


AMOURINS SHELLMOUND: UNCOVERING BIODIVERSITY AND CHRONOLOGY THROUGH CHARCOAL ANALYSES

Kita D Macario^{1*}  • Rita Scheel-Ybert² • Natacha Ribeiro-Pinto² • Bruna B Pereira¹ • Dayanne Amaral^{1,3} • Eduardo Q Alves^{1,4}

¹Universidade Federal Fluminense, Instituto de Física, Av. Gal. Milton Tavares de Souza s/n, 24210–346 - Niterói, RJ, Brazil

²Museu Nacional da Universidade Federal do Rio de Janeiro (UFRJ), Rio de Janeiro, Brazil

³Centro Federal de Educação Tecnológica Celso Suckow da Fonseca, campus Nova Friburgo, Av. Governador Roberto Silveira, 1900, Prado - Nova Friburgo, RJ, Brazil

⁴Oxford Radiocarbon Accelerator Unit, University of Oxford, OX1 3TG Oxford, United Kingdom

ABSTRACT. In paleoenvironmental research, several proxies are used to reconstruct climate and vegetation. The establishment of a chronological framework allows for the association of different proxies and correlation of events happening in different geographic areas. Cultural deposits, such as the shellmounds found along the coast of Brazil, play an important role in paleoenvironmental interpretations. Here, we have employed anthracological analysis in charcoal fragments from the Amourins shellmound, located at the margins of the Guanabara Bay, Rio de Janeiro. This allowed for the taxonomic identification and selection of short-lived trees and specific parts of plants for accurate radiocarbon dating. We recorded genera and families typical of the Atlantic Forest, *restinga* forest, open *restinga* and mangrove. The ¹⁴C ages of charred nuts from different occupational layers range from 3807 ± 35 to 3503 ± 70 BP and a sequential chronological model was built, relating the predominance of mangrove vegetation to the period between 4130–3960 cal BP.

KEYWORDS: anthracology, Brazil, chronology, paleoenvironment.

INTRODUCTION

Brazil is well known for its abundant natural resources, biodiversity, and a very productive coastal environment that allowed the proliferation of shellmounds over the last millennia (Gaspar et al. 2013). Built by fisher-gatherers, possibly gardeners (Scheel-Ybert and Boyadjian 2020), these archaeological sites are mainly constituted by marine mollusk shells, but also contain a variety of materials of different origins that can be constrained to specific occupational layers within the settlement. For this reason, shellmounds can be used for environmental reconstruction. The remains recovered from these sites comprise human bones, lithic tools, charcoal fragments, and both marine and terrestrial animal remains, reflecting the surrounding environment. These sites have been used, for example, to quantify the local radiocarbon (¹⁴C) marine reservoir effect (Macario et al. 2015, 2016), and consequently, to study ocean dynamics (Macario et al. 2016, 2017). The presence and frequency of certain mollusk species have been used as a record for biodiversity (e.g., De Souza et al. 2010), while fishery techniques could be inferred from the distribution of fish otoliths within the sites (Lopes et al. 2016). Even the soil in the surroundings can provide information regarding vegetation conditions during the site occupation (e.g., Coe et al. 2017). From a more archaeological perspective, the analysis of charcoal fragments and carbonized shells and bones is important for the study of funerary rituals happening at the sites, reflecting the importance of fire for these societies (cf. Bianchini and Scheel-Ybert 2012; Scheel-Ybert 2018b).

In order to assess the paleovegetation, techniques such as palynology (e.g., Salgado-Labouriau 1961; Jansonius and McGregor 1996), stable isotopes (e.g., Moraes et al. 2017; Lorente et al.

*Corresponding author. Email: kitamacario@id.uff.br.

2018), anthracology (e.g., Scheel-Ybert 2018a) and phytolith analysis (e.g., Calegari et al. 2017; Coe et al. 2014) are usually employed. Whenever possible, these should be accompanied by a proper chronological evaluation of the samples so variations in different records can be accurately correlated. For this reason, it is imperative that dating methods are applied to the same entities analyzed by the techniques mentioned above. In this context, the association of anthracology and the ^{14}C dating of charcoal from archaeological sites allows the identification of plants used in ritual practices, the understanding of the formation process of the site and the chronology of vegetation changes in a given region. Charcoal found in archaeological sites may be the result of either natural or anthropogenic processes.

Anthracology, which is the charcoal analysis and identification based on wood anatomy criteria, deals with both archaeological and pedological/geological samples. In archaeological contexts, it provides both palaeoenvironmental and landscape reconstitutions as well as palaeoethnobotanical information on the use of plants. This discipline allows reliable reconstructions of local woody vegetation, since the confrontation with phytosociological data (vegetation structure) is rather direct, and carbonized macroremains are usually abundant in all archaeological sediments (Scheel-Ybert 2000, 2018a). Archaeological charcoal samples have to be classified according to the context where they are found. Concentrated charcoal fragments are usually related to hearths used for various reasons (e.g., ritual, protection, cooking) and, thus, are not particularly useful for paleoenvironmental studies (Théry-Parisot et al. 2010), unless it can be asserted that these features had a long duration (Scheel-Ybert 2018a). This is because these events tend to have a short duration and therefore the plant assemblage they represent is statistically poor, meaning that the vegetation record preserved is incomplete and not representative of the environment where the site is located (Chabal 1997). Dispersed charcoal fragments, on the other hand, are considered to be a synthetic record of the surrounding vegetation, as they comprise the remains of several activities that, in the long term, result in a charcoal assemblage that reliably represents the local vegetation (Chabal 1997; Scheel-Ybert 2018a).

The palaeoecological reliability of anthracological studies in archaeological sites has already been largely demonstrated both in temperate (Vernet 1977; Chabal 1997) and in tropical sites (Scheel-Ybert 2000, 2018a), and is not hampered by human agency in the transporting of wood. Although complementary to other disciplines, such as palynology, anthracological analyses also present some advantages regarding palaeoenvironmental reconstruction (Scheel-Ybert 2018a). Palynology offers information on different plant series—trees, herbs, epiphytes, etc.—but overrepresents anemophilous taxa, while anthracology only provides data on woody plants, but all species tend to have an equal chance of appearing in the charcoal record (except in the case of wood selection, which can be perceived by archaeobotanical and ecological criteria). Palynology reconstructions pertain to a regional scale, because pollen grains may be dispersed for several thousands of kilometers, while anthracology reconstructions depict the local level. Taxonomic determination is consistently more precise in charcoal (often at the species or genus level) than in pollen studies (generally at the family level). In consequence, confrontation with phytosociological data is more straightforward in anthracological studies (Scheel-Ybert 2018a).

