although the sample size of this type of tooth ( $N = 66$ ) was not much smaller than that of molars ( $N = 86$ ).

Although the numerical value of the mean degree of dental wear seemed bigger for anterior teeth (Figure 3), its biological meaning was that anterior and posterior wear were almost equal in frequency, suggesting a diet similar to other hunter-gatherers. Due



**Figure 2.** Percentage of teeth ( $n = 247$ ) affected with occlusal caries or neck caries, and alveoli ( $n = 204$ ) affected with *antemortem* tooth loss and/or abscesses.



**Figure 3.** Mean degree of dental wear per tooth, including superior, inferior, left and right teeth of one type in the same category, using Smith's (1984) scale (range 1–8) for the anterior and Brothwell's (1963) scale (range 1–7) for the posterior dentition. On top of the bars are the numbers of teeth analyzed in each category.

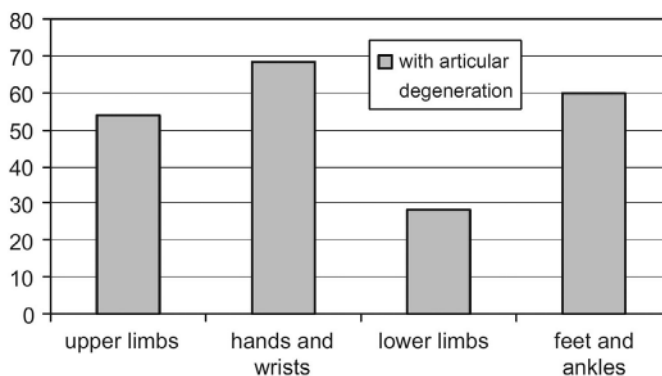
to the incompleteness of the skeletons, only 13 pairs of canines and first molars could be evaluated for dental wear pattern. Among them, four individuals (30.8%) presented more posterior wear, 3 (23.1%) presented more anterior wear, whereas six individuals (46.2%) presented similar degrees of anterior and posterior dental wear. A higher frequency of posterior dental wear was suggestive of horticulture. When however comparing pairs of incisors, instead of canines, and first molars, totaling 11 individuals, five showed more anterior, whereas four showed more posterior wear. The remaining two showed equal wear. This pattern suggested a hunter-gatherer diet. The difference between both methods was due to only one individual.

Among 204 alveoli studied, 29 (14.2%) showed at least partial resorption, indicating *antemortem* tooth loss (AMTL), while 44 (21.6%) presented active abscessing (Absc). Both pathologies were significantly more frequent ( $\chi^2 = 13.5$   $p < 0.01$ ) in the posterior (premolars: AMTL 8/55, Absc 16/55; molars: AMTL 11/64, Absc 20/64) than in the anterior dentition (incisors: AMTL 7/57, Absc 5/57; canines: AMTL 3/28, Absc 3/28) (Figure 2).

#### ***Activity markers: auditory exostosis, articular degeneration and trauma***

The remains of 61 individuals from Moraes yielded only 18 adult auditory meatii preserved well enough for the analysis of auditory exostosis. Among them, four (or 22.2%) presented bony outgrowths typical for auditory exostosis.

Since we considered only articular surfaces more than 75% preserved, only 23 out of the 61 individuals could be included in the analysis of articular degeneration. These ranged from 15 to more than 50 years of age at death and were classified as four juveniles and 19 adults. The frequency of articular degeneration was significantly higher ( $\chi^2 = 7.90$ ,  $p = 0.000$ ) in upper (43/80 = 53.8%) than lower limbs (11/39 = 28.2%) among adults (considering shoulder and elbow, hip and knee) (Figure 4). This result was corroborated by a significantly higher ( $\chi^2 = 7.23$ ,  $p = 0.010$ ) frequency of osteoarthritis



