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Brazilian Shellmounds from a Zooarchaeological Perspective

Concheros brasileños desde una perspectiva zooarqueológica

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ABSTRACT: Shellmounds are archaeological sites built by fishermen-hunters-catchers with high concentration of marine faunal remains, composed basically of shells of edible marine and terrestrial molluscs, carapaces of crustaceans, fish remains, human and animal bones, among others. They are relicts of prehistoric settlements characterized as distinct features on the sandy coastal plain, sandy bars of coastal lagoons and rocky islands and bays, constituting an important testimony of paleodiversity and Brazilian prehistory. This article aims to present studies that have been developed with the zooarchaeological vestiges recovered in shellmound of the coast of the state of Rio de Janeiro, Brazil, which broaden the scope of the concept of biodiversity, generating long term perspectives, combining multiple approaches and methods to improve understanding of environmental changes. A malacological, ichthyological and carcinological study was carried out on the zooarchaeological remains recovered in the shellmounds. Selected well-preserved shells, otoliths and charcoal from hearths in sequential layers were used for radiocarbon dating analysis and for fishery characterization over time. Shells were also used as valuable tools in the study of the ^{14}C marine reservoir effect and the terrestrial molluscs have proven to be an important alternative to represent the atmospheric carbon isotopic concentration. Besides the otoliths represent reliable chronological records, they proved to be excellent markers of environmental isotope signals. Although the shellmounds are artificial accumulations, the zooarchaeological remains there represent a sample of the existing fauna at the times of their construction and can provide information about the paleoenvironment, making it possible to establish comparisons with current times.

KEYWORDS: SAMBAQUI, BIODIVERSITY, MOLLUSC, CRUSTACEAN, PREHISTORIC FISHERY, RADIOCARBON DATING

RESUMEN: Los concheros son sitios arqueológicos conformados por pescadores-cazadores-recolectores con alta concentración de restos de fauna marina, compuestos básicamente de conchas de moluscos marinos y terrestres, caparazones de crustáceos, restos de peces, huesos humanos y animales, entre otros. Estos restos son evidencias de asentamientos prehistóricos caracterizados como rasgos distintivos en la planicie costera arenosa, barras arenosas de lagunas costeras e islas

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y bahías rocosas, que constituyen un importante testimonio de la paleodiversidad y la prehistoria brasileña. Este artículo pretende presentar los estudios que se han desarrollado con los vestigios zooarqueológicos recuperados en los concheros de la costa del estado de Río de Janeiro, Brasil, que amplían el alcance del concepto de biodiversidad, generando perspectivas a largo plazo, combinando múltiples enfoques y metodologías para mejorar la comprensión de los cambios ambientales. Se realizó un estudio malacológico, ictiológico y carcinológico sobre los restos zoarqueológicos recuperados en los concheros. Las conchas, los otolitos y el carbón vegetal bien conservados fueron seleccionados en capas sucesivas de los concheros para el análisis de las edades por radiocarbono y para la caracterización de la pesquería a lo largo del tiempo. Las conchas también se utilizaron como estructuras valiosas en el estudio del efecto del reservorio marino y los moluscos terrestres han demostrado ser una alternativa importante para representar la concentración isotópica del carbono atmosférico. Además de representar un registro cronológico confiable, los otolitos demostraron ser excelentes marcadores de señales de isótopos ambientales. Si bien los concheros son acumulaciones artificiales, los restos zooarqueológicos representan una muestra de la fauna existente en el momento de su construcción y pueden proporcionar información sobre el paleoambiente, lo que permite establecer comparaciones con los tiempos actuales.

PALABRAS CLAVE: SAMBAQUI, BIODIVERSIDAD, MOLUSCO, CRUSTÁCEO, PESQUERÍA PREHISTÓRICA, DATACIÓN POR RADIOCARBONO

SAMBAQUIS: BRAZILIAN SHELLMOUNDS

Shell-matrix sites are prominent landscape features mainly made of shells and other human activity remains. They can be the remains of subsistence activities, platform structures for safer and more adequate living/settlement, sacred mounds, burial sites, territorial markers (Roksandic *et al*., 2014). "Shell middens" are by definition accumulations of food remains, while "shellmounds" is a term more usually applied to intentionally built structures, aimed for domestic and/or ritual purposes. In any case, they carry important information on past cultures and on the past uses of natural resources.

Shell-matrix sites can be found in coastal, lacustrine, and riverine environments worldwide, from arctic regions to the tropics (Álvarez *et al*., 2011). The earliest shell middens are probably situated in Papua New Guinea and dated at c. 40000-33000 BP (Leavesley *et al*., 2002). Shell mounds from the Jomon culture, in Japan, are dated to c. 10000 BP (Habu *et al*., 2011). These sites are more frequent, however, since the Middle Holocene, having been recorded from Scandinavia to South Africa through Australia, Tasmania, Asia, Central and Eastern Africa, and Northern, Atlantic, and Mediterranean Europe (e.g. Bailey, 1975; Van Neer & Clist, 1991; Álvarez *et al*., 2011; Erlandson & Braje, 2011; Gutiérrez-Zugasti *et al*., 2011; Hardy *et al*., 2016). In the Americas, shell-matrix sites occur from the southern coast of Beringia to Patagonia (including Tierra del Fuego), both in the Pacific and Atlantic sides of North, Central, and South America (e.g. DeBlasis *et al*., 2007; Salemme & Miotti, 2008; Álvarez *et al*., 2011; Erlandson & Braje, 2011; Orquera *et al*., 2011).

In Brazil, shellmounds, locally named "sambaquis", occur all along the coast. These sites present a rather complex sequence of shellfish-rich and sandy layers of variable composition and thickness, containing different archaeological vestiges. They vary from small two-meters high to four hundred meters long and thirty meters high shellmounds, usually clustered in groups composed by sites of different size, morphology and relative contents (DeBlasis *et al.,* 1998). Typical technological assemblage is composed by different industries (on bones, shells, and lithics). Burials and hearths are present in most of the sites.