The large availability of archaeological shellmounds on the south-southeastern coasts of Brazil, with abundant charcoal presence, turns these sites into important tools for palaeovegetation reconstructions. In the Rio de Janeiro State, dozens of mounds are present amongst the open ocean shores' and the bays' sites. Here, we focus on the

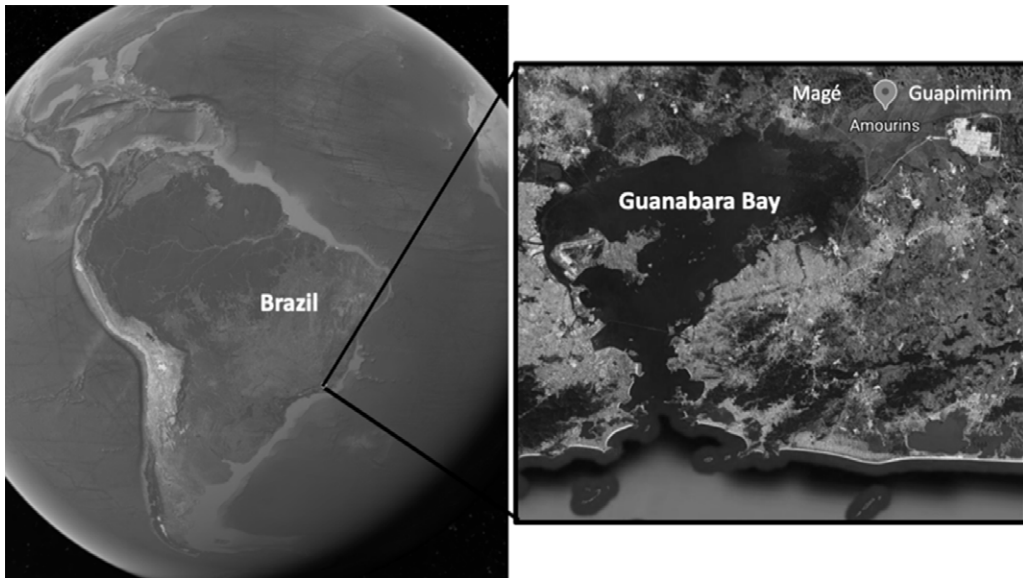


Figure 1 Location of the Amourins shellmound in the study area (Google Earth images).

Guanabara Bay, where shellmounds have an average of 3.5 m in width of archaeological pack and 7000 m² in area (Gaspar et al. 2013). In the present work, we studied the Amourins shellmound, aiming to (1) use ¹⁴C data to study the archaeology/chronology of mound reconstruction and (2) use anthracological data (taxonomic abundances) to reconstruct the palaeovegetation and palaeoclimate during the period of mound construction and use.

Study Area and Current Knowledge

The Amourins shellmound (22°38'53.5"S, 42°56'29"W) is located in the Guapimirim municipality (Figure 1), southeastern Rio de Janeiro State. The site is situated at the plain on the northeastern of the Guanabara Bay and stands next to a meander of the Guapimirim river (Heredia et al. 1981; Gaspar et al. 2013).

During the transition from the Pleistocene to the Holocene, climate and vegetation in Rio de Janeiro presented several variations (Coelho et al. 1999; Santos 2000). Since the mid-Holocene, this productive environment was occupied by fisher-gatherers, possibly gardeners (Scheel-Ybert and Boyadjian 2020) who exploited and impacted the region (Gonzalez 2005; Lopes et al. 2016). Palynological analyses performed in sediment cores collected around the Guanabara Bay show that there have been several climatic variations and, consequently, vegetation changes in the last 6000 years, marking the transition between climates and the predominance of semideciduous seasonal forest, typical of dry environments (Santos 2000). Between 6000 and 4000 cal BP, the dense vegetation, characteristic of humid environments, was replaced by savannah and dense campestral cover, typical of drier climates (Barros et al. 2003). Around 5300–5030 cal BP, the Guanabara Bay was surrounded by dense vegetation, similar to the current Atlantic Forest, which has been progressively replaced by fields (Bartholomeu 2001; Bartholomeu et al. 2001). Studies performed on the coast of the state of Rio de Janeiro indicate the intensification of a dry and cold climate, leading to

vegetation loss and the appearance of open fields during the Late Holocene (Oliveira et al. 2005).

Amador and Ponzi (1974) recorded the occurrence of a paleomangrove on the coast of the city of Magé at 4130 ± 150 BP (5030–4150 cal BP 2σ), close to Guapimirim (Figure 1). It is believed that until the arrival of the colonizers, the entire length of the coast was occupied by mangroves (Amador 1997). Pollen analyses on sediment cores recovered from the Guanabara Bay indicate the presence of Restinga Forest, open field formations, inundated forest, rainforest (Atlantic Forest), and mangroves (e.g., Aguiar et al. 2005). At the beginning of the 16th century, different indigenous cultures inhabited the region when the Europeans arrived. Mountains, forests and swamps have been destroyed for the construction of waterways and the establishment of agricultural land (Costa 2015; Lessa 2000). The Europeans would dispute over the land and even the sea, to establish residence and economic activities (Coelho 2007). In the 19th and 20th centuries, embankments were constructed over lagoons and swamps, giving origin to several areas that today are traditional places in the city of Rio de Janeiro (Coelho 2007).

After the colonial period, anthropogenic activities intensified and drastically modified the environment. Industrial activity and increasing population in the coastal areas have been gradually transforming the landscape, once dominated by diverse vegetation.

Studies performed on recent fluvial sediments (310 ± 50 BP; 410–150 cal BP, 2σ) have shown an abrupt change in the corresponding palynological record, characterizing the anthropogenic action in the region when the coffee culture begun in the middle valley of the Paraíba do Sul river (Barros et al. 2000; Souza 2005). The present regional vegetation would be a reflection of the constant deforestation that occurred during that period. The current presence of industries and habitational buildings around the Guanabara Bay led to the loss of the natural beauty of this region and, associated with this, environmental degradation compromises the biodiversity of the bay (e.g., Soares-Gomes et al. 2016).

Although vegetation changes in this region are widely known, they still lack a temporal framework and proper association with climate and anthropogenic phenomena.

MATERIALS AND METHODS

The Amourins shellmound (Figure 2) was constructed over muddy sediments from the Guanabara Bay and lost most of its original area due to river floods. During the 1980s, the mound was 120 m long, 60 m wide, and 3.0 m high, with approximately 22 m^3 volume (Heredia and Beltrão 1980). According to Gaspar et al. (2013), the present volume of the mound is not over 1.7 m^3 (60 m long, 10 m wide, 2.8 m high). Previous zooarchaeological studies in this site had identified specimens of fish (e.g., Ariidae, *Micropogonias furnieri* and *Pogonias cromis*) and mollusks (e.g., *Phacoides pectinata*, *Anomalocardia brasiliiana* and *Ostrea*) that are commonly found in mangroves, bays and estuaries, suggesting the occurrence of this kind of environment near the site (Cardoso 2013). Similar to other shellmounds in southeastern and southern Brazil, the funerary ritual seems to have played an important role in the formation of Amourins, as indicated by the association between human burials, artifacts and combustion structures (Gaspar et al. 2013), as well as by the large quantity of fish bone and ochre in the funerary layer (Cardoso 2013; Gaspar 2016). In these sites, fish bones are not domestic waste, but they have been associated with



Figure 2 Profile of the Amourins Shellmound (source: Gaspar et al. 2013; modified).

