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INTEGRATING COASTAL MARINE ZOOARCHAEOLOGY AND CONSERVATION BIOLOGY IN TROPICAL SOUTH AMERICA

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Abstract

Rapidly evolving climate change and anthropogenic pressures have significantly reshaped our environment, requiring a comprehensive understanding of their medium- and long-term impacts. This understanding is crucial in formulating effective strategies for environmental conservation and restoration. Historical Ecology, recognized and increasingly used in academic research, offers a valuable tool for this purpose. Beyond the introductory (**Chapter 1**) and concluding (**Chapter 8**) chapters, this thesis encompasses six distinct chapters employing diverse approaches, including systematic literature review, zooarchaeology, bone taphonomy and metrics, stable isotopes and palaeoproteomics. The research aims to investigate links between fishing, technology and historical events on aquatic resources from pre-colonial to historical periods in Brazil. Chapters 2 and 3 used literature reviews on published fauna remains to investigate long-term and large-scale changes in mammal and fish diversity in southern Brazil in pre-colonial time. In particular, **Chapter 2** introduces the ZooarchBR, the first database of archaeological fauna in Brazil, showcasing potential applications for archaeology and conservation science, while **Chapter 3** examines bony and cartilaginous fish species, exploring changes in their diversity and functional traits over time. **Chapter 4** examines pre-colonial fish catch compositions and related fishing artefacts from archaeological sites spanning the past 6000 years in Babitonga Bay, an important estuary on the south coast. **Chapter 5** contributes to filling the gap in zooarchaeological data from colonial and post-colonial periods in Brazil. The findings reveal the crucial role of fish and native terrestrial mammals in household consumption and economic livelihoods during the European colonisation of southern Brazil. **Chapter 6** employs otolith metrics and stable isotope analysis to comprehend the exploited environments, fishing processes and ecology of target species in pre-colonial (subsistence) and historical (subsistence and commercial) fisheries in Babitonga Bay. The chapter also explores potential changes in total body length, associated with human pressures on fish communities. Emphasising the pivotal role of historical processes in understanding contemporary environmental challenges, notably overfishing, defaunation, and anthropogenic impacts on coastal species and habitats, this thesis underscores the need for historical perspectives in conservation debates. In addition, **Chapter 7** introduces an educational booklet designed to

familiarise readers with Zooarchaeology within the broader community. This booklet emphasises the significance of preserving archaeological sites and underscores their potential contributions to ongoing discussions about environmental conservation.

CHAPTER 1

Introduction

1.1. Theoretical framework

Climate change exerts a profound influence on marine biodiversity, essentially by affecting ecosystems, habitats, and the geographic distribution of species (Doney et al., 2012; Easterling et al., 2000; McCarthy et al., 2001; Walther et al., 2002). Variations in temperature, precipitation patterns, and extreme weather events directly affect coastal ecosystems, resulting in shifts in species abundance and distribution (Doney et al., 2012; Walther et al., 2002; Worm & Lotze, 2021). Species that lack adaptability or fail to migrate in response to these changes face increased risks of local extirpation or even extinction (Doney et al., 2012; Worm & Lotze, 2021). Climate alterations can also disrupt food availability, reproductive cycles, and ecosystem dynamics, leading to modifications in species interactions and overall biodiversity (Doney et al., 2012). Furthermore, changing environmental conditions can disturb symbiotic relationships and influence the timing of seasonal events like flowering and migration, thereby further impacting biodiversity across diverse habitats and ecosystems (Doney et al., 2012; Walther et al., 2002; Worm & Lotze, 2021).

In addition to climate change, coastal areas have been subjected to anthropogenic pressures since prehistoric times (Erlandson et al., 2009), including high concentration of human population, overexploitation, pollution and habitat degradation (Dulvy et al., 2003; Lotze et al., 2006; Tuholske et al., 2021). For instance, approximately 30% of the global human population resides near to the coast (up to 100 km), leading to increased urbanisation, industrialization, and subsequent pressures on marine ecosystems (Reimann et al., 2023). Overexploitation of fish stocks is evident, with nearly a third of commercial fish stocks being overfished and many facing collapse (FAO, 2020). Pollution from various sources, including industrial waste, agricultural runoff and plastics, continues to degrade coastal waters, affecting marine life and ecosystems (Balk et al., 2009; Jambeck et al., 2015). Furthermore, habitat loss due to coastal development, land-use, and degradation of mangroves and coral reefs adds to the cumulative stress on coastal environments worldwide (Duarte et al., 2013; Herbert-Read et al., 2022). These combined pressures pose significant challenges to the resilience and sustainability of coastal and marine ecosystems, and the people that depend on them.

Both climate change and anthropogenic impacts are rapidly reshaping our environment, requiring a comprehensive understanding of the short- to medium-term effects of these transformations to develop effective strategies for environmental conservation and restoration (Finn et al., 2023; Strassburg et al., 2020). However, to gain insight into these environmental changes, it is often imperative to push our knowledge to the past, examining the historical responses of ecosystems on broader temporal scales. In this case, Historical Ecology serves as a valuable conceptual framework, which is increasingly recognized and employed within the academic community (Beller et al., 2020).

1.1.1. Historical Ecology

Historical Ecology (hereafter referred to as HE) is an interdisciplinary field of study that combines elements of ecology, archaeology, history, and other disciplines to investigate past ecosystems and human-environment interactions over various temporal scales (Balée & Erickson, 2006; Crumley, 2018). In other words, HE includes humans as a component of the ecosystems (Balée & Erickson, 2006; Crumley, 2018). Research on HE offers several insights for ecosystem management, such as historical baseline conditions and potential restoration targets (Alagona et al., 2012; Swetnam et al., 1999), identifying ecosystem responses and resilience to global environmental change over time (Nogués-Bravo et al., 2018; Vellend et al., 2013), and others.

The first studies related to HE approaches are dated as early as the 18th century, however, it was in the 20th century that the discipline increased when several scientific strands contributed to its formation (Crumley, 2018; Szabó, 2014). In a recent study, Szabó (2014) identified a few main strands to HE, including (i) forest history, (ii) the Annales school of historical method and thought (Annales d'histoire économique et sociale, founded in the 1920s), (iii) early historical geography, (iv) palaeoecology and (v) landscape history/archaeology. The author also highlighted that due to the interdisciplinary spectrum of contemporary historical ecology, more such strands could be distinguished, for example, historical climatology or environmental archaeology (Szabó, 2014).

The discipline of HE emerged in the 1960s, primarily in North America and Europe, marking its initial formal development. This period was characterised by the publication of influential studies that have significantly contributed to the field and continue to be frequently cited (e.g. (Tubbs, 1968), see Szabó, 2014 for more examples). However, only in the 2000s did HE undergo notable diversification and globalisation, with theoretical contributions to the discipline emerging from regions worldwide (Szabó, 2014). The main change in HE in recent years, without a doubt, is the consolidation of its interdisciplinarity, that is, the increasing recognition and acknowledgement of studies aligned with the principles of historical ecology, and also the diversity of sources used by studies (e.g. maps, newspapers, archaeological data). For example, Szabó (2014) observed a noticeable trend emerging from the 2000s onwards, where researchers increasingly cited studies encompassing both ecological and anthropological dimensions of historical ecology. Concurrent with the increasing volume of research on the subject of HE, an emerging connection, or at least an endeavour to establish one, with public policy becomes apparent. In their recent study focusing on a historical period spanning decades and centuries, Beller et al. (2020) identified more than 200 studies that offered at least 24 recommendations for effective ecosystem management.