In addition to a vast geographical distribution (over 7,000 km), they present a large temporal frame ranging at least from about 9000 to 1000 BP (Gaspar, 1996; Lima *et al*., 2002; Figuti *et al.,* 2013). They are among the first recognized and better-studied archaeological sites in this country (DeBlasis *et al*., 1998; Gaspar, 1998). Traditionally, sambaqui moundbuilders were seen as small nomadic shellfish gathering bands who would have shifted their economic system to fishing in more recent times (e.g. Beltrão *et al*., 1978; Schmitz, 1987). The sites were therefore considered as midden deposits. Later, the development of zooarchaeological and stable isotope studies clearly demon-

strated that fishing was preponderant over mollusc gathering since the earliest occupations (Figuti, 1993; De Masi, 2001). It is now broadly admitted that sambaqui moundbuilders were essentially fishers and that shellfish gathering, although strategical in their economical system, was secondary in diet composition. Terrestrial faunal remains are relatively rare, indirectly confirming fish as the main animal food. Shellfish remains are presently considered as building material, for the construction of the mounds themselves (Afonso & DeBlasis, 1994; Fish *et al*., 2000). At present, sambaqui builders are widely recognized to have been sedentary people with relatively large demographic parameters (DeBlasis *et al.*, 1998; Gaspar, 1998; Lima & Mazz, 1999/2000; Fish *et al*., 2013). In Southern Brazil, especially in the Santa Catarina State, these sites attain very large dimensions and are considered as exclusively funerary in purpose. In Southeastern Brazil, previous studies considered that the sambaquis, smaller than those observed in Southern Brazil, included funerary and domestic activities, but recent field research is demonstrating that at least some of these sites are also exclusively funerary (Gaspar *et al*., 2013; Scheel-Ybert, 2014). The mounds are also monumental constructions intended to mark the landscape (DeBlasis *et al.,* 1998; Gaspar *et al.,* 2013).

ZOOARCHAEOLOGICAL REMAINS

The various climatic changes that occurred during the Quaternary gave rise to a rich and complex biological record of the continental and marine environments, allowing for indirect measurements of ancient climates and environments (Gordillo *et al*., 2014). The analysis of different sources of data obtained through the zooarchaeological records enables to study the environmental conditions and to understand the composition and functioning of the ecosystems of the past. The study of shellmounds can offer relevant amount of information for establishing baselines of biodiversity, on species composition, abundances and distribution, as well as recovering paleoenvironmental information and comprehension of evolutionary change patterns for the Brazilian coast during the Holocene (Rodrigues *et al.*, 2016).

Zooarchaeological evidence exhibits high abundance and diversity of marine fauna in the Brazilian shellmounds (Santos, 1995; Kneip, 2001; Kloker *et al*., 2010; González, 2014) allowing the study through multiple approaches and methodologies to enhance understanding of environmental changes that are critical locally and globally (Jennings & Polunin, 1996; Kronen & Bender, 2007; Souza *et al*., 2016).

Mollusc shells are the most abundant and diverse remains in shellmounds (Souza *et al.*, 2010; Souza *et al.,* 2011). Bivalves and gastropods are well preserved in archaeological records and, despite the loss of soft body taxa and post burial processes, mollusc assemblages retain useful information about the life habits and habitats from where they are derived (Souza *et al*, 2010; Gordillo *et al*., 2014). They are also powerful enough to suggest and support hypotheses of global climate/weather changes (Claassen, 1998). *Anomalocardia brasiliana* (Gmelin, 1791) and *Lucina pectinata* (Gmelin, 1791) are the species of class Bivalvia that occur with greatest frequency on the Brazilian coast (Souza *et al*., 2010). Most gastropods were represented by species of carnivorous habit, which live associated with rocky, sandy substrates, on corals and/or in mangroves. *Stramonita haemastoma* (Linnaeus, 1758), *Nassarius vibex* (Say, 1822) and *Strombus pugilis* (Linnaeus, 1758) are the most common gastropods recovered in the archaeological records of sambaqui. Most of the recovered molluscs were of beach species, although species of mangrove, estuary and lagoon environments were also found (Mello, 1998, 1999; Souza *et al*., 2011).

Indices of taxonomic diversity have been used to describe the malacological community of the south-southeastern Brazilian coast and the results show that there is a tendency of reduction in biodiversity patterns in the last 5000 years (Souza *et al*., 2016). This fact can be related with changes in sea level during this period on this region (Martin & Suguio, 1975; Suguio *et al*., 1985, 2013; Angulo & Lessa, 1997; Lima, 2000; Jesus *et al*., 2017).

Among other zooarchaeological remains, terrestrial snails' shells are found in some Brazilian shellmounds, presenting a potential substitute for charcoal in radiocarbon dating analyses. They are reliable and representatives of the atmospheric carbon isotopic ratio, represent an important alternative for chronological and multiproxy studies (Macario *et al*., 2017). However, care should be taken to make sure the species used are tested for dead carbon incorporation (Carvalho *et al.,* 2015; Macario *et al*., 2016a, b, 2017). Pigati *et al*. (2010) state

that the same species may have different behaviors in different environmental conditions. Macario *et al.* (2016) have validated the use of *Megalobulimus* sp. and *Thaumastus* sp. by comparing the ^{14}C signature of land snails that lived during the nuclear testing period with the bomb peak curve (Hua *et al*., 2013).

The scarce presence of sea urchins and crustaceans in the middens point to the limited importance of these resources in the overall diet, meaning that these resources were not highly valued by human populations (Zugasti, 2011). Crustacean remains from shellmounds are also being investigated in order to produce a reference inventory and establishing baselines on biodiversity, recovering paleoenvironmental information and comprehension of evolutionary change patterns for the Brazilian coast. Nine species were identified: *Callinectes danae* Smith, 1869, *Callinectes sapidus* Rathbun, 1869 (Portunidae); *Ocypode quadrata* (Fabricius,1787) (Ocypodidae); *Ucides cordatus* (Linnaeus, 1763) (Ucididae); *Panopeus austrobesus* Williams, 1983 (Panopeidae); *Cardisoma guanhumi* Lattreille, 1825 (Gecarcinidae); *Menippe nodifrons* Stimpson, 1859 (Menippidae); *Goniopsis cruentata* (Latreille, 1803) (Grapsidae) and *Mithrax hispidus* (Herbst, 1790) (Majidae) (Rodrigues *et al*., 2016).