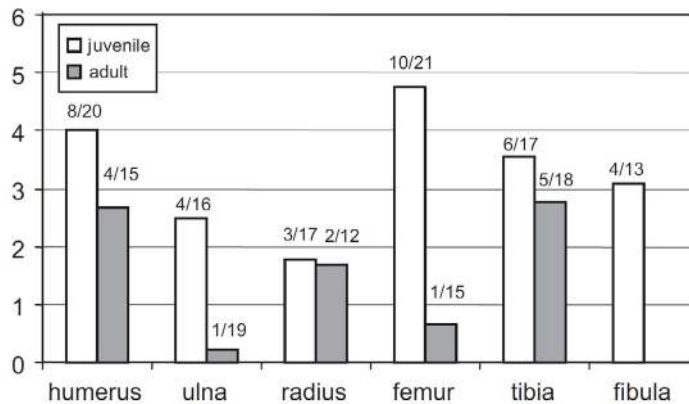
**Figure 4.** Distribution of osteoarthritis frequency (%) among adult bones from Moraes.

in hands and wrists ( $362/528 = 68.6\%$ ) than in feet and ankles ( $219/366 = 59.8\%$ ) of adults (Figure 4). Men ( $22/35 = 62.9\%$ ) showed more affected articular facets of upper limbs than women ( $17/40 = 42.5\%$ ). However, this difference reached no statistical significance, due to the small sample with estimated sex. Altogether the osteoarthrosis results suggested that more intense and/or frequent activities were carried out with upper than lower limbs, especially among males.

From the remains of 61 individuals, only three presented evidences of trauma. One young adult of undetermined sex showed a partially fractured but healing ulna and a clavicle with a healing wound. Another adult of undetermined sex presented healing fractures in the upper left radius and in a phalanx. Both these individuals showed fractures suggestive of accidents. Only one adult male showed evidence of interpersonal violence. Just above the nuchal crest, his occipital showed a compressed, elliptical ( $\sim 2 \times 1$  cm) wound, with porosity, indicating a healing inflammation possibly secondary to a violent cranial trauma.

### *Infectious diseases*

The frequency of periostitis in the bones excavated at Moraes reached values ranging from 17.6% (radius) to 47.6% (femur) among juveniles and 0 (fibula) to 27.8% (tibia) among adults depending on the bone (Figure 5). Juveniles ( $< 21$  years old) presented a significantly ( $\chi^2 = 10.27$ ,  $p = 0.00$ ) higher frequency of periostitis ( $35/104 = 33.7\%$ ) than adults ( $13/93 = 14.0\%$ ) as seen in Figure 5, holding true for all long bones analyzed. Osteomyelitis was also more frequent among juveniles ( $7/45 = 15.6\%$ ) than adults ( $2/33 = 6.1\%$ ), but reached no statistical significance. The bone most often affected with osteomyelitis in juveniles was the tibia ( $4/17 = 23.5\%$ ), followed by radius ( $2/17 = 11.8\%$ ) and femur ( $1/21 = 4.8\%$ ). Among adults the bone most often affected with osteomyelitis was the femur ( $1/15 = 6.7\%$ ), followed closely by the tibia ( $1/18 = 5.6\%$ ).



**Figure 5.** Percentage of juvenile and adult long bones affected with periostitis. On top of the bars are the numbers of affected/available bones in each category.