Despite the progress in the field, recent reviews of HE revealed significant research gaps (Beller et al., 2020; Szabó, 2014). **The first gap** is related to the scarcity of studies focused on specific areas, particularly in Asia, Central/South America, and Africa (Beller et al., 2020). This is particularly evident in South America, which contains a rich concentration of archaeological sites spanning thousands of years. Given the archaeological context, efforts have been made to integrate ancient data with current discussions in conservation biology (e.g. Few & Tortorici, 2013). However, further studies are necessary to broaden our understanding of the historical and archaeological aspects of human-environment interactions in the region. In Brazil, the term 'Historical Ecology' was initially introduced in 1998. Most Historical Ecology studies in this region concentrate on the 16th and 21st centuries, primarily centred on the Amazon Biome (Lazos-Ruíz et al., 2021). However, it's worth noticing that a recent review on Historical Ecology in Brazil highlighted a scarcity of identified archaeological studies (Lazos-Ruíz et al., 2021).

The second gap is the relative lack of research on aquatic ecosystems (Beller et al., 2020). Most studies, particularly those produced in the 20th century, have predominantly focused on the dynamics of forests and vegetation (Beller et al., 2020; Szabó, 2014). According to Szabó (2014), studies on forests and vegetation have occurred since the 18th century, with rapid development in the 19th century, and continue to garner significant attention, especially in North America and Europe. Moreover, Beller et al. (2020) also indicate that the majority of studies of their review of HE were derived from North America and Europe, with forests being the primary focus in approximately 50% of the analysed studies. However, some studies in aquatic environments have been conducted, particularly in recent years, although with greater emphasis in North America and Europe (e.g. (Haidvogl et al., 2014; McClenachan & Kittinger, 2013; Nadon et al., 2012; Thurstan, 2022; Zu Ermgassen et al., 2012).

Finally, **the third gap** involves the need to strengthen communication between Historical Ecology and Archaeology (Szabó, 2014). For instance, although studies on animal remains have been conducted since the 1700s (Reitz & Wing, 2008a), only recently archaeozoologists and zoologists have also begun to contribute with more frequency (Szabó, 2014). Studies have highlighted the potential of archaeofaunal records (Erlandson & Rick, 2010; Fitzpatrick & Keegan, 2007) and the connections between Zooarchaeology and HE (Stahl, 2008), along with an increased contribution from both disciplines, in discussions concerning conservation (Lyman, 2015; Lyman & Cannon, 2017; Rick & Lockwood, 2013) and global changes (Vellend et al., 2013). Despite the demonstrated potential of Archaeology in recent times, there have been modest endeavours in Brazil to integrate this discipline into ongoing conservation debates. This could be associated with the evolution of the discipline, in which the anthropological aspect of HE is intricately connected to European and North American environmental archaeology (Szabó, 2014), as well as the influence of post-processual schools on Brazilian archaeology (Funari, 2008).

These gaps highlight the need for a long-term perspective on coastal-marine ecology in Brazil, which can be achieved by analysing the rich archaeological record of this region, and particularly their abundant faunal remains. This thesis employed a multidisciplinary approach to archaeological faunal remains to leverage the value of archaeology to debates in conservation biology in southern Brazil (Figure 1.1A-B), a region with at least 9000 years of human exploitation of marine resources (Colonese et al., 2014; Fossile et al., 2019), and where the development of commercial fisheries in the last century has caused unprecedented changes in coastal social-ecological systems (Diegues, 1998).

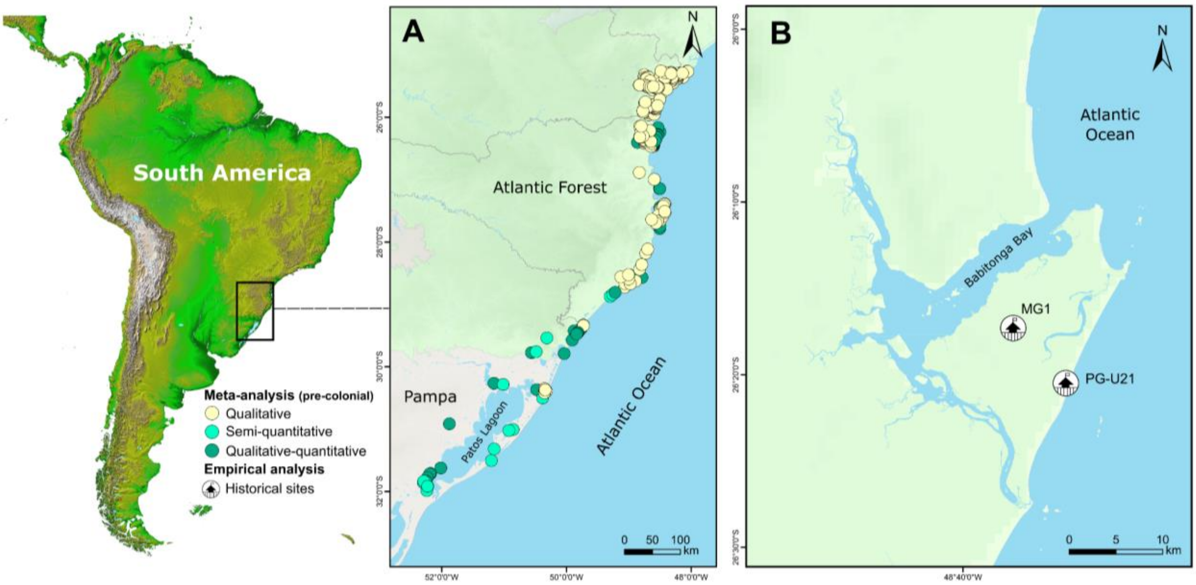

Figure 1.1. Study area. (A) Archaeological sites with zooarchaeological remains mapped on the southern coast of Brazil, and (B) Historical sites analysed in this study.

1.2. Methodological approaches

Faunal remains are frequently recovered from archaeological sites, particularly those belonging to the phylum Chordata (vertebrates, e.g., mammals), Arthropoda (e.g., crustaceans), Mollusca (e.g., bivalves), and Echinodermata (e.g., sea urchins) (Reitz & Wing, 2008b). In general, teeth, bones and shells are more readily found at archaeological sites due to calcified matrix and resistance to environmental factors (Reitz & Wing, 2008b). These remains reflect the historical interaction between humans and the environment, whether as a food, ritual and/or symbolic source (Gilson et al., 2023; Reitz & Wing, 2008c). Consequently, the study of these remains facilitates the reconstruction of various aspects of the daily life of past communities and offers an opportunity to document and study changes in the local biodiversity. Drawing from the Shifting Baselines Syndrome concept (Pauly, 1995), the absence of suitable reference points for analysing fauna composition creates a significant challenge in establishing the foundation for effective management. Thus, there is an urgent call to investigate historical and archaeological data to understand major drivers of spatial-temporal changes in species distribution and composition, in particular prior to the unprecedented levels of anthropogenic activities of the 20th and 21st centuries.

Throughout this thesis, the objective was to generate a comprehensive dataset of the marine and terrestrial animals exploited by local human populations that occupied the southern Brazilian coast in pre-colonial and late colonial/post-colonial times. This dataset was constructed by analysing archaeological faunal remains using a range of techniques, including literature review, zooarchaeology, and stable isotopes. The primary goal was to explore the connections between fishing practices, technology, and historical events in the context of aquatic resources, spanning from the pre-colonial era to historical times. Additionally, palaeoproteomics, commonly referred to as Zooarchaeology by Mass Spectrometry (ZooMS), was applied to facilitate the identification of remains from archaeological sites. It's worth noting that the author was not directly involved in conducting this specific method.