Despite the disproportionate amounts of clam shells found in shellmounds, fish were the most important source of protein for prehistoric human populations on the Brazilian coast (Figuti, 1993; Lima, 1999/2000; Villagran *et al*., 2011). Ichthyoarchaeological vestige shows clear evidence of efficient and well-developed fishing strategies, indicating coastal navigation skills, and the great importance of fishing for these communities in the Holocene period (Walker, 2000; Tenorio *et al*., 2010; Wagner *et al*., 2011; Guimarães, 2012).

The taxonomic study of the archaeological remains of the ichthyofauna in shellmounds of Southeastern Brazil resulted in the recognition of a marine diversity that represents 38% of all the species registered today in the main landing points of the region. The frequency of *Micropogonias furnieri* (whitemouth croaker) observed in the shellmounds suggests the preference of this species for the pre-colonial populations and shows a long history of fishery exploitation (5595 cal BP until today). Body sizes estimated based on otoliths of whitemouth croaker and compared with modern sizes landed by artisanal or semi-industrial fishing, shows a probabilistic tendency of a reduction in body size of 28% in modern catches that may be attributed to overexploitation. As well as a fishery focused on large oceanic sharks that used coastal areas as nurseries, and which in modern times do not occur on the coast of Rio de Janeiro or are rare specimens in danger of extinction (Lopes *et al*., 2016).

Still considering the fish assemblages analyzed in Lopes *et al.* (2016), the first records of inshore fisheries come from 5595 cal BP (Saquarema Lagoon) and around 4414 cal BP the fishing was focused on pelagic resources in protected areas (Angra dos Reis, rocky bays and coastal islets). From 3290 cal BP, it was evidenced the mastery of complex techniques strongly indicating the pelagic fishing (Cabo Frio and Ilha Grande) (Figure 1).

The high diversity of sharks found in shell mounds in Southeastern Brazil provides clear evidences about the exploitation of natural populations of sharks and rays, such as *Lamna nasus* Bonnaterre, 1788, *Carcharias taurus* Rafinesque, 1810, *Carcharodon carcharias* Lineu, 1758 (the great white shark) and *Pristis* sp. Teleosts identified are mainly concentrated in families such as Sciaenidae, Lutjanidae, Serranidae and Centropomidae. Species of Scaridae, Tetraodontidae and Diodontidae were particularly frequent in localities associated with rocky islands, and pelagic fishes including Istiophoridae, Coryphaenidae, Carangidae and Scombridae were commonly found near rocky cliffs and islands (Lopes *et al*., 2016).

Among zooarchaeological collections of Rio de Janeiro shellmounds there were found fish bones of *Chaetodipterus faber* (Broussonet, 1782), *Caranx hippos* (Linnaeus, 1766) and *Centropomus parallelus* (Poey, 1860) with the pathology defined as hyperostosis, which makes it impossible to use them to radiocarbon and for others isotope analyses (Aguilera *et al*., 2017). Fish otoliths, on the other hand, are acellular structures of aragonite and their composition is relatively pure compared to most biological and mineralogical structures, being dominated by calcium carbonate that is resistant to the diagenetic process under burial conditions (Campana & Neilson, 1985). Therefore, it is an ideal carbonate substrate for geochemical studies, particularly for radiocarbon and others isotopes analyses, representing an excellent marker of environmental conditions (Carvalho *et al.*, 2018).

Bertucci *et al*. (2018) developed a broad research in which they evaluated past ocean variability using the chemical composition of *Micropogonias*

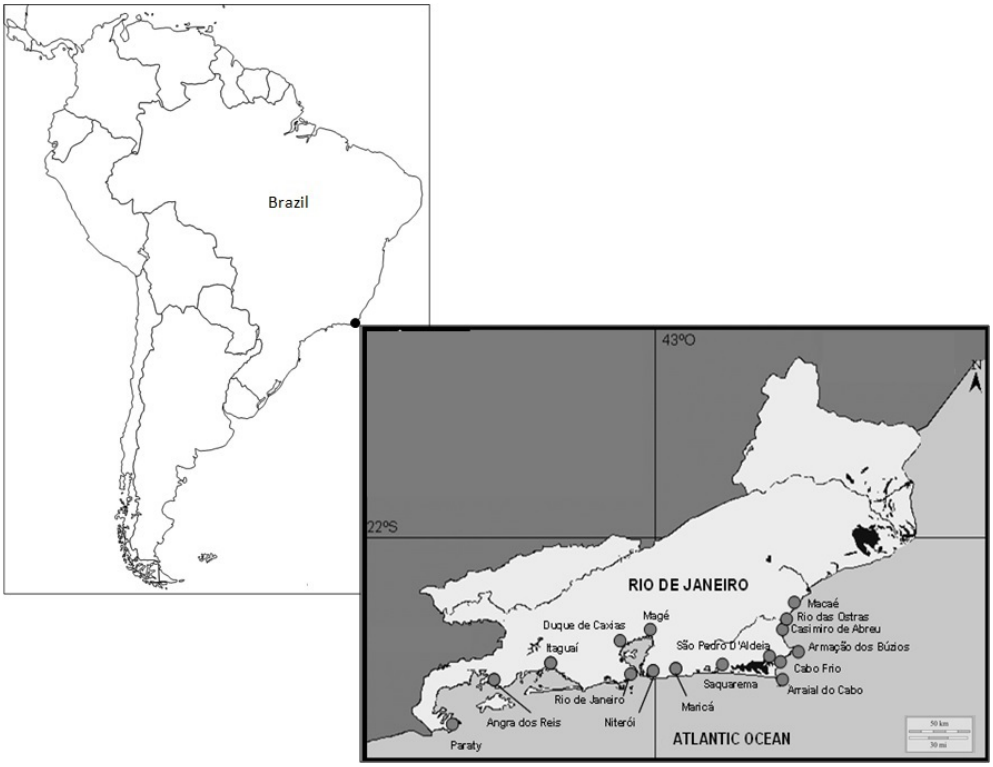

FIGURE 1

Study area. Map of the state of Rio de Janeiro showing the location of shellmounds studied (modified of Souza *et al.*, 2010).

furnieri (Desmarest, 1823) otoliths as proxies for water temperatures during the Holocene. They studied the records of climate anomalies expressed as increased high range of temperatures variabilities, evidence of palaeoupwelling and relative variability in the sea level along the coast of Rio de Janeiro.