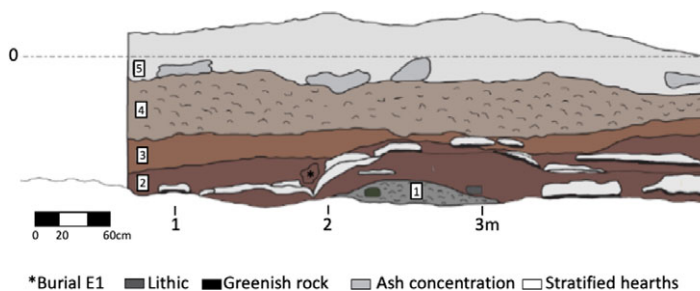


Figure 3 Representation of profile 30–35 m of the Amourins site, in which the zooanthracological column was established. The archaeological layers, hearths, lenses, as well as one of the burials are highlighted (modified from Gaspar et al. 2013).

ceremonial feasts and funerary offerings, while shells are presently interpreted as construction material (Gaspar et al. 2008; Gaspar et al. 2013; Klokler et al. 2018).

The samples were collected during archaeological interventions performed by a team from the National Museum of the Federal University of Rio de Janeiro (MN/UFRJ), the National School of Public Health (FIOCRUZ), and collaborators from other institutions (Gaspar et al. 2013). Archaeological excavations were performed according to cultural levels but also following a 10 cm stratigraphic control. All artifacts, ecofacts and sediment samples were labelled with a provenance number (PN).

Five archaeological layers composed by mollusk shells and sediments and containing different proportions of fish bones, lithic and bone artifacts, were identified (Figure 3). Layer 1 is the base of the site, closest to the mangrove muddy sediments, composed essentially of oysters

(80%); it is interpreted as a landfill. Layer 2 is composed of dark brown sandy sediments containing mollusk shells and fish bones, besides large hearths and burials; it was recognized as a funerary layer. Layer 3 is a thick brown layer composed of reddish mollusk shells, fragments of fish bones and small charcoal fragments. Layer 4 is a brown-grayish layer predominantly composed of mollusk shells, while layer 5 is a more compact layer formed by fragile fragments of shells, some charcoal fragments and charred material. Ash lenses are frequent between layers 4 and 5 (Cardoso 2013). Previous dating for the Amourins shellmound gave results of 3800 ± 40 BP and 3530 ± 60 BP for a different sector (Gaspar et al. 2013).

Sediment samples for anthracological and zooarchaeological analyses were collected in standard volume from a column with dimensions $2.00 \text{ m} \times 0.50 \text{ m}$ excavated at the 30–35-m trench according to standard sampling methodology (Scheel-Ybert et al. 2006b, 2013). Charcoal samples were separated from the sediments through flotation. Short-lived samples were selected for ^{14}C dating and were then subjected to physical and chemical pretreatment at the Radiocarbon Laboratory of the Fluminense Federal University (LAC-UFF). Conventional acid-base-acid treatment was followed by combustion and graphitization following standard protocols applied at the LAC-UFF (Macario et al. 2013; Oliveira et al. 2021). ^{14}C ages (Table 1) were calibrated with the Southern Hemisphere curve SHCal20 (Hogg et al. 2020). Archaeostratigraphy and ^{14}C data were used for the construction of a sequential model using the OxCal software version 4.4.2 (Bronk Ramsey 1995, 2013). The model code is presented in Figure 4.

For anthracological investigations, we have analyzed 2150 charred pieces randomly picked from different sediment samples of each archaeological layer, in addition to samples associated with two burials. We established a minimum of 100 charcoal fragments to be studied from each archaeological layer, but in layer 1 only half of this was available; all the archaeological layers and features were rather poor in charcoal, hampering the analysis of a larger sample. In addition to that, we counted as many palm nuts as they appeared in the sample until the 100th charcoal fragment was reached (Table 2). In the laboratory, the charcoal fragments were manually broken in three fundamental sections (transversal, longitudinal tangential, and longitudinal radial) and observed using a brightfield/darkfield reflected light microscope. Taxonomic identification was based in analysis of the wood anatomy and aided by comparison with databases, reference collections and descriptions and images available in the literature (Scheel-Ybert et al. 2006a; Scheel-Ybert 2018a). (Table 3). The results were organized in an anthracological diagram in which the identified taxa were classified according to vegetation types using the C2 software (Juggins 2005).

RESULTS AND DISCUSSION

Chronological Framework

Considering the ^{14}C analyses, sample selection by anthracology guarantees the use of short-lived plant parts such as barks, twigs and nuts. In this work, 7 nutshell samples were selected to represent the 5 archaeological layers sampled within the studied sector. Three other charcoal samples were analyzed for comparison. Table 1 shows the description of each sample, the conventional, calibrated and modeled ages, the latter assuming a simple sequence, which takes into account the temporal ordering of the samples (Figure 5). A larger number of samples from layer 2 was dated because this layer was richer in charcoal and in archaeological features than the others.

Table 1 Position, description, conventional, calibrated, and modeled ages of the analyzed samples.

LACUFF	Location (layer)	Depth (cm)	Description	¹⁴ C age (BP)	cal BP (2 σ)	Modeled cal BP (2 σ)
180070	1	140–150	NP 98, Palm nut	3807 \pm 35	4245–3985	4217–4006
180069	2	130–140	NP 84, Palm nut	3741 \pm 35	4151–3915	4118–3982
180067	2	130	Burial C, unknown charcoal	3691 \pm 37	4089–3851	4094–3978
180100	2	130	Burial C, Laguncularia sp	3738 \pm 47	4224–3887	4118–3982
180101	2	130	Burial C, unknown charcoal	3775 \pm 43	4237–3929	4125–3987
180068	2	130–140	NP 145, hearth 4, burial C, Palm nut	3731 \pm 39	4150–3897	4131–3980
180112	2	120–130	NP 106, burial 1, Palm nut	3503 \pm 70	3957–3560	—
180071	3	110–120	NP 62, Palm nut	3752 \pm 33	4219–3925	4073–3933
180072	4	100–110	NP 49, Palm nut	3728 \pm 33	4147–3902	4066–3924
180111	5	50–60	NP 35, Palm nut	3668 \pm 64	4147–3725	4066–3879

Table 2 Number of sediment samples analyzed in each archaeological layer and their stratigraphic position; there seems to be overlapping in the stratigraphic levels, but this happens because the limits between archaeological layers are not linear, therefore the sample position depends on the part of the profile they were collected from. The number of charcoal pieces and number of palm nuts of the analyzed samples are also given.

Sample	Stratigraphic position (cm)	Number of sediment samples analyzed	Number of charcoal pieces	Number of palm nuts	Total number of analyzed pieces
Layer 1	150–160	1	50	300	350
	140–150	1			
Layer 2	150–160	3	100	158	258
	140–150	1			
	130–140	2			
Layer 3	120–130	1	100	221	321
	130–140	1			
	120–130	3			
Layer 4	110–120	1	100	218	318
	110–120	2			
	100–110	1			
	90–100	1			
Layer 5	80–90	1	100	399	499
	80–90	3			
	70–80	1			
	60–70	1			
	50–60	1			
Burial 1	Hearth 4	7	100	111	211
Burial 3	Feature x	8	100	93	193
Total		40	650	1500	2150

Table 3 Taxa identified in the Sambaqui de Amourins organized according to the vegetation types in which they occur. “*Restinga*” taxa comprise genera and species that occur mostly in open *restinga* but may also occur in the *restinga* forest. “*Restinga* forest/Atlantic forest” taxa are those that present species in both formations or that may occur in any of these formations.