1.2.1. Literature review

To gain a more comprehensive understanding of the fauna composition and tools used by past communities along the Brazilian coast, it was essential to conduct a **literature review**. Regarding fauna composition, or zooarchaeological data, in **Chapter 2** and **Chapter 3**, the review focused on the southern coast of Brazil, an area with a high number of sites and, consequently, the most extensively studied of the country (Gaspar et al., 2008; Lima, 2000). Research articles, academic dissertations and theses, and book chapters were analysed, all available as physical and electronic copies in institutional repositories (universities, museums, public libraries) and publishers’ websites (e.g. Scielo, Scopus). These reports were categorised according to qualitative and quantitative criteria proposed by Fossile et al. (2020): Source A (qualitative-quantitative) - presented detailed taxonomic identifications, and absolute and relative abundance for all taxa (Number of Identified Specimens (NISP) and/or Minimum Number of Individuals (MNI)); Source B (semi-quantitative) - presented detailed taxonomic identifications, and absolute and relative abundance for selected taxa; Source C (qualitative) - presented taxonomic identification with no quantitative information. Data in sources A and B were used to calculate and compare relative taxonomic abundances within and among faunal collections. In contrast, data in sources A, B and C were used to derive species richness and their relative frequency distribution among sites. Whenever possible, taxonomic information was recorded to the species level, but for most sites only genus, and often classes, orders, and/or families were available. Regarding the nomenclature and ecological attributions, it follows the World Register of Marine Species - WoRMS (Horton et al., 2020), Eschmeyer's Catalog of Fishes (Fricke et al., 2021), MolluscaBase (Auffenberg et al., 2020), FishBase (Frose & Pauly, 2021), Animal Diversity Web - ADW (Myers et al., 2020), Brazilian Ornithological Records Committee (Pacheco et al., 2021), Reptile Database (Uetz, 1995) and Amphibian Species of the World (Frost, 2020). Species richness (SR) was calculated using the Minimal Level of Taxonomic Identification, considering only the minimum hierarchical level for particular taxa. The conservation status of species was compiled from the IUCN Red List of Threatened Species (IUCN, 2022) and the updated Red List of Threatened Species of the Chico Mendes Institute for Biodiversity Conservation (*Instituto Chico Mendes de Conservação da Biodiversidade* - ICMBio) (ICMBio, 2018). The socioeconomic importance of species was compiled from the National Action Plan for the Conservation of Endangered Species and of Socioeconomic Importance in the Mangrove Ecosystem - PAN Mangrove (ICMBio, 2015).

The debate over whether the emergence or spread of new fishing technology enabled ancient coastal societies to access previously untapped marine resources remains debatable. Within this context, **Chapter 4** undertook a review that combined evidence from portable fishing gear and faunal remains in Babitonga Bay, spanning from the Middle to the Late Holocene. Similar to the approach taken in the zooarchaeological data review **(Chapter 2** and **Chapter 3**), in this article both published and unpublished studies (e.g., research articles, academic dissertations and theses) were analysed.

1.2.2. Zooarchaeology

Conservation strategies usually incorporate information generated in the last few decades, while studies have shown that pre-colonial groups in Brazil exploited a large variety of taxa (Fossile et al., 2020; Lopes et al., 2016; Mendes et al., 2018) and levels of fish biomass equivalent to historical records (Fossile et al., 2019). Thus, the analysis of faunal remains, namely **zooarchaeology (or archaeozoology)**, emerges as a valuable discipline to assess changes in biodiversity and trophic structures through time. Zooarchaeological analysis constitutes the primary methodology throughout this thesis. In particular, in **Chapter 2** and **Chapter 3**, a zooarchaeological approach was used to estimate the absolute and relative abundances of species in pre-colonial time. In **Chapter 5,** zooarchaeological analyses were used to identify and quantify vertebrate remains (e.g., bones and teeth) and taxa (e.g., genus and species), as well as to explore taphonomic processes that may have affected the faunal record in the first place. In **Chapter 6,** hundreds of fish otoliths were identificatified and measured to investigate variations in the total body length of key fish species across different chronological periods.

Zooarchaeology entails the examination of animal remains recovered from archaeological sites (Reitz & Wing, 2008a). Although studies on animal remains have been conducted since the 1700s, the establishment of zooarchaeology as a discipline is relatively recent, marked by its distinctive interdisciplinary character (Davis, 1995; Reitz & Wing, 2008a). Applying a range of concepts and methods from natural and social sciences, history, and humanities, zooarchaeologists provide data on the development of human groups and the environment, including ecosystems and species (Lyman, 2015). In practice, the first step of zooarchaeological studies involves identifying species and specimens (such as teeth and bones). This is followed by establishing information about individuals, including aspects like abundance, body size, age and sex (Davis, 1995; O'Connor, 2000b; Reitz & Wing, 2008f). The identification phase demands an advanced and comprehensive understanding of anatomy and taxonomy. Initially, specimens (e.g., shell, dentary, and femur) are identified using conventional anatomical terminology derived from comparative anatomy (O'Connor, 2000a; Reitz & Wing, 2008d). For this, a representative reference collection is essential, usually assembled from the local fauna and prior research conducted within the study region (O'Connor, 2000a; Reitz & Wing, 2008d). The measure of taxonomic abundance consists of quantitative analysis. The most common quantitative indices in Zooarchaeology are the Number of Identified Specimens (NISP) and the Minimum Number of Individuals (MNI) (Grayson, 1984; Lyman, 2008b). NISP represents the count of identified specimens in a sample that can be attributed to a specific taxon, while MNI corresponds to the smallest number of individuals inferred from the identified specimens of a particular taxon (Grayson, 1984; Lyman, 2008b). MNI is based on the observation that vertebrate animals, as well as many crustaceans and mollusks, are symmetrical (Grayson, 1984; Lyman, 2008b), therefore, it is calculated by pairing skeletal elements from symmetrical parts of the body (left and right) or unique body parts (axial), and the final value is the highest count achieved for that element. In addition to NISP and MNI, the Number of Specimens (NSP) is sometimes mentioned and used. This quantitative index encompasses the entire analysed assemblage, incorporating both identified and unidentified specimens attributed to a specific taxon (Lyman, 2008b).

The application of NISP and MNI has been subject to discussions concerning their limitations. First, certain specimens are lost or altered through pre- and post-depositional processes. To unravel these processes, zooarchaeologists apply concepts of Taphonomy, which refers to the processes that a deceased animal's skeletal structure undergoes from the time of death to its eventual discovery, as well as methodological precautions (Lyman, 1994b). The pre-depositional process corresponds to cultural practices, such as butchering and cooking (Lyman, 1994a). All these processes have the potential to lead to the destruction or dispersal of remains, consequently impacting the NISP and MNI (Reitz & Wing, 2008e). Furthermore, an additional factor influencing the NISP is the post-depositional processes, which encompass both natural activities and field and laboratory practices (Reitz & Wing, 2008e). For instance, differences in recovery and analytical methods, such as excavated area/volume, mesh size and limitation of identification to a small number of specimens or species, can dramatically affect the quantitative indices (NISP and MNI) and species richness (SR) (Grayson, 2014; Lyman, 2008b; Reitz & Wing, 1999), restricting the comparability of values across collections, sites, or groups (Reitz & Wing, 2008e). To mitigate potential biases in results and interpretations, it is adequate to use a mesh size of 2-3 mm for recovery of faunal remains and to standardise the values based on the excavated area or volume (e.g. NISP/m^3) (McKechnie & Moss, 2016; Zohar & Belmaker, 2005). The second interpretative challenge concerning NISP arises from biological variations. Different animal species exhibit variations in the number and type of specimens. Therefore, it is advisable to conduct relative frequency comparisons using NISP within the same taxonomic group (order, family, or genus) or specific size classes, such as large, medium, and small species (Lyman, 2018; Reitz & Wing, 2008e). For example, it is possible to compare the NISP of pigs/peccaries and large canids (Reitz & Wing, 2008e).