RADIOCARBON DATING OF ZOOARCHAEOLOGICAL REMAINS

Constraining the information obtained from the archaeological records usually depends upon radiocarbon dating and a proper dating strategy is needed. Although most of the archaeological remains are useful for dating, each sample matrix requires specific chemical protocols for sample preparation and specific interpretation based on the sample origin. The first thing to be considered is the route of ^{14}C incorporation in each specific reservoir. Radiocarbon is produced by the interaction of cosmic rays with the atmosphere and follows to its incorporation to the carbon cycle (Libby, 1946; Lingenfelter, 1963; Lal & Peters, 1967; Lal, 1992). It is assumed that living organisms are in isotopic equilibrium with the atmosphere and the latter has constant isotopic concentration.

In the context of archaeological shellmounds of Brazil, terrestrial material is calibrated with the Southern Hemisphere atmosphere curve (SHCal13-Hogg *et al.*, 2013) and marine samples with the Marine13 curve (Reimer *et al.,* 2013). In both cases, care should be taken when considering specific sources of ^{14}C, since this will dictate the interpretation of radiocarbon ages.

Marine samples include fish bones, barnacles and mollusc shells. Fish skeletons in general can be highly susceptible to diagenesis (Aguilera *et al*., 2016) but fish otoliths are extremely resistant (Carvalho *et al*., 2018). For all marine samples, Marine Resevoir Effect (MRE) should be considered, not only by applying the Marine13 calibration curve, but also taking into account the specific ocean dynamics in each region, since this will contribute

to a local component of the MRE represented by an offset (ΔR) from the marine calibration curve (Stuiver & Braziunas, 1993; Alves *et al.,* 2018). In the case of fish bones, care should be taken to avoid species that travel long distances as their ^{14}C concentration would reflect a mixture of several reservoirs.

Ideally, the ΔR value for each region and time period should be used for the proper calibration of marine radiocarbon ages in that location. Macario & Alves (2018) and Macario *et al*. (2018) summarize what is currently known about the temporal and spatial variability of the MRE on the Brazilian coast, including studies using pre-bomb (collected before 1950) samples and archaeological material. In the sambaquis, terrestrial and marine material is often found in close stratigraphic association, which suggests contemporaneity. By radiocarbon dating both materials and comparing their ^{14}C dates, one can derive a marine reservoir correction for a specific location and time period (Ascough *et al*., 2005; Alves *et al*., 2018). The local MRE, has been assessed through the ^{14}C-dating of archaeological material for the coasts of Santa Catarina (Eastoe *et al.,* 2002) and Rio de Janeiro (Angulo *et al.,* 2007; Macario *et al*., 2014, 2015; Alves *et al.,* 2015; Carvalho *et al*., 2015; Macario *et al*., 2016a, b; Macario *et al*., 2018).

Eastoe *et al.* (2002) used pairs of charcoal and mollusc shell from the Jabuticabeira shellmound, in Santa Catarina, to estimate a correction for the local MRE. The authors combined their results with those found by Nadal de Masi (2001), who used the pre-bomb samples approach in the same region, to derive a local MRE correction (ΔR) of 185 ± 30 ^{14}C yr. It was not only until 2007 that the archaeological approach was used again for the study of the MRE in Brazil. Angulo *et al.* (2007) studied the sambaquis of Ilha de Cabo Frio and Boqueirão but their results were considered to be inconclusive in identifying the effects of the upwelling in the region. Nevertheless, from paired samples collected in the Usiminas shellmound, Rio de Janeiro, Angulo *et al.* (2007) derived R values varying from 358 ± 44 to 565 ± 44 ^{14}C yr.

With the establishment of the Radiocarbon Laboratory of the Universidade Federal Fluminense (LAC-UFF) in 2009 (Anjos *et al.,* 2013), radiocarbon analyses became more accessible in Brazil and a significant amount of research effort has been dedicated to quantifying the MRE, using different approaches, for different parts of the Brazilian coast. Based on Angulo *et al.* (2007), Macario *et al.* (2015) re-calculated the ΔR value for the Usiminas shellmound and found 152 ± 110 ^{14}C yr. Moreover, Macario *et al.* (2014, 2015) found the ΔR value of -127 ± 67 ^{14}C yr for the Tarioba shellmound, in Rio das Ostras, Rio de Janeiro. Also in Rio de Janeiro, the sambaquis of Saquarema (-140 ± 66 ^{14}C yr; Alves *et al*., 2015a, b) and Manitiba (ΔR=-82 ± 71 ^{14}C yr; Carvalho *et al.,* 2015), both in the Saquarema region, were studied through the use of charcoal, marine and terrestrial molluscs, and fish otoliths. More recently, Macario *et al*. (2016a, b) performed a new investigation on the Usiminas shellmound and found a ΔR value of 67 ± 33 ^{14}C yr, confirming the positive values previously found by Macario *et al.* (2015). Finally, Macario *et al.* (2018), working with samples from the Acaiá shellmound, in Ilha Grande, Rio de Janeiro, found a ΔR value of -80 ± 87 ^{14}C yr.

Given the pros and cons of each sample matrix and their respective original reservoir, the best approach for a robust chronological study is to combine as many different materials as possible (Alves *et al*., 2015a, b). Another problematic aspect in the radiocarbon dating of shellmounds is that there is no correlation of age and depth (Macario *et al*., 2014; Alves *et al*., 2015a, b) often preventing chronological sequences to be established. In shellmounds, spatial distribution of remains is complex and in many times related to funerary structures (Klokler, 2008). To compensate for age variability within same depths, the largest possible ensemble is considered so that a distribution of ages can represent a given occupation (Macario *et al*., 2014, 2016a, b; Alves *et al*., 2015a, b). Bayesian statistics can be used to establish probability distributions for the occupational periods, not only in the case of shellmounds but in any archaeological context (Milheira *et al*., 2017).