Plant formations	Families and genera identified
Mangrove	ACANTHACEAE – <i>Avicennia</i> sp. COMBRETACEAE – <i>Combretum</i> sp., <i>Laguncularia</i> sp., Combretaceae indet
<i>Restinga</i>	ANACARDIACEAE - <i>Anacardium</i> sp. CELASTRACEAE – <i>Maytenus</i> sp. CLUSIACEAE – <i>Clusia</i> sp. HUMIRIACEAE – <i>Humiria</i> sp. HYPERICACEAE – <i>Vismia</i> sp. MYRTACEAE – cf. <i>Eugenia</i> sp., cf. <i>Myrcia</i> sp., cf. <i>Myrciaria</i> sp., Myrtaceae indet SAPOTACEAE – <i>Chrysophyllum</i> sp. ARECACEAE (palms)
<i>Restinga</i> Forest / Atlantic Forest	APOCYNACEAE – <i>Aspidosperma</i> sp. ANNONACEAE AQUIFOLIACEAE – <i>Ilex</i> sp. BORAGINACEAE – <i>Cordia</i> sp. CHRYSOBALANACEAE EUPHORBIACEAE – <i>Alchornea</i> sp. LEGUMINOSAE CAESALPINIOIDEAE – <i>Zollernia</i> sp. LEGUMINOSAE MIMOSOIDEAE LEGUMINOSAE PAPILIONOIDEAE – <i>Machaerium</i> sp. MELASTOMATACEAE MORACEAE – cf. <i>Ficus/Sorocea</i> RUBIACEAE – <i>Amaioua</i> sp., <i>Cordia</i> sp., <i>Psychotria</i> sp., <i>Randia</i> sp., Rubiaceae indet
Atlantic Forest	ANNONACEAE – <i>Xylopia</i> sp. MALVACEAE – <i>Luehea</i> sp. MELASTOMATACEAE – <i>Mouriri</i> sp.

The ^{14}C ages obtained for the nut shells cover a range from 3807 ± 35 to 3503 ± 70 BP, in agreement with the available dates for the other sector (Gaspar et al. 2013). The outlier model was useful to evaluate whether the samples belong to the layers where they had been found. The results for the charcoal samples are in agreement with nutshell results for the same layers. For most of the samples, there was no significant temporal variation between the ages of each layer, since the results are statistically overlapping.

The well-defined stratigraphy of the site can be observed in the zooanthracological column representation shown in Figure 3. Based on this ordering, a sequential age model was constructed and is presented in Figure 4. A general outlier model was used to test the behavior of each date within the chronological model. For all layers a short-lived sample is present, but for the burial, a few charcoal samples were measured to evaluate their synchronicity to the model. Considering that all the results have a prior 5% probability of being outliers and the obtained overall agreement for the model, sample LAC-180112 was

```

● Plot()
  ● Curve("SHCal20", "SHCal20.14c")
  ● Outlier_Model("General", T(5), U(0,4), "t")
  ● Sequence("")
    ● Boundary("Start")
      ● R_Date("L1-180070", 3807, 35)
        ● z=145
          ● Outlier(0.05)
            ●
      ● Sequence()
        ● Boundary()
          ● Phase("L2")
            ● R_Date("180069", 3741, 35)
              ● z=135
                ● Outlier(0.05)
                  ●
            ● R_Date("180067", 3691, 37)
              ● Outlier(0.05)
                ● z=130
                  ●
            ● R_Date("180100", 3738, 47)
              ● Outlier(0.05)
                ● z=130
                  ●
            ● R_Date("180101", 3775, 43)
              ● Outlier(0.05)
                ● z=130
                  ●
            ● R_Date("180068", 3731, 39)
              ● Outlier(0.05)
                ● z=130
                  ●
          ● Boundary()
            ● R_Date("L3-180071", 3752, 33)
              ● z=115
                ● Outlier(0.05)
                  ●
            ● R_Date("L4-180072", 3728, 33)
              ● z=105
                ● Outlier(0.05)
                  ●
            ● R_Date("L5-180111", 3668, 64)
              ● z=55
                ● Outlier(0.05)
                  ●
          ● Boundary("End")
            ●
  ●
  ●
  ●
  
```

Figure 4 OxCal code for the Sequence model used after the removal of sample LACUFF 180112. Samples were ordered from layers 1–5, and a Phase model was used to represent layer 2. A general outlier model was used since the dated samples were short-lived palm nuts.

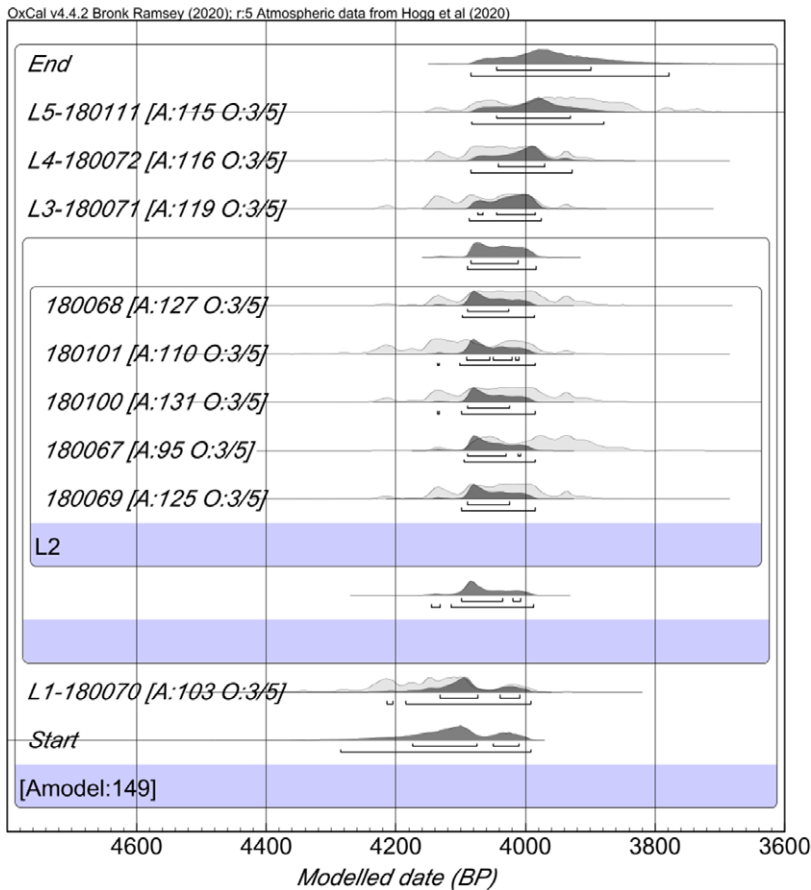


Figure 5 Simple sequence model based on charcoal dates from the Amourins shellmound after removal of the outlier (sample LACUFF 180112). Light gray distributions represent the regular calibration (as individual samples) while dark gray distributions represent the modeled probabilities. Individual samples' agreement within the model (A) and overall agreement (A_{model}) are satisfactory. All individual results gave a posterior outlier probability of 3%. Median values are marked as crosses and 2 sigma ranges are presented for the modeled distributions.

discarded with 22% posterior outlier probability. The A_{model} index, which measures the agreement between models, is 148% after removing this outlier. According to Bronk Ramsey (2009), A_{model} values above 60% statistically ensure good agreement between model and measurements. The presence of this sample can be interpreted as an intrusion, a charcoal fragment mixed with an inferior layer by disturbance of the archaeological package, for example by the opening of a stack hole.