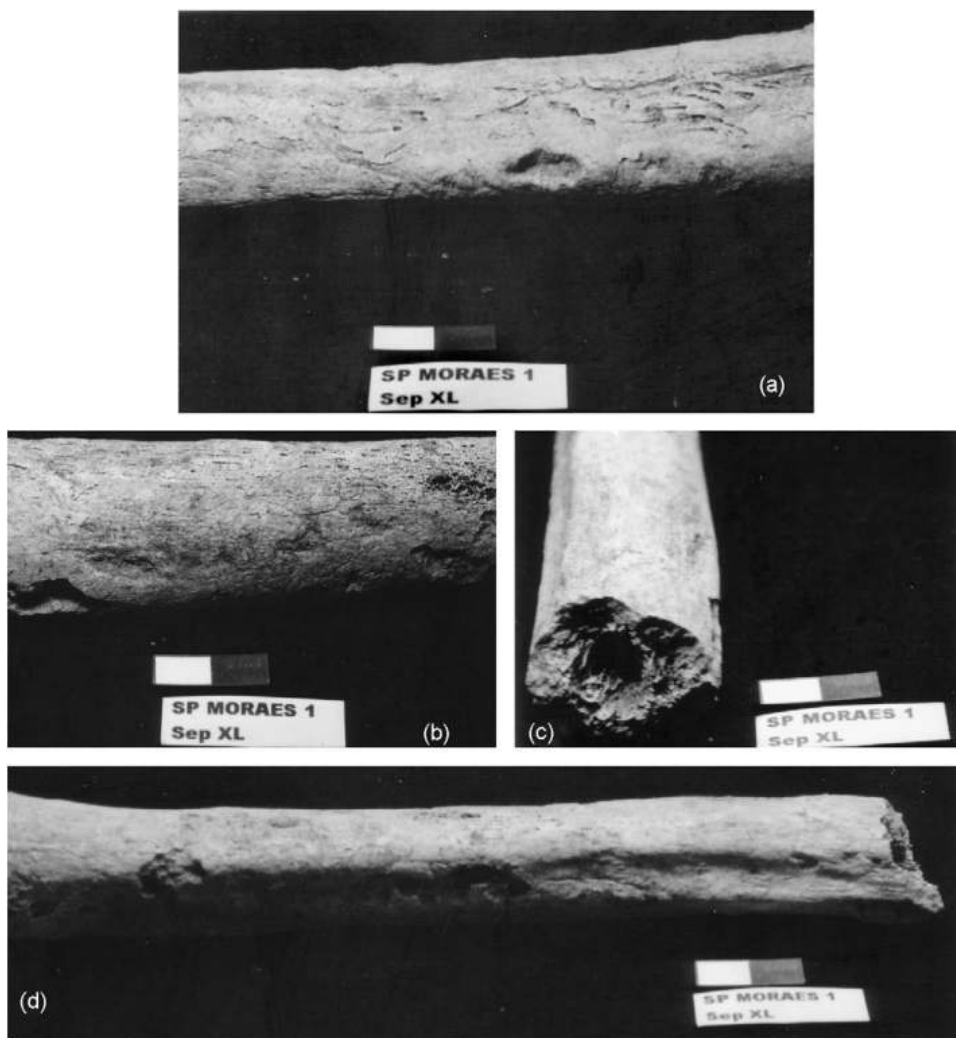
There was only one individual with clear evidence of treponematosi in the analyzed sample. It was a robust adult of undetermined sex, whose disturbed burial contained disarticulated, but very well preserved long bone fragments. Diaphyses of tibiae, femora and a fibula presented active lytic, porous and gummatous lesions, signs of osteomyelitis (however without evidence of cloacae) and bony bridges (Figure 6). The bony bridges seemed to have covered blood vessels running up the femoral shaft. On cross section, the medullary cavities of the femora were reduced and there was anterior thickening of the tibiae and one of the femora. Although the cranium was not present and could not be evaluated, the observations on the long bones suggest treponematosi.

### **Other markers**

Only nine orbital roofs and 17 parietals and occipitals more than 50% complete could be analyzed for *cribra orbitalia* and porotic hyperostosis, yielding frequencies of 55.6% and 41.2% respectively. Although not statistically significant, juveniles presented a higher frequency of *cribra orbitalia* (*cribra*: 4/6 = 66.7%; hyperostosis: 3/10 = 33.3%), whereas adults showed a higher frequency of porotic hyperostosis (*cribra*: 1/3 = 33.3%; hyperostosis: 4/7 = 57.1%). In fact, four among five recorded *cribra orbitalia* were associated with juveniles and were still active at death, and all four adult cranial bones with porotic hyperostosis were already remodeled at death. Curiously, when dividing the already small sample according to sex, males tended to show higher frequencies of *cribra orbitalia* (2/5) as well as porotic hyperostosis (4/5) than females (0/5 and 2/5 respectively). If this was not due to a bias, males seemed to have suffered more from nutritional and health problems than females.