FINAL REMARKS

Shellmounds are complex archaeological sites that are distributed along the Brazilian coast. They present a temporal variation between 9000 to 1000 yrs BP and are composed of different archaeological vestiges with intricate structure, chronology and interpretation. Through their zooarchaeological sequences, these prehistoric settlements serve as excellent repositories of data to the human activity,

biodiversity, climatic geochemical, sea level variation and others. When corroborated with flora data such as phytoliths, pollen and charcoal (Scheel-Ybert, 2014; Coe *et al*., 2017; Scheel-Ybert & Gonçalves, 2017), these studies describe the environmental characteristics of the past. Thus, the shellmounds on the Brazilian coast remains an important subject for archaeological and environmental studies.

REFERENCES

Afonso, M.C. & Deblasis, P. 1994: Aspectos da formação de um grande sambaqui: Alguns indicadores em Espinheiros II, Joinville. *Rev. MAE-USP* 4: 21-30.

Aguilera, O.; Belem, A.L.; Angelica, R.; Macario, K.; Crapez, M.; Nepomuceno, A.; Paes, E.; Tenório, M.C.; Dias, F.; Souza, R.; Rapagnã, L.; Carvalho, C. & Silva, E. 2016: Fish bone diagenesis in southeastern Brazilian shell mounds and its importance for paleoenvironmental studies. *Quaternary International* 391: 18-25.

Aguilera, O.A.; Rocha, I.; Lopes, M.; Lima, I.; Lopes, R.T.; Machado, A.S.; Guimarães, R.B.; Crapez, M.A.C.; Tenório, M.C. & Nepomuceno, A. 2017: The bone degenerative processes in senile fishes from Holocene Brazilian shell mounds. *J Fish Dis* 40(12): 1869-1881.

ÁLvarez, M.; Godino, I.B.; Balbo, A. & Madella, M. 2011: Shell middens as archives of past environments, human dispersal and specialized resource management. *Quaternary International* 239: 1-7.

Alves, E.; Macario, K.; Souza, R.; Pimenta, A.; Douka, K.; Oliveira, F.; Chanca, I. & Angulo, R. 2015a: Radiocarbon reservoir corrections on the Brazilian coast from pre- bomb marine shells. *Quaternary, Geochronology* 29: 30-35.

Alves, E.Q.; Macario, K.D.; Souza, R.C.C.L.; Aguilera, O.; Goulart, A.C.; Scheel-Ybert, R.; Bachelet, C.; Carvalho, C.; Oliveira, F.M. & Douka, K. 2015b: Marine Reservoir Corrections on the Southeastern Coast of Brazil: Paired Samples from the Saquarema Shellmound. *Radiocarbon* 57: 517-525.

Alves, E.Q.; Macario, K.; Ascough, P. & Bronk Ramsey, C. 2018: The worldwide marine radiocarbon reservoir effect: Definitions, mechanisms, and prospects. *Reviews of Geophysics* 56: 278-305. https://doi.org/10.1002/2017RG000588

Angulo, R.J. & Lessa, G.C. 1997: The Brazilian sea-level curves: a critical review with emphasis on the curves from the Paranaguá and Cananéia regions. *Marine Geology* 140: 141-166.

Angulo, R.; Reimer, P.; Souza, M.A.; Scheel-Ybert, R.; Tenório, M.C.; Disaró, S.T. & Gaspar, M.D. 2007: A tentative determination of upwelling influence on the paleo-surficial marine water reservoir effect in southeastern Brazil. *Radiocarbon* 49(03): 1255-1259.

Anjos, R.M.; Macario, K.D.; Gomes, P.R.S.; Linares, R.; Queiroz, E. & Carvalho, C. 2013: Towards a complete 14C AMS facility at the Universidade Federal Fluminense (Niterói, Brazil): Sample preparation laboratory tests. *Nuclear Instruments and Methods in Physics Research* B 294: 173-175.

Ascough, P.; Cook, G. & Dugmore, A. 2005: Methodological approaches to determining the marine radiocarbon reservoir effect. *Progress in Physical Geography* 29(4): 532-547.

Bailey, G.N. 1975: The role of molluscs in coastal economies: The results of midden analysis in Australia. *Journal of Archaeological Science* 2: 45-62.

Beltrão, M.C.M.; Heredia, O.R.; Neme, S.M.N. & Gaspar, M.D. 1978: Os coletores de moluscos litorâneos e sua adaptação ambiental. O sambaqui de Sernambetiba. *Arquivos do Museu de História Natural*, v. II: 97-116.

Bertucci, T.; Aguilera, O.; Vasconcelos, C.; Nascimento, G.; Marques, G.; Macario, K. De; Albuquerque, C.Q.; Lima, T. & Belém, A. 2018: Late Holocene palaeotemperatures and palaeoenviroments in the southeastern Brazilian coast inferred from otolith geochemistry. *Palaeogeography*, *Palaeoclimatology*, *Palaeoecology* 503: 40-50.

Campana, S.E. & Neilson, J.D. 1985: Microstructure of fish otoliths. *Can. J. Fish. Aquat. Sci.* 42: 1014-1032.

Carvalho, C.; Macario, K.; Oliveira, M.I.; Oliveira, F.; Chanca, I.; Alves, E.; Souza, R.; Aguilera, O. & Douka, K. 2015: Potential use of archaeological snail shells for the calculation of local marine reservoir effect. *Radiocarbon* 57(3): 459-467.

Carvalho, C.; Macario, K.; Lima, T.; Chanca, I.; Oliveira, F.; Alves, E.; Bertucci, T. & Aguilera, O. 2018: Otolith -based chronology of Brazilian Shellmounds. *Radiocarbon* (in press).

Claassen, C. 1998: *Shells*. Cambridge Manuals in Archaeology Series. Cambridge University Press, Cambridge.