Finally, concerning MNI, the process of pairing elements from archaeological sites can be quite challenging. To obtain a more accurate representation, it is recommended, whenever possible, to consider evidence of sex and age of individuals, even though these aspects can be challenging to determine in archaeological remains. Additionally, taking into account the symmetry of remains can further enhance the accuracy of the analysis (Reitz & Wing, 2008e). Lyman (Lyman, 2008a) identified seven issues associated with MNI: (1) calculating MNI can be complex due to its non-additive nature, (2) various methods can be employed to derive MNI, leading to reduced comparability, (3) MNI values may not accurately represent the thanatocoenose or the biocoenose, (4) MNI values tend to overemphasise the significance of rarely represented taxa or those with low NISP values, (5) MNI values are minimums and thus ratios of taxonomic abundances cannot be calculated, (6) MNI is influenced by sample size or NISP, increasing as NISP increases, and (7) different combinations of specimens within a total collection may result in different MNI values.

Although there are limitations in their applications, NISP and MNI are the most widely employed indices in zooarchaeological research (Grayson, 1984; Lyman, 2008b). Both quantitative units are typically considered good quantitative indices, however, NISP has been frequently used to estimate abundance, while MNI was originally designed to measure past human diet and estimate the amount of meat per species (Lyman, 2008a, 2018).

1.2.3. Stable Isotope Analysis

Stable Isotope Analysis (hereafter referred to as SIA) measure the isotopic composition of elements in various sources like tissues and sediments (Fry, 2006; Michener & Lajtha, 2008). This analysis provided valuable insights into shifts in ecology, trophic interactions, and anthropogenic influences within coastal regions throughout both archaeological and contemporary periods (Fry, 2006; Michener & Lajtha, 2008). SIA has proven to be versatile in its applications, extending its reach to the field of archaeology, with extensive use in studying ancient fish remains recovered from archaeological sites (Elliott Smith et al., 2023; Guiry & Hunt, 2020; Llorente-Rodríguez et al., 2022). Overall, archaeological and ecological studies often focus on carbon, hydrogen, oxygen, nitrogen and sulphur (CHONS), due to their prevalence in biological compounds and their greater sensitivity to changes in mass when a single neutron is added (Fry, 2006; Michener & Lajtha, 2008). In **Chapter 6**, our attention is dedicated to examining the carbon ($\delta^{13}C$), nitrogen ($\delta^{15}N$) and sulphur ($\delta^{34}S$) values in bulk collagen extracted from key species discovered in archaeological contexts spanning approximately 5000 years along the southern coast of Brazil.

1.2.3.1. Stable isotopes

Isotopes are atoms with the same number of protons (Z) and differ in the number of neutrons (N) within the nucleus (Brown & Brown, 2011; Fry, 2006; Michener & Lajtha, 2008). Therefore, the number of neutrons that alter the atomic mass of elements. These variations in the number of neutrons result in different isotopes of the same element possessing slightly different atomic weights. Each isotope of an element exhibits similar chemical behaviour but may have distinct physical properties, such as stability or radioactivity, due to differences in their atomic structure (Fry, 2006; Sulzman, 2008). Stable isotopes refer to elements that maintain stability without undergoing decay or radioactivity. In other words, isotopes are considered stable when the numbers of neutrons (N) and protons (Z) are relatively close, with a general rule of $N/Z \leq 1.5$ (Fry, 2006; Sulzman, 2008).

Isotopes have the capacity to undergo mixing or fractionation (Fry 2006). Mixing refers to the combination or blending of different isotopic sources, resulting in an intermediate isotopic composition (Figure 1.2). This occurs when materials from various sources with distinct isotopic signatures, such as plants or nutrients, merge or interact. Fractionation, on the other hand, describes the process where isotopes are selectively taken up or used at varying rates, resulting in the alteration of isotopic ratios (Figure 1.2). Fractionation can occur due to different physical or biochemical processes such as diffusion, evaporation, or metabolic reactions. These processes often lead to variations in isotopic compositions between products and their source materials.

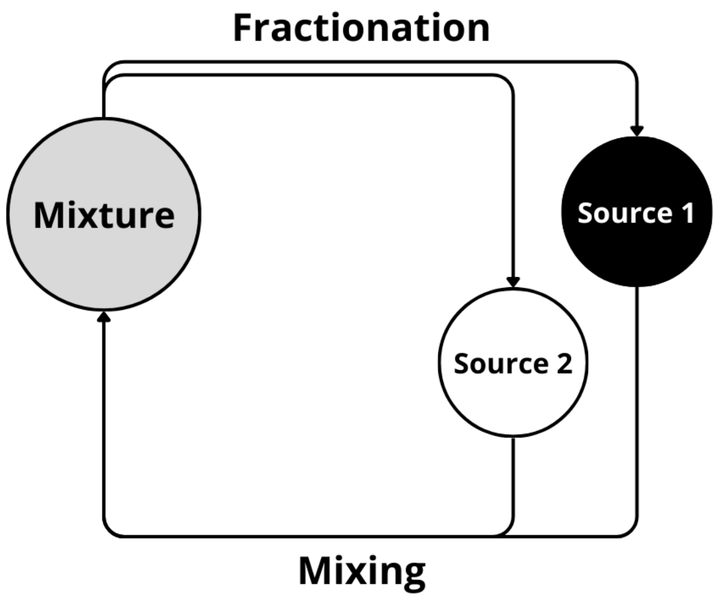

Figure 1.2. Fractionation and mixing process of isotopes. Adapted from Fry (2006).

1.2.3.2. Delta notation (δ)

The isotope with fewer neutrons is termed the lighter isotope, while those with more neutrons (or greater atomic mass) are referred to as heavier isotopes. Lighter isotopes are substantially more abundant in nature, and their relative abundance in specific substances can be estimated by the ratio or relationship between the heavier and lighter isotopes within samples. Nier and Gulbransen (1939) were the pioneers in analysing the isotopic fractionation of carbon ($^{13}C/^{12}C$) across a variety of samples, observing significant variations in the isotopic ratio among them.

Subsequently, advancements in methodology and mass spectrometers (e.g. isotope-ratio mass spectrometry - IRMS) transformed isotopic analyses. In one such study, McKinney et al. (1950) expressed, for the first time, the isotopic ratio of a sample as a deviation from an established standard. Since then, isotopic compositions are compared to a globally recognized standard (Table 1.1) and represented in parts per thousand (per mil; ‰) relative to that standard using the formula (Fry, 2006; Sulzman, 2008):

$$\delta\ (‰) = (R_{sample} / R_{standard} - 1) \times 1000$$

where R is the ratio of heavy-to-light isotope, R_{sample} denotes the ratio in the sample analysed, while $R_{standard}$ refers to the ratio found in the standard reference material. The δ value is multiplicated by 1000 to amplify the very small differences measured between samples and standards (Fry, 2006; Sulzman, 2008).

Table 1.1. Isotope Compositions of International Reference Standards from carbon, nitrogen and sulphur. H and L indicate heavy and light isotope components, respectively. Adapted from Fry (2006).

	Ratio, H/La	**Value, H/La**	**%H**	**%L**
Vienna-PeeDee Belemnite (VPDB)	$^{13}C/^{12}C$	0.011180	1.1056	98.8944
Air (AIR)	$^{15}N/^{14}N$	0.0036765	0.36630	99.63370
Canyon Diablo Troilite (CDT) and Vienna-Canyon Diablo Troilite (VCDT)	$^{33}S/^{32}S$ $^{34}S/^{32}S$ $^{36}S/^{32}S$	0.0078772 0.0441626 0.0001533	0.74865 4.19719 0.01459	95.03957 95.03957 95.03957

1.2.3.3. Bone collagen

As mentioned previously (see Methodological approaches), hard tissues such as shells, teeth, and bones are frequently recovered in archaeological sites. In the context of bones, they consist of both a mineral component (bioapatite) and an organic matrix (primarily collagen). Collagen is a protein composed of long chains of amino acids (polypeptide chains), primarily consisting of “Glycine-X-Y”, where “X” and “Y” represent any amino acid, although typically "X" is occupied by proline (Pro) and "Y" by hydroxyproline (Hyp). These amino acids combine to form a triple helix structure (Figure 1.3). There are various types of collagen separated in families, all of which share this common structure but exhibit significant variations in size, function, and distribution among tissues (Gelse et al., 2003; Von Der Mark, 2006). Among vertebrates, approximately 30 different collagen types have been recognized, each exhibiting diverse structural and biochemical characteristics. However, only a specific collagen type stands out as the primary component of the organic matrix of bones: type I, comprising 90% of their composition. This specific type of collagen is not only the most abundant but also recognized as the longest-known and extensively studied among collagens found in vertebrates, serving as a fundamental reference for other types of collagen (Gelse et al., 2003; Von Der Mark, 2006).