Stature could be calculated only for four adults (two men and two women). As seen in Figure 7, women were expectedly smaller than men, the sexual dimorphism varying between 10.6 and 13.1 cm. Adult male (143.45, SD = 2.74; 150.58, SD = 3.92 cm) and female (133.39, SD = 3.61; 137.57, SD = 2.54 cm) stature in Moraes was very short.



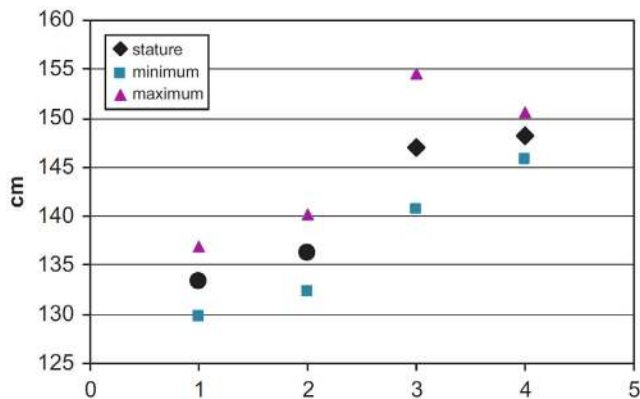


**Figure 6.** Lesions of a robust adult of undetermined sex (Moraes burial 40 or Sep XL): (a) bony bridges and gummateous lesions-femur; (b) active lithic and porous lesion-femur; (c) reduced medullary cavity-femur and (d) lesions on fibula.

## Discussion

The ecological and size differences between the culturally similar settlements occupied by inland and coastal shellmound groups in south-southeastern Brazil, led us to investigate whether this settlement distinctiveness had an impact on health status of the inland group. Specifically we tested, in comparison to the published data on coastal groups, if the rare evidence of fish and mollusk remains in the riverine shellmound led





**Figure 7.** Mean, minimum and maximum stature (estimated according to Sciulli and Giesen, 1993) of adults from Moraes. Individuals 1 and 2 are female and individuals 3 and 4 are male.

to (1) higher caries rates and (2) lower frequency of auditory exostoses and (3) whether the small size of the riverine shellmound translated into lower population density, and thus to rare occurrence of communicable infectious diseases.

Place, time and nature of the contact of Brazilian inland populations with those living at the coast (Barreto, 1988; Schmitz, 1996; Schmitz et al., 1993) are still a matter of discussion. One of the regions where this contact was not hindered by geographic barriers is the Ribeira valley. The only reasonably large human osteological collection excavated in this region, contemporaneous and geographically close to most of the already better studied coastal shellmounds, is the riverine shellmound Moraes. This paper, apart from testing the above-mentioned hypotheses, also represents the first bioarchaeological report on the Moraes site for an international readership. Albeit a unique opportunity for research, the osteological collection of this recently excavated riverine shellmound has clear drawbacks, precluding paleodemographic studies and hindering the estimation of osteological markers per individual, until further material can be analyzed. Thus, the results presented and discussed herein are frequencies per anatomical unit or bone. Whilst these problems can only be solved through new excavations, the Moraes osteological collection today is the only one in Brazil that permits testing adaptation to a riverine paleoenvironment of a shellmound group with clear cultural associations to the shellmound dwellers living at the coast. In the following sections we address and discuss each of the initial hypotheses.