Coe, H.H.G.; Souza, R.C.C.L.; Duarte, M.R.; Ricardo, S.D.F.; Machado, D.O.B.F.; Macario, K.C.D. & Silva, E.P. 2017: Characterisation of phytoliths from the stratigraphic layers of the Sambaqui da Tarioba (Rio das Ostras, RJ, Brazil). *Flora:* 236-237.

Deblasis, P.; Fish, S.K.; Gaspar, M.D. & Fish, P.R. 1998: Some references for the discussion of complexity

among the sambaqui moundbuilders from the southern shores of Brazil. *Rev. Arqueol. Amer*. 15: 75-105.

Deblasis, P.; Kneip, A.; Scheel-Ybert, R.; Giannini, P.C. & Gaspar, M.D. 2007: Sambaquis e paisagem: Dinâmica natural e arqueologia regional no litoral do sul do Brasil. *Arqueologia Suramericana* 3: 29-61.

De Masi, M.A.N. 2001: Pescadores coletores da costa sul do Brasil. *Pesquisas* 57: 1-136.

Eastoe, C.J.; Fish, S.; Fish, P.; Gaspar, M.D. & Long, A. 2002: Reservoir corrections for marine samples from the South Atlantic Coast, Santa Catarina state, Brazil. *Radiocarbon* 44: 145-148.

Erlandson, J.M. & Braje, T.J. 2011: From Asia to the Americas by boat? Paleogeography, paleoecology, and stemmed points of the northwest Pacific. *Quaternary International* 239: 28-37.

Figuti, L. 1993: O homem pré-histórico, o molusco e os sambaquis: considerações sobre a subsistência dos povos sambaquieiros. *Rev. MAE-USP* 3: 67-80.

Figuti, L.; Plens, C.R. & Deblasis, P. 2013: Small sambaquis and big chronologies: shellmound building and hunter-gatherers in Neotropical highlands. *Radiocarbon* 55(3): 1215-1221.

Fish, P.; Fish, S.; De Blasis, P. & Gaspar, M.D. 2013: Monumental Shell Mounds as Persistent Places in Southern Coastal Brazil. In: Thompson, V.D. & Waggoner Jr, J.C. (Org.): *The Archaelogy and Historical Ecology of Small Scale Economies*: 120-140. University Press of Florida, Gainesville.

Fish, S.K.; Deblasis, P.; Gaspar, M.D. & Fish, P.R. 2000: Eventos incrementais na construção de sambaquis, litoral sul do estado de Santa Catarina. *Rev. MAE-USP* 10: 69-87.

Gaspar, M.D. 1996: Análises das datações radiocarbônicas dos sítios de pescadores, coletores e caçadores. *Boletim do Museu Paranaense Emilio Goeldi*, *Ciências da Terra*, 8: 81-91.

— 1998: Considerations of sambaquis of the Brazilian coast. *Antiquity* 72: 592-615.

Gaspar, M.D.; Kloker, D.; Scheel-Ybert, R. & Bianchini, G.F. 2013: Sambaqui de Amourins: mesmo sítio, perspectivas diferentes. Arqueologia de um Sambaqui 30 anos depois. *Revista do Museo de Antropologia* 6: 7-20.

González, M.M.B. 2014: Utilização de ferrões de raias pelos grupos de pescadores-coletores do litoral de São Paulo. *Cad Ceon Cult Mater* 24: 99-122.

Gordillo, S.; Bayer, M.S.; Boretto, G. & Charó, M. 2014: Paleoecology. In: *Mollusk shells as bio-geo-archives*. Springer, Cham.

Guimaraes, M. 2012: Fishing strategies among prehistoric populations at Saquarema lagoonal complex, Rio de Janeiro. *An. Acad. Bras. Ciênc* 85(1): 415-429.

Gutiérrez-Zugasti, I.; Andersen, S.H.; Araújo, A.C.; Dupont, C.; Milner, N. & Monge-Soares, A.M. 2011: Shell midden research in Atlantic Europe: State of the art, research problems and perspectives for the future. *Quaternary International* 239: 70-85.

Habu, J.; Matsui, A.; Yamamoto, N. & Kanno, T. 2011: Shell midden archaeology in Japan: Aquatic food acquisition and long-term change in the Jomon culture. *Quaternary International* 239: 19-27.

Hardy, K.; Camara, A.; Piqué, R.; Dioh, E.; Guèye, M.; Diaw-Diadhiou, H.; Faye, M. & Carré, M. 2016: Shellfishing and shell midden construction in the Saloum Delta, Senegal. *Journal of Anthropological Archaeology* 41: 19-32.

Hogg, A.G.; Hua, Q.; Blackwell, P.G.; Niu, M.; Buck, C.E.; Guilderson, T.P.; Heaton, T.J.; Palmer, J.G.; Reimer, P.J.; Reimer, R.W.; Turney, C.S.M. & Zimmerman, S.R.H. 2013: SHCal13 Southern Hemisphere Calibration, 0-50,000 Years cal BP. *Radiocarbon* 55(4): 1889-1903.

Hua, Q.; Barbetti, M. & Rakowski, A.J. 2013: Atmospheric Radiocarbon for the Period 1950-2010. *Radiocarbon* 55(4): 2059-2072.

Jennings, S. & Polunin, N.V.C. 1996: Impacts of fishing on tropical reef ecosystems. *Ambio* 25: 44-49.

Jesus, P.B.; Dias, F.F.; Muniz, R.D.A.; Macario, K.C.D.; Seoane, J.C.S.; Quattrociocchi, D.G.S. & Araujo, J.C. 2017: Holocene paleo-sea level in southeastern Brazil: an approach based on vermetids shells. *Journal of Sedimentary Environments* 2(1): 35-48.

Klokler, D. 2008: Food for body and soul: mortuary ritual in shell mounds (Laguna-Brazil) [PhD dissertation]. Department of Anthropology. University of Arizona, Tucson.