Based on the sequential chronological model built, the period between the Start and End boundaries was considered the most likely related to the occupation of the studied sector, and therefore, to the vegetation types identified in this work. Such probability distribution is displayed in Figure 6, representing the mean of the two boundary distributions (Start and End boundaries in the sequence). The most likely period representing the dataset is then 4130–3960 cal BP (1 σ) or 4310–3800 cal BP, (2 σ).

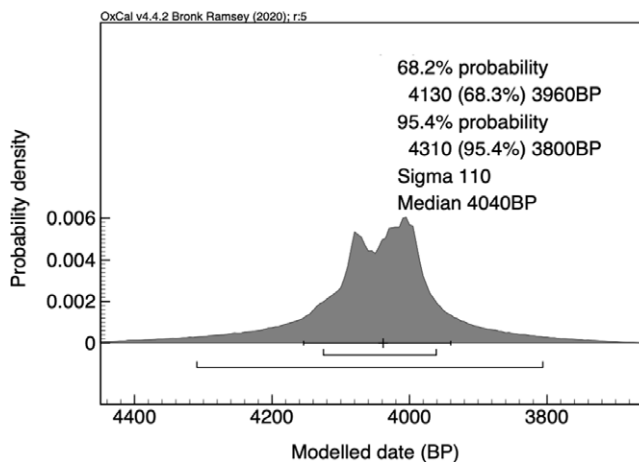


Figure 6 Probability distribution of the interval between Start and End boundaries in the sequence. The most likely period representing the dataset is 4130–3960 cal BP (1σ) or 4310–3800 cal BP (2σ).

Vegetation Reconstruction

The anthracological results demonstrate that several vegetation types existed around the Amourins shellmound during the time it was occupied, including the Atlantic Forest, the *restinga* forest, open *restinga* formations and the mangrove (Figure 7). The Atlantic Forest presently covers the hills and valleys inland, while mangroves occur by the edges of lagoons and rivers. The *restinga* vegetation thrives on the Quaternary coastal sandy deposits; it is a mosaic of plant associations with diverse physiognomies that vary from sparse open plant communities, such as herbaceous and shrub formations (“open *restinga*”) to a denser evergreen forest (“*restinga* forest”) typical of the Brazilian coast (Araujo and Henriques 1984). It is likely that during the shellmound occupation all these vegetation types already occurred along these same geomorphological settings.

Mangrove species, especially *Laguncularia* sp., but also an undetermined Combretaceae (probably *Laguncularia*), *Combretum* sp., and *Avicennia* sp. are predominant in all samples. *Clusia* sp., Myrtaceae, Rubiaceae, and Melastomataceae species follow as the most frequent taxa, attesting the importance of *restinga* formations in the region. The Atlantic Forest is represented by only three taxa (*Xylopia* sp., *Luehea* sp., *Mouriri* sp., see Table 3), which are limited to the two most recent archaeological layers, indicating that this type of vegetation was less used for firewood gathering (Figure 7).

Several typical *restinga* taxa, together with taxa that may occur both in the *restinga* and the Atlantic forest are present in both burials and in the profile layers, indicating that they were common species. This corroborates the results of previous studies, which demonstrated that shellmound builders were strongly associated with the *restinga* environment (Scheel-Ybert 2000, 2018b).

Palm nuts were the most abundant charred remains in all five archaeological layers, especially in the first one; they are less frequent in the burials, when compared to charcoal, but still preponderant (Table 2). Although their prevalence indicates the importance of palms in the

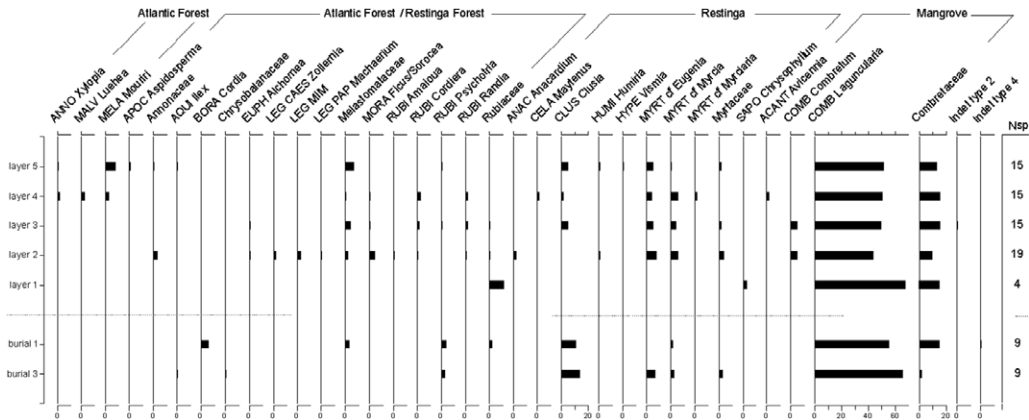


Figure 7 Anthracological diagram, Sambaqui de Amourins, profile 30–35 m, in relative frequency of each taxon. Dispersed charcoal from each archaeological layer and concentrated charcoal associated with burials (layer 2) are separated by a dashed line. Nut shells are not indicated, as their frequencies are not ecologically significant. However, they are present in all samples and constitute a very good material for dating. Nsp = Number of taxa identified.

surrounding environment, their frequencies are not ecologically significant since they are purposely collected as food.

Despite minor variations, species richness and composition are overall very similar in all archaeological layers and burial features analyzed. Layer 1 stands out for the scarcity of charcoal remains, low species richness and strong dominance of palm nuts. Layer 2 presents the highest species richness in all the assemblage; the burial features analyzed (which are situated in layer 2) present lower species richness, but this is expected for short-duration fire activities which characterize hearths. Layers 3, 4, and 5 are very similar in species richness and composition, though Atlantic forest elements are restricted to layers 4 and 5.

Together, the ¹⁴C and anthracology results show that at 4130–3960 cal BP typical *restinga* and mangrove vegetations were well represented in the area around the Guanabara Bay *restinga*. Atlantic forest elements were rarer, but this is due to the fact that this vegetation was situated farther inland.

Previous palaeoenvironmental and landscape reconstructions based on anthracological studies at the Southeastern and Southern Brazilian coasts attest that shellmounds used to be established in the *restinga* environment, but always in the range of access to other vegetation types, especially the mangrove and the Atlantic Forest (Scheel-Ybert 2000; Scheel-Ybert et al. 2003, 2009; Scheel-Ybert and Dias 2007; Bianchini et al. 2011). Mangrove elements have already been recorded in several sites (Forte, Boca da Barra, Salinas Peroano, Ponta da Cabeça, Corondó, Pontinha and Beirada, in the Lagos Region, southeastern Rio de Janeiro State; Jabuticabeira-II and Encantada-III in Santa Catarina State, Southern Brazil). However, higher frequencies of mangrove in relation to other vegetation types were only verified in the more recent levels of site Ponta da Cabeça (at ca. 2080 ± 40 BP, or 2100–1890 cal BP) and in the earlier levels of site Encantada-III (at ca. 4320 ± 40 BP, or 5030–4640 cal BP). In both cases, the prevalence of mangrove is

probably related to human choices in the firewood gathering, and not to environmental changes (Scheel-Ybert 2000; Scheel-Ybert et al. 2009).