### ***High caries frequency, carbohydrate rich diet and short stature***

The frequency of 12% carious teeth in Moraes lies well above the less than 4% rates found for the majority of coastal shellmound groups that lived in south-southeastern Brazil (Neves and Wesolowski, 2002; Scheel-Ybert et al., 2003). Some rare coastal

series of this region, however, do show caries frequencies between 6% and 13%, and albeit not associated with pottery, their diet must have been rich in carbohydrates (Neves and Wesolowski, 2002; Scheel-Ybert et al., 2003; Wesolowski, 2000). These high caries frequencies for hunter-gatherers are not unique: Palaeoamericans from Santana do Riacho and Sumidouro, located in the State of Minas Gerais (see Figure 1), show about 9% of their teeth affected by caries (Neves and Cornero, 1997). Thus, the people from Moraes must also have had a cariogenic diet with high carbohydrate intake, as opposed to the majority, but not all, coastal shellmound builders.

Often high caries rates have been directly associated with plant domestication. The small sample size however, did not permit us to clearly distinguish if the dental wear pattern resembled more that of a hunter-gatherer diet or the pattern associated with a diet based on domesticated plants. Thus, the dental wear analysis in Moraes must be considered either non-informative or indicative of a mixed diet, but it seems to exclude a typical agricultural diet. Similar dental wear studies of human remains from coastal shellmounds have indicated a hunter-gatherer diet in eight among nine sites studied (Scheel-Ybert et al., 2003). The high frequency of neck caries suggests food impaction, low fluoride in the water, poor hygiene and consumption of alcoholic beverages (that could have been produced by fermented tubers).

The results of microfossil analysis of dental calculus show that Moraes' high caries rate (12%) is possibly associated with a significantly higher concentration of starch grains (some of them cooked) in dental calculus than that observed in the people from the coastal site Jabuticabeira II (Boyadjian et al., 2007), who show a very low caries frequency (0.44%—Okumura and Eggers, 2005). Considering this evidence and the absence of indicators of plant domestication at a large scale, we conclude that the cariogenic intake in Moraes possibly consisted of energy rich plants, such as tubers (Boyadjian et al., 2007), gathered randomly and/or harvested as a product of incipient farming.

Zooarchaeological studies suggest that protein intake in Moraes was composed of a wide range of small terrestrial game, such as little primates, peccary, skunk and small deer (Figuti et al., 2004). In contrast, most coastal shellmound groups based their subsistence mainly on fish (Scheel-Ybert et al., 2003; de Masi, 1999).

These indicators and the fact, that the Atlantic forest is a combination of coastal rain-forest and semi-deciduous forest with high species diversity (Morellato and Haddad, 2000), suggest that protein and caloric intake among the Moraes people could have been adequate. If this inference is correct, the very short stature of the people from Moraes is unexpected. Even in comparison to adult stature of coastal sambaquis and other pre-historic and extant Amerindians (156–167 cm for males and 148–157 cm for females—Okumura and Eggers, 2005; Scheel-Ybert et al., 2003; Storto et al., 1999), the people from Moraes are indeed very small (males: 141–155 cm; females: 130–140 cm).

Since, in Moraes, malnutrition might be excluded as an explanation for adult stature stunting, other physiological stressors, must be explored. Two markers are especially useful for that: *cribra orbitalia* and porotic hyperostosis. The high frequencies of *cribra orbitalia* (~56%) and porotic hyperostosis (~41%) found in the sample from Moraes suggest that childhood and growth in Moraes was physiologically stressing, especially for males. These juvenile stress indicators are also frequent in most coastal

shellmound builders, ranging from 20% to 70% (Mendonça de Souza, 1995; Neves and Wesolowski, 2002; Okumura and Eggers, 2005; Scheel-Ybert et al., 2003; Storto et al., 1999). Since the frequencies of these markers in Moraes are not much different as compared to the majority of coastal sites (with higher adult stature), they do not satisfactorily explain adult stature stunting in this inland site.