Klokler, D.M.; Villagrán, X.; Giannini, P.; Peixoto, S. & Deblasis, P. 2010: Juntos na costa: zooarqueologia e geoarqueologia de sambaquis do litoral sul catarinense. *Rev. Mus. Arqueol. Etnol.* 20: 53-75.

Kneip, L.M. 2001: O sambaqui de Manitiba e outros sambaquis de Saquarema, RJ. *Documento de trabalho. Série Arqueologia* 5: 1-91.

Kronen, M. & Bender, A. 2007: Assessing marine resource exploitation in Lofanga, Tonga: One case study-Two approaches. *Human Ecology* 35: 195-207.

Lal, D. 1992: Cosmogenic in situ radiocarbon on the earth. In: *Radiocarbon After Four Decades*: 146-161. Springer, New York.

Lal, D. & Peters, B. 1967: Cosmic ray produced radioactivity on the earth. *Kosmische Strahlung II/Cosmic Rays* II: 551-612.

Leavesley, M.G.; Bird, M.I.; Fifield, L.K.; Hausladen, P.A.; Santos, G.M. & Di Tada, M.L. 2002: Buang Merabak: early evidence for human occupation in the Bismarck Archipelago, Papua New Guinea. *Australian Archaeology* 54: 55-57.

Libby, W. 1946: Atmospheric helium three and radiocarbon from cosmic radiation. *Physical Review* 69(11-12): 671.

Lima, T.A. 1999-2000: Em busca dos frutos do mar: os pescadores-coletores do litoral centro-sul do Brasil. *Rev USP* 44: 270-332.

Lima, T.A. & Mazz, J.M.L. 1999/2000: La emergencia de complejidad entre los cazadores colectores de la costa atlántica meridional sudamericana. *Rev.Arq.Amer*. 17/18/19: 129-175.

Lima, T.A.; Macario, K.D.; Anjos, R.M.; Gomes, P.R.S.; Coimbra, M.M. & Elmore, D. 2002: The Antiquity of the Prehistoric Settlement of the Central-South Brazilian Coast. *Radiocarbon* 44: 733-738.

Lingenfelter, R.E. 1963: Production of 14C by cosmic-ray neutrons. *Reviews of Geophysics* 1: 35-53.

Lopes, M.; Bertucci, T.C.; Rapagnã, L.; Tubino, R.A.; Monteiro-Neto, C. *et al*. 2016: The path towards endangered species: prehistoric fisheries in Southeastern Brazil. *PloS One* 11(6): e0154476.

Macario, K.D. & Alves, E.Q. 2018: Efeito de reservatório marinho na costa do Brasil. *Quaternary and Environmental Geosciences* 09(1):11-17.

Macario, K.D.; Souza, R.C.C.L.; Trindade, D.C.; Decco, J.; Lima, T.A.; Aguilera, O.A.; Marques, A.N.; Alves, E.Q.; Oliveira, F.M.; Chanca, I.S. & Carvalho, C. 2014: Chronological model of a Brazilian Holocene shellmound (Sambaqui da Tarioba, Rio de Janeiro, Brazil). *Radiocarbon* 56(2): 489-499.

Macario, K.D.; Souza, R.C.C.L.; Aguilera, O.A.; Carvalho, C.; Oliveira, F.M.; Alves, E.Q.; Chanca, I.S.; Silva, E.P.; Douka, K.; Decco, J.; Trindade, D.C.; Marques, A.N.; Anjos, R.M. & Pamplona, F.C. 2015: Marine reservoir effect on the Southeastern coast of Brazil: results from the Tarioba shellmound paired samples. *J. Environ. Radioact*. 143: 14-19.

Macario, K.D.; Alves, E.Q.; Chanca, I.S.; Oliveira, F.M.; Carvalho, C.; Souza, R.; Aguilera, O.; Tenório, M.C.; Rapagnã, L.C.; Douka, K. & Silva, E. 2016a: The Usiminas shellmound on the Cabo Frio Island: Marine reservoir effect in an upwelling region on the coast of Brazil. *Quaternary Geochronology* 35: 36-42.

Macario, K.D.; Alves, E.Q.; Carvalho, C.; Oliveira, F.M.; Bronk-Ramsey, C.; Chivall, D.; Souza, R.; Simone, L.R.L. & Cavallari, D. 2016b: The use of the terrestrial snails of the genera *Megalobulimus* and *Thaumastus* as representatives of the atmospheric carbon reservoir. *Sci. Rep*. 6: 27395. https://doi.org/10.1038/srep27395

Macario, K.D.; Tenório, M.C.; Alves, E.Q.; Oliveira, F.M.; Chanca, I.S.; Netto, B.; Carvalho, C.; Souza, R.; Aguilera, O. & Guimarães, R.B. 2017: Terrestrial mollusks as chronological records in Brazilian shellmounds. *Radiocarbon* 1-17.

Macario, K.D.; Alves, E.Q.; Belém, A.L.; Aguilera, O.; Bertucci, T.; Tenório, M.C.; Oliveira, F.M.; Chanca, I.; Carvalho, C.; Souza, R.; Scheel-Ybert, R.; Nascimento, G.; Dias, F. & Caon, J. 2018: The marine reservoir effect on the coast of Rio de Janeiro: deriving Δr values from fish otoliths and mollusk shells. *Radiocarbon* 2018: 1-18. https://doi.org/10.1017/RDC.2018.23.

Martin, L. & Suguio, K. 1975: The State of São Paulo coastal marine Quaternary Geology: The ancient strandlines. Anais da Academia Brasileira de Ciências 47: 249-263.

Mello, E.M.B. 1998: Fauna malacológica de sítios arqueológicos do Estado do Rio de Janeiro, Brasil: Veneroida (Mollusca, Bivalvia). Publicações Avulsas do Museu Nacional, nº 75, 38 p.

— 1999: Fauna malacológica de sítios arqueológicos do Estado do Rio de Janeiro, Brasil: Mesogastropoda, Neogastropoda (Mollusca, Gastropoda, Prosobranchia). Publicações Avulsas do Museu Nacional, nº 79, 36 p.