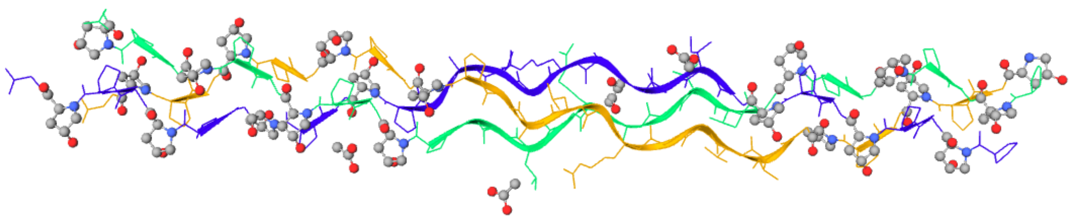

Figure 1.3. Collagen structure. Source: MolView (https://molview.org).

Fortunately, much like bones, collagen resists degradation over millennia, making it an invaluable resource for studying ancient populations (Koch, 2008). Its ability to retain isotopic signatures from the consumed diet enables researchers to reconstruct the dietary history of human individuals and animals (Ambrose, 1990). However, it is vital to note that chemical and ultrastructural variations exist between collagen derived from marine and terrestrial species. For instance, differences in amino acid compositions, leading to a lower carbon and nitrogen (C:N) ratio in fish compared to mammals (Szpak, 2011). Moreover, there are differences in the amount of carbon (wt%C) and nitrogen (wt%N) between collagen from fish and mammals, with a difference between the means of <1% for both elements (Szpak, 2011). Furthermore, fish bones contain a relatively higher percentage of lipids compared to mammals, which can potentially lead to alterations in C:N ratios and carbon isotope ($\delta^{13}C$) values. Since lipids lack nitrogen, their presence in bone collagen may primarily increase carbon content, thus affecting the C:N ratio (Szpak, 2011). Additionally, a significant contrast exists in the amino acid composition among fish species inhabiting polar and temperate (cold) waters compared to those in tropical and subtropical (warm) waters. Most importantly, collagen found in warm-water fish exhibits significantly higher HyP (carbon rich) content in comparison to collagen from cold-water fish. In contrast, mammals generally contain notably higher quantities of HyP in their collagen structures (Guiry & Szpak, 2020; Szpak, 2011). Nevertheless, it is important to note that within an archaeological context, bones experience degradation processes within the burial environment, which significantly impacts their chemical and structural properties. For instance, bone collagen subjected to intense bacterial degradation tends to have a lower C:N ratio due to a higher concentration of Glycine and Alanine. Additionally, contamination with humic substances tends to alter the values of $\delta^{13}C$ and C:N ratio of bone collagen (Szpak, 2011). Despite variations observed between species, as illustrated in this section, collagen exhibits a well-characterised chemical structure and established quality criteria (Ambrose, 1990; DeNiro, 1985).

1.2.3.4. Collagen quality criteria

Ancient collagen quality criteria (QC) primarily revolves around the concentrations of carbon (wt%C) and nitrogen (wt%N) greater than 13% and 4.8%, respectively, whereas their ratio ($C:N_{atomic}$ or C:N molar) ranges between 2.9 and 3.6 (Ambrose, 1990; DeNiro, 1985). Regarding modern collagen QC, previous study observed wt%C at 41.91 ± 0.39%, wt%N at 15.40 ± 0.20%, and C:N molar ratio at 3.17 ± 0.17, which range between 3.00 and 3.30 for fish and between 3.00 and 3.28 for mammals and birds. Moreover, proposals of collagen QC related to sulphur were done by some authors (Nehlich & Richards, 2009; Privat et al., 2007; Richards et al., 2001), of which Nehlich and Richards (2009) is acceptable in the field of stable isotope. However, previous studies have indicated variations in C:N molar ratio, wt%S, C:S, and N:S ratios among bony fish species from cold and warm waters (Guiry & Szpak, 2020; Rigby & Spikes, 1960; Szpak, 2011). Further discussions on this topic of fish collagen QC are explored in Chapter 6.

1.2.3.5. Carbon, nitrogen and sulphur

Following an introduction on isotopes, notation, collagen, and its quality standards, this section adresses the specifics of carbon, nitrogen, and sulphur isotopes. Carbon comprises two stable isotopes: ^{12}C, which has six protons and six neutrons (abundance of 98.89%), and ^{13}C, possessing one additional neutron (abundance of 1.11%) (Fry, 2006; Michener & Lajtha, 2008). Nitrogen also has two stable isotopes: ^{14}N with seven protons and seven neutrons, and ^{15}N with an extra neutron. Conversely, sulphur encompasses four stable isotopes: ^{32}S (abundance of 95.02%), ^{33}S (abundance of 0.75%), ^{34}S (abundance of 4.21%), and ^{36}S (abundance of 0.02%).

These elements are absorbed into the animal's tissues from the nutrients present in the diet. They are metabolically processed and used in the synthesis of collagen and other compounds essential for the structure and functioning of the organism. During collagen formation, the carbon, nitrogen, and sulphur atoms from the amino acids are incorporated into the polypeptide chains that make up this structural protein. Carbon, for example, is primarily obtained from carbohydrates, proteins, and lipids. Carbon is initially obtained during the process of photosynthesis, which can be categorised into three different types (C_3, C_4, and CAM) based on the pathway of CO_2 fixation (Hatch et al., 1967; Johnson, 2016). These distinct pathways of CO_2 fixation result in differences on isotopic values. C_3 plants, such as most trees and many crop plants like wheat and rice, have a lighter carbon isotope ratio (lower $\delta^{13}C$ values, between -20‰ and -37‰) because they assimilate CO_2 directly from the atmosphere and incorporate it into the Calvin cycle without an additional carbon fixation step (Bender, 1968; Farquhar, 1983; Farquhar et al., 1982, 1989; Johnson, 2016). Generally, the carbon isotopic signature of marine phytoplankton ($\delta^{13}C$) ranges from around -24‰ to -20‰, reflecting the values typical of C3 plants. On the other hand, C4 plants, like corn, sugarcane and some grasses, have slightly heavier carbon isotope ratios (higher $\delta^{13}C$ values between -16‰ and -9‰) due to the additional biochemical steps involved in carbon fixation (Bender, 1968; Farquhar, 1983; Farquhar et al., 1982, 1989; Johnson, 2016). CAM plants (crassulacean acid metabolism), including succulents and cacti, typically exhibit isotopic values ranging from -38.2‰ to -8.3‰ (Messerschmid et al., 2021), representing an intermediary range between C3 and C4. These plants fix CO_2 during the day using PEP carboxylase, store it within the vacuole at night, and then release it to be fixed via normal C_3 photosynthesis (Johnson, 2016). Subsequently, carbon is integrated into the food chain as it passes through primary consumers (herbivores) and secondary consumers (omnivores and carnivores), resulting in a slight ^{13}C-enrichment (+0.5 to +1‰) in consumers in relation to their dietary sources (Fry, 2006; Michener & Kaufman, 2008). For instance, studies have shown that fish bone collagen is ^{13}C-enriched by ~3.5‰ compared to assimilated food items thus complementing trophic information that is often obtained from consumer’s nitrogen isotopic composition (Matsubayashi et al., 2018; Sholto-Douglas et al., 1991).