An alternative or complementary hypothesis for adult stature stunting regards the frequent unspecific infections that affect significantly more juveniles than adults. Indeed juveniles from Moraes show significantly higher frequencies of periostitis than adults (34% and 14%). High frequency of infections can be expected since infant mortality is usually high in prehistoric populations, although the high mortality of adolescents is usually not expected (Aufderheide and Rodríguez-Martín, 1998; Waldron, 1994). Furthermore, juveniles and especially children are more prone to infectious diseases and parasitism (Reinhard, 1992) and show weaker immunological responses especially in the weaning period. Frequencies of stress indicators in Moraes (*cribra orbitalia*, porotic hyperostosis, unspecific infections) decrease from juveniles to adults, suggesting that nutrition and general health at this site may have improved with adulthood.

Frequency of unspecific infections in adults, however, seems not to have been so high in Moraes. The rate of adult tibiae affected with periostitis (28%) is lower than in eight of nine coastal shellmounds, where frequencies range from 20% to 96% (Scheel-Ybert et al., 2003). Thus, overall, infectious diseases seem not to have afflicted the adults from the inland group as intensely as they usually did affect the coastal groups. In fact, some of the causes leading to high infection rates among coastal dwellers, such as frequent contact with dead animals (mollusks used for site construction), living in swamp regions with brackish waters, rendering a high pathogenic load (Mendonça de Souza, 1995) do not apply to Moraes because of its site location characteristics (Eggers, in press; Figuti et al., 2004). On the other hand, the good overall health index reported for the coastal shellmounds analyzed by Neves and Wesolowski (2002), and interpreted as a consequence of natural waste removal by the tide, also does not apply to Moraes.

Finally, the main contributors to adult stature stunting in Moraes (if not a bias) seem not to have been either generalized malnutrition or (adaptation to) recurrent infections. Either the premise that caloric and dietary protein intake was sufficient is incorrect or many factors acted together to lead to such a small adult stature. Identification of plants eaten, microfossil identification in stone tools, research on enamel hypoplasia, stable isotopes and elemental analyses are among the subjects that should be studied to further elucidate this question.

In conclusion, the caries data and the inferences made on paleodiet so far confirm the first hypothesis addressed in this paper: the people of Moraes had a higher caries rate than the coastal populations. This must be related, at least in part, to less frequent intake of aquatic foods, as predicted, and also to a more cariogenic food intake than is inferred for most coastal shellmounds. It should be stressed however, that no evidence, until now, supports an agricultural subsistence for this group.

### ***Frequency of auditory exostoses: Aquatic activity?***

Curiously, the frequency of auditory exostoses (traditionally seen as an aquatic activity marker) is as high (22%) in Moraes as in coastal shellmounds from South Brazil (23–24%) and higher than in nearby coastal states of São Paulo and Paraná (16%) (Okumura et al., 2007). This is especially noteworthy when considering that the people from Moraes did not live at the coast or near lakes; they did not base their subsistence on aquatic resources (despite the rare fishhooks and scarce marine faunal remains found at the site); and, they lived in a subtropical environment, where this frequency is usually low, even in people highly dependent on aquatic resources (Okumura et al., 2007). The high frequency of auditory exostoses in Moraes could be due to (a) a small sample size; (b) cold atmospheric temperatures associated with strong wind chill effects, (c) frequent contact with water during trips to and seasons (perhaps preferably winter) spent at the coast or (d) bathing rituals where the ears are exposed to thermal shock (as described in detail in Lambert, 2001). To reject the interpretation of a small sample size, more skeletons need to be excavated and analyzed. Since there is not enough data on paleoclimate in nearby regions (b) cannot be entirely rejected (but see Melo et al., 2003). Even in view of the total lack of ethnographic data on bathing rituals for prehistoric populations of this region, (d) also cannot be rejected, because these rituals were documented for many different extant Brazilian Amerindian tribes, such as the Kaingang (Baptista da Silva, 2002). Finally, the possibility (c) is discussed below.