Environmental changes were recorded by oscillations in the mangrove vegetation in sites from southeastern Rio de Janeiro State (southeastern Brazil). This study recorded at least two more humid episodes (from ca. 6000 to 5500/5000 cal BP and from ca. 2300 to 2000 cal BP), intercalated with two episodes of increased dryness with enhanced lagoon salinity (from ca. 5500/5000–2300 cal BP and from ca. 2000 to 1200 cal BP) (Scheel-Ybert 2000). These episodes were correlated with modifications of lagoon sedimentation, which also suggest regional climatic variations during the Holocene (Tasayco-Ortega 1996). During the same period, however, the coastal *restinga* vegetation has not suffered any considerable variations, which was attributed to the edaphic character of coastal *restinga* formations, adapted to sandy soils, and therefore much more resilient to climatic variations and climate changes. Even though the coastal geomorphology was in permanent change during the Holocene, especially due to significant sea level variations, the coastal plains remained during all this time covered by the *restinga* vegetation, of which the structure and floristic composition remained relatively stable (Scheel-Ybert 2000).

The results obtained from the Amourins site, in turn, stand out for the strong dominance of mangrove taxa in all samples. The site location explains these results. Indeed, Amourins is situated next to a meander of the Guapimirim river, which was certainly covered by a mangrove swamp during the site's construction and occupation, and plants from the mangrove provided most of the firewood used in this site. The *restinga*, however, was also present during the site occupation, as attested both by the anthracological results presented here (in which *restinga* taxa are the second most important vegetation in frequency of charcoal pieces) and by the geomorphological nature of the area (Suguio and Tessler 1984).

Sedimentological analysis in this same area also recorded paleomangroves at 4130 ± 150 BP (5030–4150 cal BP) (Amador and Ponzi 1974). Only remnants of these mangroves exist in the present day, but they were still abundant at least until the 18th century, when European colonization increased the persistent destruction of the native vegetation (Amador 1997).

Palynological studies in different sites around the Guanabara Bay recorded the occurrence of the Atlantic Forest, *restingas*, savannas, mangroves, and marshes since at least 4520 ± 80 BP, 5440–4860 cal BP (Barreto et al. 2005; Barros and Barth 2005; Bartholomeu et al. 2014). These studies detected environmental degradation due to European colonization through the increase in field vegetation and the presence of exotic pollen grains in historical times (after 530 ± 25 BP, 540–500 cal BP). Barros and Barth (2005) highlight that regional vegetation is better represented in their analyses than local vegetation, which may explain the high importance of Atlantic Forest elements in most palynological records.

All these studies agree in presenting a scenario where different plant formations occurred around the Guanabara Bay during the Late Holocene. The humid Atlantic Forest thrived on the hills and valleys inland; the various *restinga* formations (including *restinga* forests and different open *restinga* facies) occupied the coastal plains; marshes and herbaceous vegetation thrived in the edges of the bay and coastal lagoons and in depressed areas; mangrove swamps occurred in river margins and also in some places by the edges of the bay and of coastal lagoons.

CONCLUSIONS

This work shows the results of the association of the techniques of anthracological analysis and ^{14}C dating in archaeological charcoal samples from the Amourins shellmound, located in the northeastern portion of Guanabara Bay. The application of both techniques to the same sample enhanced the accuracy of the results used in the construction of a sequential model. This allowed for a representation of the environmental picture of Guanabara Bay during the Holocene. Such information benefits not only the study and cataloguing of the species that have occupied the area, but also serves as a base for the implementation of actions and projects aimed at the recovery of the region, remodeling, and revitalizing the coastal ecosystem, highly degraded today.

The presence of several families and genera characteristic of the Atlantic Forest, *restinga* forest, open *restinga* and mainly mangrove in the site's successive layers confirms that from ca. 4040 cal BP these vegetation types resisted the climatic changes and were perpetuated in the place, remaining until the present day, despite having been greatly affected by anthropogenic interference. The dates show a period of about 220 years when the major dominance of the vegetation cover was characteristic of estuarine environments.

ACKNOWLEDGMENTS

The authors would like to thank Brazilian financial agencies CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico, 307771/2017-2 and INCT-FNA, 464898/2014-5) and FAPERJ (Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro, E-26/110.138/2014 and E26/203.019/2016) for the financial support. This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001. The authors thank the team of the National Museum of the Universidade Federal do Rio de Janeiro, especially Maria Dulce Gaspar, coordinator of the project "Sambaquis Médios, Grandes e Monumentais." We thank the reviewers and editors for their valuable comments and suggestions.

REFERENCES

- Aguiar MB 2005. A vegetação no entorno das Baías de Guanabara e Sepetiba (RJ) durante o Holoceno: dados palinológicos. Anais de congresso, ABEQUA.
- Amador ES, Ponzi VRA. 1974. Estratigrafia e sedimentação dos depósitos fluviomarinhos da orla da baía de Guanabara. Anais da Academia Brasileira de Ciências 46:3–4.
- Amador ES. 1997. Baía de Guanabara e Ecossistemas Periféricos: Homem e Natureza. Rio de Janeiro. 539 p.
- Araujo DD, Henriques RP. 1984. Análise florística das restingas do Estado do Rio de Janeiro. Restingas: origem, estrutura e processos. p. 159–93.
- Barreto CF, Barth OM, Luz CFP, Baptista Neto JA, Vilela CG. 2005. Reconstrução paleoambiental do Holoceno da Baía de Guanabara, Rio de Janeiro, através de análise palinológica: resultados preliminares. X Congresso da Associação Brasileira de Estudos do Quaternário, Guarapari. p. 1–6.
- Barros MA, Barth OM, Mello CL, Moura JRS, Peixoto MNO. 2000. História recente da vegetação e o uso da terra no médio vale do rio Paraíba do Sul. Leandra 15:47–57.
- Barros MA. 2003. Transição Pleistoceno/Holoceno, médio vale do Rio Paraíba do Sul (SP/RJ): uma abordagem palinológica. Tese de Doutorado, Instituto de Geociências, Universidade Federal do Rio de Janeiro.
- Barros MA, Barth OM. 2005. A vegetação no entorno das Baías de Guanabara e Sepetiba (RJ) durante o Holoceno: dados palinológicos. X Congresso da Associação Brasileira de Estudos do Quaternário, Guarapari. 6 p.
- Bartholomeu RL. 2001. Alterações ambientais ocorridas na paisagem da Praia Vermelha, Urca, Rio de Janeiro: uma abordagem sedimentológica e palinológica. Monografia de