Nitrogen isotopes reflect the protein fraction in diet, thus reflecting the trophic levels of species within the food chain. In marine ecosystems, dissolved inorganic nitrogen (DIN), such as nitrate (NO_3^-), nitrogen dioxide (NO_2^-) and ammonium (NH_4^+), are the main source of nitrogen for primary production (Montoya, 2008). Consequently, the isotopic composition of DIN serves as a key factor dictating the isotopic composition of marine plankton. Besides the importance of NO_3^- for marine primary production, N_2 fixation is a dominant local source of nitrogen supporting production in open ocean ecosystems (Montoya, 2008). A variety of factors and biological processes, including runoff, atmospheric deposition, subsurface NO_3^-, N_2 fixation, denitrification and nitrification, can alter the nitrogen isotopic composition in organisms, however, the isotopic fractionation often remains consistent throughout the trophic chain (Michener & Kaufman, 2008; Montoya, 2008). Different organisms occupy specific positions within the food web, resulting in variations in the nitrogen isotopic composition. There is typically an increase in the $\delta^{15}N$ range from +2‰ to +4‰ between an animal's tissues and its food (Fry, 2006; Michener & Kaufman, 2008; Montoya, 2008), thus, higher $\delta^{15}N$ values generally indicate an organism's position at a higher trophic level. For instance, previous studies have demonstrated that bone collagen $\delta^{15}N$ values in marine fish tend to increase by ~1‰ to 2.5‰ with each successive trophic level (Matsubayashi et al., 2018; Sholto-Douglas et al., 1991). Moreover, it is important to highlight that the DIN originating from sewage and agricultural waste may exhibit significant enrichment in ^{15}N due to nitrogen volatilization and microbial processing in solution (Montoya, 2008).

Sulphur is present in essential (methionine) and non-essential (cysteine; Cys) amino acids. Methionine (Met) is obtained through dietary intake, whereas cysteine (Cys) is a metabolite in the metabolism of methionine and is not present in bone collagen. In bone collagen, sulphur is found in the Met and is transferred through the food web with relatively minor, but variable, isotope fractionation (Guiry et al., 2021; McCutchan et al., 2003; Nehlich, 2015; Szpak & Buckley, 2020). Although there seems to be minimal enrichment in ^{34}S, but variable, across various trophic levels, sulphur ($\delta^{34}S$) provides additional information on energy and nutrient flows. In marine environments, the distinct isotopic variance between seawater sulphates (~ +21‰) and sulphides (~ −10‰) provides valuable insights for the differentiation between benthic and pelagic producers, as well as marsh plants and phytoplankton (Michener

& Kaufman, 2008; Connolly et al., 2004; Peterson et al., 1986; Szpak & Buckley, 2020). Planktonic algae and seaweed uptake and assimilate marine sulphates (~ +21‰) producing little isotope fractionation (Fry, 2007; Peterson et al., 1986). By contrast, dissimilatory sulphate reduction by anaerobic bacteria/archaea causes high isotope fractionation of marine sulphates in nearshore environments (e.g. estuaries), producing ^{34}S-depleted sulphides (~ -26‰) or other oxidation products that are used by plants such as mangroves and seagrasses rooted in anoxic sediments (Connolly et al., 2004; Fry, 2007; Fry et al., 1982; Goldhaber, 2003; Okada & Sasaki, 1997; Peterson et al., 1986). This results in ^{34}S-depleted organic matter at the base of the food web compared to marine algae and seaweed. Nearshore habitats are also exposed to continental waters with extremely variable $\delta^{34}S$ values (-40‰ to +20‰, Nehlich, 2015) compared to marine sulphates (Peterson et al., 1986), but their isotopic effect on food webs will be perceptible only in very low saline habitats (Fry & Chumchal, 2011). It is worth noticing, however, that archaeological and modern $\delta^{34}S$ values may not be directly comparable due to anthropogenic SO_2 emissions in the last decades (Zhao et al., 2003). Moreover, modern samples may be additionally affected by industrial and agricultural effluents with variable $\delta^{34}S$ values (Wayland & Hobson, 2011).

Overall, through $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ analysis on collagen, archaeologists can gain valuable insights into the dietary preferences, fishing strategies, and environmental contexts of ancient societies, shedding light on the dynamic relationship between humans and aquatic resources throughout history (Britton, 2020; Michener & Lajtha, 2008; Richards, 2020; Schoeninger & Moore, 1992).

1.3. Aims and structure

Faunal remains from pre-colonial and historical sites on the Southern coast of Brazil (see Figure 1.1), which are dated from 9500 to ~200 years ago, were analysed to address the following Specific Objectives (SO):

- **SO1** - To identify the main biological aspects of pre-colonial and historical fisheries and provide quantitative-qualitative baselines for comparisons with contemporary biological composition.

- **SO2** - To explore differences in species size and fishing ground preferences between pre-colonial and historical fisheries
- **SO3** - To get insights into the isotope ecology of past fishing populations, and set references for studying stable carbon, nitrogen and sulphur isotopes in modern stocks in the region.

To achieve these objectives, **six chapters** were developed, employing distinct methodological approaches (see section 1.2). Below, it is offered a succinct overview of each chapter's content and its corresponding relationship with each specific objective.

Chapter 2. The field of Zooarchaeology has been developed in Brazil since the end of the 1960s and early 1970s (Garcia, 1969; Schorr, 1975), however, the resulting data are dispersed across scientific articles, book chapters, as well as master's and doctoral theses. In response to this consideration, this thesis initiated the Brazilian Zooarch Database (ZooarchBR), which is the first collaborative and open access zooarchaeological database in Brazil (https://zenodo.org/records/8198809). This database not only facilitates users in accessing existing data but also empowers them to actively contribute by adding new or supplementary information, thus expanding the collection of faunal data associated with Brazilian archaeological sites (**SO1**).

Chapter 3. Using the ZooarchBR database as a foundation, this thesis has focused on bony and cartilaginous fishes for a more comprehensive analysis. In this study, we assessed snapshots of species compositions and relative abundances spanning the last 9500 years and modelled differences in species' functional traits between archaeological and contemporary fisheries (**SO1** and **SO2**). The study aims to investigate the hypothesis that contemporary fisheries in southern Brazil may have led to a reduction in the size of relevant stocks over the past decades, consequently altering trophic interactions and ecosystem functions (Pauly et al., 1998).

Chapter 4. To enhance our comprehension of fishing development in Brazil, we examined fish catch composition and associated fishing technology employed in Babitonga Bay spanning the last 6000 years (**SO1** and **SO2**). In this study, we identified the presence of four distinct fishing artefacts in a total of eight archaeological sites. Moreover, we found evidence for changes in fishing practices over time and an increase in the capture of pelagic and high trophic level species from 2000 to 1500 years ago. The results indicate an expansion of fishing to deep waters and invite us to reconsider the antiquity of the human footprint on ocean ecosystems in the region.

Chapter 5. Brazilian archaeology has predominantly focused on the study of pre-colonial groups, such as Sambaquis, Cerritos and Guaranis. Consequently, limited attention has been directed towards historical sites from the colonial and post-colonial periods. Recognizing this information gap, faunal remains from two historical sites along the southern coast of Brazil. Morro Grande 1 (MG1) and Praia Grande Unit 21 (PG-U21), situated in São Francisco do Sul, were examined. This study offered unique insights into the fauna exploited during the historical period (1750 to 1950 AD) but also investigates the hunting patterns of native species from the pre-colonial era to the present day in the region (**SO1** and **SO2**). Additionally, novel molecular markers of native and domesticated species, like peccary, deer, armadillo, chicken, and cattle, exploited along the Brazilian coast during pre-colonial and historical periods are provided. This is the first study of this kind in Brazil, which expands the ZooMS database to this region.