Although the results of osteoarthritis distribution in the human bones from Moraes show that the peoples' upper limbs were more frequently and more intensely affected than their lower limbs, no specific activity can be considered as the only contributing factor. What can be said is that walking distances seem to have been relatively small in comparison to the effort, frequency and intensity of physical activities carried out with the upper limbs. These would include aquatic activities, as suggested for coastal sambaqui groups (Neves, 1986; Okumura and Eggers, 2005; Petronilho, 2005; Rodrigues-Carvalho, 2004), and indirectly supported by the few marine faunal elements found at this inland shellmound. However, inland site distribution, zooarchaeological, caries and dental calculus results seem not to be in conformity with that, since few fish remains, a high caries rate and many starch grains suggesting highly cariogenic (and low marine) diet were found. It is intriguing, however, that the data on auditory exostoses may be interpreted as pointing towards aquatic activities. If indeed they were carried out intensely by the people of Moraes, males seem to have engaged more often in these activities than females, since males show significantly more osteoarthritis in upper than in lower limbs, whereas females do not; and only males from Moraes have auditory exostoses. Another explanation would be a matrilineal social pattern, where males would have come from the coast to live with inland women in Moraes. However, cranial biodistance data have not yielded significant differences between men and women in Moraes, most probably due to the small sample size (Neves and Okumura, 2005).

The excavation of larger samples of both sexes from Moraes for biodistance analyses is needed in order to shed more light on the possibility of matrilineal pattern. Additionally, stable isotope studies should reveal whether diet, especially among males, was based more on marine resources than zooarchaeological data have revealed until now. This is to see whether men spent much time living in coastal environments. Alternatively, more intensive articular degeneration in upper than lower limbs can also occur as a result of polishing stone artefacts, as those found in Moraes (Figuti et al., 2004). But this assumption seems not so parsimonious. Finally, as mentioned before, the ritual bathing hypothesis developed by Lambert (2001) cannot be excluded in the case of the people from Moraes, since accounts on ritual bathing abound for extant Brazilian Amerindian groups.

In conclusion, the second hypothesis tested in this paper is rejected, since this inland shellmound population does not show as low a frequency of auditory exostoses as has been expected. What caused the high frequency of auditory exostoses in the Moraes group has to be further investigated.

### *Inferences on treponemal disease*

Some inferences about contact with other human groups can be drawn on the basis of contagious diseases. Although, among the human remains from Moraes only one incomplete but well preserved skeleton of a robust adult of undetermined sex showed evidence of treponematoses, treponematoses have been repeatedly reported among pre-Columbian Amerindians, especially in sedentary agricultural groups with high population density (Hutchinson and Richman, 2006; Larsen, 1994).

One single case of treponematoses in a group of 61 individuals does not allow stringent inferences about population density. This is based on the finding that the same types of skeletal lesions suggestive of treponematoses appear in the archaic as in the later pre-contact groups of North America (Powell and Cook, 2005). However, the prevalence of treponemal diseases in North-American Indians rises sharply from pre-sedentary and small archaic groups (5.8%) to the beginning of village life (with much higher population density) by 1000 BCE (9.0%). If the varying percentage of yaws-seropositive people with bone lesions (8.5–58.0%; Manning and Ogle, 2002; Pampiglione and Wilkinson, 1975) is considered, then it can be assumed that in Moraes, many more individuals than the one found with the treponemal osseous lesions, could have been infected by some kind of treponematoses. However, these individuals are not showing bony signs of the disease, as predicted by the osteological paradox. For this reason this single case is noteworthy. This also adds new data to the very scanty information on pre-contact treponematoses in non-Andean South America (Brothwell, 2005). It should not be forgotten also, that the high prevalences of unspecific periostitis shown by the juveniles from Moraes can be suggestive of treponemal diseases (as well as other chronic diseases) affecting mainly young children.