Milheira, R.G.; Macario, K.D.; Chanca, I.S. & Alves, E.Q. 2017: Archaeological earthen mound complex in Patos Lagoon, southern Brazil: chronological model and freshwater influence. *Radiocarbon* 59 (1): 195-214.

Orquera, L.A.; Legoupil, D. & Piana, E.L. 2011: Littoral adaptation at the southern end of South America. *Quaternary International* 239: 61-69.

Pigati, J.; Rech, J. & Nekola. J. 2010: Radiocarbon dating of small terrestrial gastropod shells in North America. *Quaternary Geochronology* 5: 519-532.

Reimer, P.J.; Bard, E.; Bayliss, A.; Beck, J.W.; Blackwell, P.G.; Bronk Ramsey, C.; Grootes, P.M.; Guilderson, T.P.; Haflidason, H.; Hajdas, I.; Hatté, C.; Heaton, T.J.; Hoffmann, D.L.; Hogg, A.G.; Hughen, K.A.; Kaiser, K.F.; Kromer, B.; Manning, S.W.; Niu, M.; Reimer, R.W.; Richards, D.A.; Scott, E.M.; Southon, J.R.; Staff, R.A.; Turney, C.S.M. & Van Der Plicht, J. 2013: IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0-50,000 Years cal BP. *Radiocarbon* 55(4): 1869-1887.

Rodrigues, F.B.; Duarte, M.R.; Souza, R.C.C.L.; Soares-Gomes, A. & Silva, E.P. 2016: Holocene crusta-

ceans from the Tarioba shell mound, Rio das Ostras, Rio de Janeiro, Brazil. *Check List* 12: 1-5.

Roksandic, M.; Mendonça De Souza, S.M.F.; Klokler, D.; Eggers, S. & Burchell, M. 2014: Cultural dynamics of shell-matrix sites: diverse perspectives on biological remains from shell mounds and shell middens. In: Roksandic, M.; Mendonça de Souza, S.M.F.; Eggers, S.; Burchell, M. & Klokler, D. (eds.): *The cultural dynamics of shell-matrix sites*. University of New Mexico Press, Albuquerque.

Salemme, M. & Miotti, L.L. 2008: Archeological Hunter-Gatherer Landscapes Since the Latest Pleistocene in Fuego-Patagonia. *Developments in Quaternary Sciences* 11: 437-483.

Santos, C.M.C. 1995: A ictiofauna do Sambaqui de Camboinhas, Niterói, RJ. *Documento de Trabalho, Sér Arqueol* 3: 65-72.

Scheel-Ybert, R. 2014: Landscape and use of plants by Southern and Southeastern Brazilian shell mound builders. In: Roksandic, M.; Mendonça de Souza, S.M.F.; Eggers, S.; Burchell, M. & Klokler, D. (eds.): *The cultural dynamics of shell-matrix sites*: 289-300. University of New Mexico Press, Albuquerque.

Scheel-Ybert, R. & Gonçalves, T. 2017: *Primeiro Atlas Antracológico de Espécies Brasileiras*. Museu Nacional - Série Livro Digital.

Schmitz, P.I. 1987: Prehistoric hunters and gatherers of Brazil. *Journal of World Prehistory* 1(1): 53-126.

Souza, R.C.; Lima, T.A. & Silva, E.P. 2010: Holocene molluscs from Rio de Janeiro state coast, Brazil. *Check List* 6(2): 301-308.

— 2011: *Conchas marinhas de sambaquis do Brasil*. Technical Books, Rio de Janeiro.

Souza, R.C.; Lima, T.A.; Duarte, M.R. & Silva, E.P. 2016: Changes in patterns of biodiversity of marine mollusks along the Brazilian coast during the late Holocene inferred from shell-mound (sambaquis) data. *The Holocene* 26(11): 1802-1809.

Stuiver, M. & Braziunas, T. 1993: Modeling atmospheric 14C influences and 14C ages of marine samples to 10,000 BC. *Radiocarbon* 35: 137-189.

Suguio, K.; Martin, L.; Bittencourt, A.C.S.P.; Dominguez, J.M.L.; Flexor, J-M. & Azevedo, E.G. 1985: Flutuações do nível relativo do mar durante o Quaternário superior ao longo do litoral brasileiro e suas implicações na sedimentação costeira. *Revista Brasileira de Geociências* 15(4): 273-286.

Suguio, K.; Barreto, A.M.F.; Oliveira, P.E.; Bezerra, F.H.R. & Vilela, M.C.S.H. 2013: Indicators of Holocene sea level changes along the coast of the states of Pernambuco and Paraíba, Brazil. *Geologia USP*, Série Científica 13(4): 141-152.

Tenorio, M.C.; Afonso, M.C. & Pinto, D. 2010: Arqueologia do Arraial do Cabo com foco nos sítios da Ilha do Cabo Frio. *Rev. Mus. Arqueol. Etnol.* 20: 127-145.

Van Neer, W. & Clist, B. 1991: Le site de l'Age du Fer Ancien d'Oveng (Province de l'Estuaire, Gabon), analyse de sa faune et de son importance pour la problématique de l'expansion des locuteurs bantu en Afrique Centrale. *Comptes Rendus de l'Académie des Sciences* Série II 312: 105-110.

Villagran, X.S.; Klokler, D.; Peixoto, S.; Deblasis, P. & Giannini, P.C.F. 2011: Building coastal Landscapes: zooarchaeology and geoarchaeology of Brazilian shellmounds. *Journal of Island and Coastal Archaeology* 6: 211-234.

Wagner, G.; Hilbert, K.; Bandeira, D.; Tenório, M.C. & Okumura, M.M. 2011: Sambaquis (shell mounds) of the Brazilian coast. *Quaternary International* 239: 51-60.

Walker, K.J. 2000: The material culture of precolumbian fishing: artifacts and fish remains from coastal southwest Florida. *Southeastern Archaeology* 19: 24-45.

Zugasti, F.I.G. 2011: The Use of Echinoids and Crustaceans as Food During the Pleistocene-Holocene Transition in Northern Spain: Methodological Contribution and Dietary Assessment. *The Journal of Island and Coastal Archaeology* 6(1): 115-133.