Chapter 6. As mentioned in the earlier sections, the Brazilian coastline has been inhabited for at least 9500 years (Dias, 2003; Gaspar, 1998), and population density continues to rise in this region (Lembi et al., 2020; Sosma, 2023). Anthropogenic impacts such as deforestation, defaunation and overfishing along with climate change, have significantly affected coastal environments. Nonetheless, there remains limited understanding of the broader impacts on environments and species beyond the scope of the last few decades. To address this question, metric (otoliths) and isotope (collagen from bones) analysis of commonly exploited species in the coast of Brazil were performed from 4800–4550 BP to late 19th–early 20th century AD in the region (**SO2** and **SO3**). The results were discussed within the context of changing fishing technologies, market demand, and environmental conditions. This information was used to test the hypothesis that contemporary marine fisheries in southern Brazil may have reduced the size of relevant stock in past decades, altering trophic interactions and ecosystem functions.

In addition to these chapters, **Chapter 7** introduces an educational booklet designed to familiarise readers with Zooarchaeology within the broader community. The booklet was created based on the compiled data from Chapter 2. This booklet emphasises the significance of preserving archaeological sites and underscores their potential contributions to ongoing discussions about environmental conservation. Furthermore, this booklet also contributes significantly to enhancing Ocean Literacy - an understanding of the ocean's influence on us and our influence on the ocean (UNESCO 2017).

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CHAPTER 2

Brazilian Zooarch Database (ZooarchBR): database of the archaeological fauna of Brazil

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2.1. Introduction

Humanity, through adaptations and abilities to master the environment throughout its evolution, has played a fundamental role in its relationship with wildlife, which can be observed through archaeological records. In this way, there is a need to understand the cultural complexity through interaction with wildlife in order to generate interpretations about subsistence and sustainability. In this context, we have the privilege of studying a territory known for having the greatest biological diversity in the world: Brazil, a country with a wide variety of ecosystems, including the Atlantic Forest and the Amazon Rainforest, which hold the highest diversity of biological reserves on the planet. Its vast size, combined with its geographical location, influences biodiversity, as well as the extensive history of millennia-old landscape formations. Given such diversity, it is not surprising that in a continent-sized country, there is also a broad cultural complexity formed by a diversity of pre-colonial peoples.

As a result, over the past 48 years, numerous scientists have conducted studies and research in Brazil to understand the interactions between societies and the environment, resulting in a substantial production of zooarchaeological studies that have provided valuable data for the scientific community, both in Archaeology and Conservation Biology (FOSSILE et al., 2019; ASSUMPÇÃO et al., 2022; MENDES; SILVA; DUARTE, 2020). In the southern coastal region of Brazil, systematic zooarchaeological studies began in the 1970s in cemeteries within the Pampa biome, Rio Grande do Sul (SCHORR, 1975). Approximately 20 years later, studies shifted to the southern coast of the Atlantic Forest in Santa Catarina (e.g., BANDEIRA, 1992). Despite just under 50 years of zooarchaeological publications, they have provided crucial information for understanding the cultural complexity of pre-colonial peoples, particularly concerning hunting, fishing, and gathering techniques, as well as the use of fauna for sustenance (food, construction, and utility [e.g., hooks and points/bipoints]) and in ritual ceremonies (symbolic use) (FERREIRA et al., 2019; KLOKLER, 2016; PROUS, 2018). While cultural aspects show a certain selectivity, studies have demonstrated that zooarchaeological data have high potential for providing unique information about past biodiversity and the structure and function of ecosystems (STAHL, 2008; LYMAN, 2017; FOSSILE et al., 2023). This information contributes to approaches to species and habitat ecology, helping in conservation and preservation analyses, such as defaunation (BOGONI et al., 2018; GALETTI et al., 2017). Despite this potential, until recently, zooarchaeological studies in Brazil were more focused on identifying the species and environments exploited by archaeological groups. However, there have been recent attempts to integrate this information into conservation discussions, seeking a better understanding of the historical role of past biodiversity and its relevance for the conservation of current ecosystems (MENDES; SILVA; DUARTE, 2020; LOPES et al., 2016; FOSSILE et al., 2020, 2019; SILVA et al., 2017; SOUZA et al., 2016).

The abundance of zooarchaeological data being developed in Brazil contributes to deepening our understanding of pre-colonial peoples and providing records of fauna that have never been systematically documented before, considering the chronology and location of archaeological sites. However, it is essential to unify this information, following the example of current biodiversity databases (IUCN, 2022; GBIF.org, 2023; SiBBr, 2022) and some international archaeological initiatives (MONDINI et al., 2013; LEFEBVRE et al., 2019). While there are well-developed publications presenting checklists of species in the archaeofauna of Brazil (SOUZA; LIMA; SILVA, 2010; LOPES et al., 2016; MENDES; DUARTE; SILVA, 2018; FOSSILE et al., 2020), the absence of a unified and accessible database for the scientific community hinders a comprehensive view of the paleodiversity in the Brazilian territory. In this context, this article aims to introduce a database to unify information about Brazilian archaeofauna, as well as the cultural context in which it was collected.

2.2. ZooarchBR: Building the Database

2.2.1. Literature Review and Data Recording

The Brazilian Zooarch Database (ZooarchBR) is the first collaborative and open-access database in Brazil dedicated to archaeological fauna. Users not only have the ability to view available data but can also contribute to expanding the country's zooarchaeological records. ZooarchBR is a database in OpenDocument format (".ods") and is in the process of integration with the Brazilian Biodiversity Information System, SiBBr (SiBBr, 2022, more details below). It collects georeferenced zooarchaeological information from various bibliographic sources in both physical and electronic formats. Currently, this information is sourced from scientific articles (55%), academic dissertations and theses (38%), and book chapters (7%). It is available in institutional repositories such as universities, museums, and public libraries, as well as in editorial platforms like Scielo and Scopus. Only studies that utilised reference collections and were reviewed by experts have been and will be considered. This selection criterion aims to ensure the quality and reliability of the information in the database, guaranteeing that the zooarchaeological data made available are based on well-developed academic work and research.

Due to the vast expanse of Brazil and its high number of archaeological sites, in this initial phase, we have limited our review to coastal sites in the Southern Region, using a maximum distance of 100 km from the current coastline. This distance was determined based on the distribution of the global population near the coast (SMALL; NICHOLLS, 2003), taking into consideration that the relative sea level during the Middle Holocene (approximately +3 m) shifted the coastline further inland in areas with gentle slopes (ANGULO; LESSA; SOUZA, 2006; TONIOLO et al., 2020). The southern coast of Brazil, represented by the states of Paraná, Santa Catarina, and Rio Grande do Sul, is characterised by its rich diversity of species and ecosystems, as well as the socio-environmental and socio-economic significance of the Atlantic Forest and Pampa biomes (PAGLIA et al., 2002; COSTA et al., 2017). Coastal ecosystems were vital to indigenous populations before and during the arrival of Europeans in the 16th century (MILHEIRA; DE-SOUZA; IRIARTE, 2019), with evidence of occupation dating back approximately 9000 years (DIAS, 2003). The Umbu Tradition (9000 years ago), Sambaquis (7000 to 500 years ago), Cerritos (4,700 to 200 years ago), the Taquara-Itararé Tradition (1200 to 500 years ago), and the Tupi Guaranis and Guaranis (1000 years ago) are significant archaeological markers in the region (DIAS, 2003; GASPAR et al., 2008; MILHEIRA; GARCIA, 2018; BANDEIRA, 2004; MILHEIRA; WAGNER, 2014). Each of these groups and periods represents crucial moments in the history of indigenous populations that inhabited the southern coast of Brazil, leaving their mark on the landscape and coastal ecosystems.