On the other hand, Moraes was a relatively small site, thus high population density would not be expected there. Alternatively, treponematoses in huge, sedentary, complex

coastal shellmounds nearby, could have been the source of infection among the people from Moraes during their hypothetical seasonal trips to the coast. The scarcity of reports about treponematoses in shellmound populations (but see, Okumura and Eggers, 2005), unfortunately still precludes inferences about where and how exactly the people from Moraes might have become infected with treponematoses.

The last and important evidence linking riverine and coastal shellmound builders in south–southeastern Brazil is their cranial and dental morphology. Although there is one study reporting significant difference of non-metric cranial variables between these groups (Filippini and Eggers, 2005/2006), two other studies reach different conclusions, possibly due to the fact that more sites have been included for comparison (Eggers, *in press*). These reveal the gene flow between the inhabitants of Moraes and those living on nearby seashores of the states of São Paulo and Paraná (Bartolomucci, 2006; Neves and Okumura, 2005).

If there was gene flow between the riverine shellmound dwellers from Moraes and the shellmound groups from the coastal strip of the São Paulo and Paraná states, and this was significant, and if those people at the coast were numerous living in high population density, then this combination of factors could explain the presence of treponematosis in Moraes.

As found for most coastal shellmound dwellers of south and southeastern Brazil (Lessa, 2005/2006; Lessa and Medeiros, 2001; Okumura and Eggers, 2005; Storto et al., 1999), the people from Moraes also seem to have been rarely engaged in interpersonal conflicts that lead to physical violence and accidents. Only one out of 61 Moraes individuals showed lesions compatible with violence. From this perspective, life seems to have been tranquil for these people since trauma of any origin was very rare. Thus, considering that shellmound dwellers from the inland and the coast show low trauma rates, the contact between these groups must have been amicable. This conclusion might be wrong when we consider the incomplete state of the osteological collection and, that bones with lesions can more frequently get damaged by taphonomic factors than the healthy ones, thus, leading to underestimation of trauma occurrence.

Finally, according to the third hypothesis, it was predicted that the small size of the site would translate into low population density and thus, low frequency of communicable infectious diseases. Albeit controversial, the evidence available until the present, points towards the rejection of this hypothesis. The single case of possible treponematosis in Moraes can suggest higher population density than predicted, or can suggest contact with other groups where treponemae could thrive. Of these two explanations the second seems more reasonable, since there are genetic affinities between Moraes and nearby coastal groups, some marine faunal remains in the inland site and cultural similarities between riverine and coastal shellmounds.

## Concluding remarks

Of the three initial hypotheses one was confirmed, one was rejected and the last partly rejected. High caries frequency indeed suggests a cariogenic diet; frequency of



auditory exostoses is unexpectedly high suggesting seasons spent at the coast, whereas the single case of treponematosi may point to a higher population density or to contacts with groups living in conditions where treponematosi could have an impact on the population.

There are many bioanthropological similarities between the riverine shellmound Moraes and coastal sambaquis in the south-southeastern part of Brazil. These similarities include (a) auditory exostoses with equally high frequencies (this work; Okumura et al., 2007); (b) significantly more frequent osteoarthritis in upper than in lower limbs (this work and Scheel-Ybert et al., 2003; Scheel-Ybert et al., 2008); (c) similarities in craniometric and non-metric dental characteristics (Bartolomucci, 2006; Neves and Okumura, 2005) and finally (d) low frequencies, if any, of violent trauma (this work; Lessa, 2005/2006; Lessa and Medeiros, 2001; Okumura and Eggers, 2005). These biological similarities are in accordance with some cultural similarities between these two groups such as the use of shark teeth, ray spines, hooks, and especially the habit of collecting shells and using them for site construction in both types of sites.

There are also differences in some important aspects. The riverine group seems to have subsisted on a much broader protein diet and consumed more cariogenic food than did the coastal groups. Nevertheless, the stature of the riverine people is even smaller than of the coastal people. The reasons for that are not yet clear, and need further investigation. In general, there seems to have been enough time for the people at the riverine site Moraes to adapt to local conditions.

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