- bacharelado, Departamento de Geografia, Instituto de Geociências, Universidade do Estado do Rio de Janeiro.
- Bartholomeu RL, Barth OM, Barros MA. 2001. Estudos palinológicos em sedimentos quaternários turfosos da praia Vermelha, Urca, Rio de Janeiro. *Boletim de Resumos do VIII Congresso da Associação Brasileira de Estudos do Quaternário*. p. 398–399.
- Bartholomeu RL, Barros MA, Lopes MRS, Vilela CG, Barth OM. 2014. Evolução paleogeográfica da planície costeira da Praia Vermelha, entrada da Baía de Guanabara, Rio de Janeiro, por meio de registros palinológicos. *Anuário do Instituto de Geociências* 37(1): 92–103.
- Bianchini, G.F. and Scheel-Ybert, R. 2012. Plants in a funerary context at the Jabuticabeira-II shellmound (Santa Catarina, Brazil) – feasting or ritual offerings? In: Badal E, Carrión Y, Macías M, Ntinou M, editors. *Wood and charcoal: evidence for human and natural history*. Valencia: *Sagvntvm Extra*. p. 253–258.
- Bianchini GF et al. 2011. Processo de formação do sambaqui Jabuticabeira-II: interpretações através da análise estratigráfica de vestígios vegetais carbonizados. *Revista do Museu de Arqueologia e Etnologia*, São Paulo 21:51–69.
- Bronk Ramsey C. 1995. Radiocarbon calibration and analysis of stratigraphy: the OxCal program. *Radiocarbon* 37(2):425–430.
- Bronk Ramsey C. 2009. Bayesian analysis of radiocarbon dates. *Radiocarbon* 51(1):337–360.
- Bronk Ramsey C, Scott EM, van der Plicht J. 2013. Calibration for archaeological and environmental terrestrial samples in the time range 26–50 ka cal BP. *Radiocarbon* 55(4): 2021–2027.
- Calegari MR, Madella M, Brustolin LT, Ruiz Pessenda LCR, Buso Jr AA, Francisquini MI, Bendassolli JA, Vidal-Torrado P. 2017. Potential of soil phytoliths, organic matter and carbon isotopes for small-scale differentiation of tropical rainforest vegetation: a pilot study from the campos nativos of the Atlantic Forest in Espírito Santo State (Brazil). *Quaternary International*, 437:156–164.
- Cardoso LSCP. 2013. Além das Conchas: Análise Zooarqueológica do Sambaqui de Amourins/Lilian Cardoso e Silva Costa Pinto. 176 f.: il. MSc aissertation (Archaeology) – Universidade Federal do Rio de Janeiro, Museu Nacional, Rio de Janeiro.
- Chabal L. 1997. Forêts et Sociétés en Languedoc (Néolithique Final, Antiquité Tardive) *L'Anthracologie, Méthode et Paleoécologie*. *Documents d'archéologie française* 63:188.
- Coe HHG, Macario K, Jenifer G, Karina F, Oliveira F, Gomes PRS, Carvalho C, Linares R, Alves E, Guaciara M. 2014. Understanding Holocene variations in the vegetation of Sao Joao River basin, southeastern coast of Brazil, using phytolith and carbon isotopic analyses. *Palaeogeography, Palaeoclimatology, Palaeoecology* 415:59–68.
- Coe HHG, Souza RL, Duarte MR, Ricardo SF, Machado DF, Macario KD, Silva EP. 2017. Characterisation of phytoliths from the stratigraphic layers of the sambaqui da Tarioba (Rio das Ostras), RJ, Brazil. *Flora* 236:1–8.
- Coelho LG, Barth O M, Chaves H F. 1999. O registro palinológico das mudanças de vegetação na região da Baía de Sepetiba, Rio de Janeiro, nos últimos 1.000 anos. *Leandra* 14:51–63.
- Coelho LN. 2007. Alterações Hidrogeomorfológicas no Médio-Baixo Rio Doce/ES 2007. 227 f. Tese de Doutorado (Universidade Federal Fluminense, Instituto de Geociências, Departamento de Geografia), Niterói.
- Costa MA. 2015. Da lama ao caos: um estuário chamado Baía de Guanabara. *Cad. Metrop., São Paulo* 17(33):15–39.
- Gaspar MD, DeBlasis P, Fish SK, Fish PR. 2008. Sambaqui (shell mound) societies of coastal Brazil. *The handbook of South American archaeology*. New York: Springer. p. 319–335.
- Gaspar MD. 2016. Tudo junto e misturado, separado pela crença e compactado pelo tempo. *Revista Habitus*. Goiânia 14(1):35–50.
- Gaspar MD, Klokler DM, Scheel-Ybert R, Bianchini GF. 2013. Sambaqui de Amourins: mesmo sítio, perspectivas diferentes. *Arqueologia de um sambaqui 30 anos depois*. *Revista do Museu de Antropologia* 6:7–20.
- Gonzalez MMB. 2005. Use of *Pristis* spp. (Elasmobranchii: Pristidae) by hunter-gatherers on the coast of São Paulo, Brazil. *Neotropical Ichthyology* 3:421–426.
- Heredia OR, Beltrão MCMC. 1980. Mariscadores e pescadores pré-históricos do litoral centro-sul brasileiro. *Pesquisas, Série Antropologia* 31:101–119.
- Hogg AG, Heaton TJ, Hua Q, Palmer JG, Turney CSM, Southon J, Bayliss A, Blackwell PG, Boswijk G, Bronk Ramsey C, Pearson C, Petchey F, Reimer P, Reimer R, Wacker L. 2020. SHCal20 Southern Hemisphere calibration, 0–55,000 years cal BP. *Radiocarbon* 62(4):759–778. doi: [10.1017/RDC.2020.59](https://doi.org/10.1017/RDC.2020.59).
- Heredia OR, Beltrão MCMC, Oliveira MDG, Gatti MP. 1981/1982. Pesquisas arqueológicas no sambaqui de Amourins, Magé, RJ. Separata do arquivos do Museu de História Natural – UFMG, col. VI/VII. p. 175–188.
- Jansonius J, McGregor DC. 1996. Introduction. In: Jansonius J, McGregor DC, editors. *Palynology: principles and applications*. Vol. 1. Salt Lake City: American Association of Stratigraphic Palynologist Foundation. 462 p.
- Juggins S. 2005. C2 Version 1.5. Software for ecological and paleoecological data analysis and

- visualisation. Newcastle University, Newcastle Upon Tyne, UK. Available at: http://www.campus.ncl.ac.uk/staff/Stephen_Juggins/software/C2Home.htm.
- Klokler D, Gaspar MD, Scheel-Ybert R. 2018. Why clam? Why clams? Shell mound construction in southern Brazil. *Journal of Archaeological Science: Reports* 20:856–863.
- Lessa C. 2000. O Rio de todos os Brasis: uma reflexão em busca de auto-estima. Rio de Janeiro, Record.
- Lorente FL, Pessenda LCR, Oboh-Ikuenobe F, Junior AAB, Rossetti DF, Giannini PCF, Cohen MCL, Oliveira PE, Mayle FE, Francisquini MI, França M C, Bendassolli JA, Macario KD. 2018. An 11,000-year record of depositional environmental change based upon particulate organic matter and stable isotopes (C and N) in a lake sediment in southeastern Brazil. *Journal of South American Earth Sciences* 84:373–384.
- Lopes MS, Bertucci TCP, Rapagnã L, Tubino RA, Neto CM, Tomas ARG, Tenório MC, Lima T, Souza R, Jorge Domingo Briceño JDC, Haimovici M, Macario KD, Carvalho C, Socorro OA. 2016. The path towards endangered species: prehistoric fisheries in southeastern Brazil. *PLoS One* 11(6):0154476.
- Macario KD, Souza RCCL, Aguilera OA, Carvalho C, Oliveira FM, Alves EQ, Chanca IS, Silva E, Douka K, Decco J, Trindade D, Marques JRAN, Anjos RM, Pamplona FC. 2015. Marine reservoir effect on the Southeastern coast of Brazil: results from the Tarioba shellmound paired samples. *Journal of Environmental Radioactivity* 143:14–19.
- Macario KD, Alves EQ, Carvalho C, Oliveira FM, Bronk RC, David C, Souza R, Simone LRL, Cavallari DC. 2016. The use of the terrestrial snails of the genera *Megalobulimus* and *Thaumastus* as representatives of the atmospheric carbon reservoir. *Scientific Reports* 6: 27395.
- Macario KD, Tenório MC, Alves EQ, Oliveira FM, Chanca IS, Netto B, Carvalho C, Souza R, Aguilera O, Guimarães RB. 2017. Terrestrial mollusks as chronological records in Brazilian shellmounds. *Radiocarbon* 59(5):1561–1577. doi: [10.1017/RDC.2017.34](https://doi.org/10.1017/RDC.2017.34).
- Macario KD, Gomes PRS, Anjos RM, Carvalho C, Linares R, Alves EQ, Oliveira FM, Castro MD, Chanca IS, Silveira MFM, Pessenda LCR. 2013. The Brazilian AMS Radiocarbon Laboratory (LAC-UFF) and the intercomparison of results with CENA and UGAMS. *Radiocarbon* 55(2–3):325–330.
- Moraes CA, Fontes NA, Cohen MC, França MC, Pessenda LC, Rossetti DF, Francisquini MI, Bendassolli JA, Macario K. 2017. Late Holocene mangrove dynamics dominated by autogenic processes. *Earth Surface Processes and Landforms* 42(13):2013–2023.
- Oliveira PE, Behling H, Ledru MP, Barberi M, Bush M, Garcia MJ, Medeanic S, Barth OM, Scheel-Ybert R. 2005. Paleovegetação e Paleoclimas do Quaternário do Brasil. In: Gouveia CR, Suguio K, Oliveira AMS, Oliveira PE de, editors. *O Quaternário do Brasil*. Ribeirão Preto: Holos editora 1:52–74.
- Oliveira F, Macario K, Carvalho C, Moreira V, Alves EQ, Chanca I, Diaz M, Jou R, Hammerschlag I, Netto BM, Oliveira MI, Assumpção FD. 2021. LAC-UFF status report: current protocols and recent developments. *Radiocarbon*: 1–13. doi: [10.1017/RDC.2020.138](https://doi.org/10.1017/RDC.2020.138).
- Théry-Pariset I, Chabal L, Chrzavzez J. 2010. Anthracology and taphonomy, from wood gathering to charcoal analysis. A review of the taphonomic processes modifying charcoal assemblages, in archaeological contexts, *Palaeogeography, Palaeoclimatology, Palaeoecology* 291(1–2):142–153.
- Santos DS. 2000. Análise palinológica como ferramenta de interpretação de oscilações climáticas, ambientais e do nível do mar na Baía de Sepetiba, RJ [MSc dissertation (Geology)]. Departamento de Geologia/UERJ, Rio de Janeiro. 85 p.
- Salgado-Labouriau ML. 1961. Palinologia: fundamentos, técnicas e algumas perspectivas. *Revista Brasileira de Geografia* 4:107–129.
- Scheel-Ybert R. 2000. Vegetation stability in the Southeastern Brazilian coastal area from 5500 to 1400 ¹⁴C yr BP deduced from charcoal analysis. *Review of Palaeobotany and Palynology* 110(2):111–138.
- Scheel-Ybert R, Dias OF. 2007. Corondó: palaeoenvironmental reconstruction and palaeoethnobotanical considerations in a probable locus of early plant cultivation (southeastern Brazil). *Environmental Archaeology* 12:129–138.
- Scheel-Ybert R, Eggers S, Wesolowski V, Petronilho CC, Boyadjian CHC, DeBlasis PAD, Barbosa-Guimarães M, Gaspar MD. 2003. Novas perspectivas na reconstituição do modo de vida dos sambaquieiros. *Revista de Arqueologia* 16(1):109–137.
- Scheel-Ybert R, Bianchini GF, DeBlasis P. 2009. Registro de mangue em um sambaqui de pequeno porte do litoral sul de Santa Catarina, Brasil, a cerca de 4900 anos cal yrs BP, e considerações sobre o processo de ocupação do sítio Encantada-III. *Revista do Museu de Arqueologia e Etnologia, São Paulo* 19:103–118.
- Scheel-Ybert R, Carvalho MA, Moura RPO, Gonçalves TAP, Scheel M, Ybert JP. 2006a. Coleções de referência e bancos de dados de estruturas vegetais: subsídios para estudos paleoecológicos e paleoetnobotânicos. *Arquivos do Museu Nacional, Rio de Janeiro* 64(3): 255–266.

- Scheel-Ybert R, Klokler DM, Gaspar MD, Figuti L. 2006b. Proposta de amostragem padronizada para macrovestígios bioarqueológicos: antracologia, arqueobotânica, zooarqueologia. *Revista do Museu de Arqueologia e Etnologia* 15-16:139-163.
- Scheel-Ybert R. 2013. Antracologia: preservados pelo fogo. In: Gaspar MD, Mendonça de Souza SM, editors. *Abordagens estratégicas em sambaquis*. Vol. 1. Erechin: Habilis. p. 193-218.
- Scheel-Ybert R. 2018a. Anthracology: charcoal analysis. In: Smith C, editor. *Encyclopedia of global archaeology*. New York: Springer-Verlag.
- Scheel-Ybert R. 2018b. Landscape and plants use in Brazilian shell mounds In: Smith C, editor. *Encyclopedia of global archaeology*. New York: Springer-Verlag.
- Scheel-Ybert R, Boyadjian C. 2020. Gardens on the coast: considerations on food production by Brazilian shellmound builders. *Journal of Anthropological Archaeology* 60:101211. doi: [10.1016/j.jaa.2020.101211](https://doi.org/10.1016/j.jaa.2020.101211).
- Soares-Gomes A, Da Gama BA, Neto JB, Freire DG, Cordeiro RC, Machado W, Bernardes MC, Coutinho R, Thompson FL, Pereira RC. 2016. An environmental overview of Guanabara Bay, Rio de Janeiro. *Regional Studies in Marine Science* 8(2):319-330.
- Souza CR. 2005. Quaternário do Brasil. Ribeirão Preto, Holos Editora 28:382.
- Souza RCCL, Lima TA, Silva EP. 2010. Holocene mollusks from Rio de Janeiro state coast, Brazil. *Check List Journal of Species Lists and Distribution* 6(2):301-308.
- Suguio K, Tessler MG. 1984. Planícies de cordões litorâneos quaternários do Brasil: origem e nomenclatura. In: UFF, editor. *Restingas: origem, estrutura e processos*. UFF: Universidade Federal Fluminense - Rio de Janeiro. p. 15-25.
- Tasayco-Ortega LA. 1996. Variations paléohydrologiques et paléoclimatiques d'une région d'upwelling au cours de l'Holocène: enregistrement dans les lagunes côtières de Cabo Frio (État de Rio de Janeiro, Brésil) [doctoral thesis]. Paris: Univ. Pierre et Marie Curie. 321 p.
- Vernet JL. 1977. Les Macrofossiles Végétaux et la Paléoécologie du Pléistocène. *Bulletin de l'Association Française pour l'étude du Quaternaire, Suppl.* 47:53-55.