Data collection follows the qualitative and quantitative criteria proposed by Fossile and other authors (2020): Reference A (quali-quantitative) - provided detailed taxonomic identifications and absolute and relative abundance for all taxa [Number of Identified Specimens (NISP) and/or Minimum Number of Individuals (MNI)]. Reference

B (semi-quantitative) - provided detailed taxonomic identifications and absolute and relative abundance for selected taxa. Reference C (qualitative) - provided taxonomic identification without quantitative information.

Due to the different types of data presented in the publications, faunal diversity information was recorded in two tables: one for species richness and another for species abundance. In cases where data for a particular site were published multiple times, the publication with the most detailed taxonomic and quantitative information was selected for the perspective of abundance. The scientific nomenclature and ecological assignments follow information from the World Register of Marine Species, WoRMS (HORTON et al., 2020), Eschmeyer's Catalog of Fishes (FRICKE; ESCHMEYER; VAN DER LAAN, 2021), MolluscaBase (AUFFENBERG et al., 2020), FishBase (FROESE; PAULY, 2021), Animal Diversity Web, ADW (MYERS et al., 2020), Brazilian Ornithological Records Committee (PACHECO et al., 2021), Reptile Database (UETZ, 1995), and Amphibian Species of the World (FROST, 2020). The conservation status of species was compiled from the Red Lists of Threatened Species by the International Union for Conservation of Nature, IUCN (2022), and the Chico Mendes Institute for Biodiversity Conservation, ICMBio (BRASIL, 2018).

Regarding the compilation of species lists, specific richness was calculated using the Minimum Level of Taxonomic Identification (MLTI), representing the minimum number of species. The frequency of taxa is expressed by the number of archaeological sites where they were recorded, while abundance is expressed using the Number of Identified Specimens (NISP, reported in 96% of the currently compiled References A and B), and when not provided, the Minimum Number of Individuals (MNI, reported in 4% of References A and B) was used. The information aggregated in these biodiversity indices reflects multiple collection and hunting events by different human groups over thousands of years. However, it is necessary to highlight significant differences in the collection of primary information (REITZ; WING, 1999), referring to the recovery of the archaeological remains presented and discussed in various works. For example, there are discrepancies in the mesh sizes used (ranging from 5 to 2 mm), and it is not always clear whether reference collections and the volume of sediment used for the recovery of remains were employed. Given the impact of recovery methods on quantitative data (number of specimens and species) and qualitative data (types of species) (ZOHAR; BELMAKER, 2005; GRAYSON, 2014; JAMES, 1997; REITZ; WING, 1999), caution is emphasised in using the collected data for inferences about the representation and abundance of species found at archaeological sites.

2.2.2. Integration of Zooarchaeological Data into Biodiversity Platforms

The data consist of information about the archaeological context in which the faunal records were collected (e.g., archaeological site name, cultural attribution, and radiocarbon dating), as well as qualitative and quantitative information about the fauna. In addition to the supplementary material available in the Zenodo repository (https://doi.org/10.5281/zenodo.8198809), the dataset is in the process of integration into SiBBr (2022) and will be available in the first half of 2024, following the Darwin Core (DwC) standard, an internationally recognized standard for metadata. SiBBr is a dataset and information platform about Brazilian biodiversity and ecosystems developed by the Ministry of Science, Technology, and Innovation (MCTI), with technical support from the UN Environment Programme (UNEP) and financial support from the Global Environment Facility (GEF), and linked to the Global Biodiversity Information Facility (GBIF). It provides support for government management related to conservation and sustainable use.

Users, in addition to viewing the data available in ZooarchBR, can also contribute by adding new data to expand the record of fauna in pre-colonial and historical archaeological sites in Brazil. To publish data on the platform, users should fill out the form available at https://forms.gle/YxBK3wrzk3AcFuXYA. They will need to attach the source document for the data (article, thesis, etc.) with the name of the lead author, publication year, and publication type (e.g., Fossile et al., 2023, article), and an editable table containing the name of the archaeological site, cultural attribution, chronology, longitude and latitude of the site, and the volume (liters, cm^3, or m^3) of sediment relative to the analysed sample, as well as zooarchaeological information, such as animal class, taxonomy, common species name, and, if available, the total Number of Specimens analysed (NPS), including unidentified remains/fragments (e.g., Animalia), and NISP (see Table 1 in the Supplementary Material). With this integration, we aim to provide greater visibility and worldwide access to Neotropical zooarchaeology studies and, therefore, the opportunity to contribute to the participatory construction of knowledge and the management of biodiversity and natural resources.

2.3. Results

2.3.1. Zooarchaeological literature and archaeological sites

Currently, ZooarchBR consists of 71 publications produced between 1975 and 2022, with an exponential increase over the years (Figure 2.1A, Table 2 in Supplementary Material). One of these publications contains data from sites found in all three states of the Southern Region (SOUZA; LIMA; SILVA, 2011). Santa Catarina has the highest number of publications (n = 42), followed by Rio Grande do Sul (n = 26) and Paraná (n = 5) (Figure 2.1B, Table 2 in Supplementary Material). The literature is currently composed of 55% scientific articles (n = 39 publications), 38% academic dissertations and theses (n = 27 publications), and 7% book chapters (n = 5 publications). Most of the publications fall into the qualitative-quantitative category (n = 43), followed by the semi-quantitative category (n = 19) and the qualitative category (n = 9). Regarding publication categories, Santa Catarina has the highest amount of data (with qualitative and quantitative data), followed by Rio Grande do Sul and Paraná (Figure 2.1B). Some publications specialize in particular taxonomic groups, such as mollusks (FERREIRA, 2017; SOUZA; LIMA; SILVA, 2011; GERNET; BIRCKOLZ, 2011), fish (HILBERT, 2011; CARDOSO, 2011), and marine mammals (CASTILHO, 2008). However, the integration of data and publications provides a comprehensive and unique overview of the diversity of species recovered in the Neotropical archaeological record.

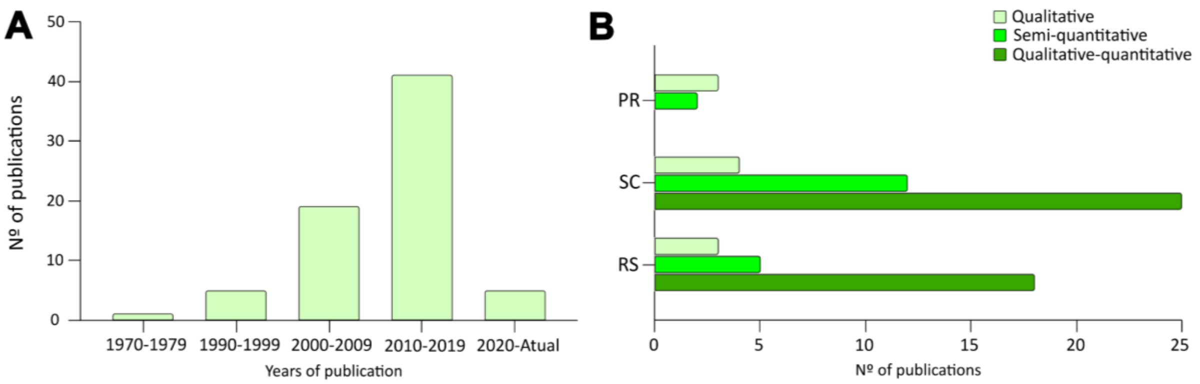

Figure 2.1. (A) Chronological distribution and (B) spatial distribution of zooarchaeological publications on the southern coast of Brazil.

Regarding the archaeological sites, a total of 374 sites were mapped on the southern coast of Brazil between latitude 25.2°S and 31.6°S, encompassing the Atlantic Forest (89%) and Pampa (11%) biomes. Paraná has the highest number of sites (n = 171 sites), followed by Santa Catarina (n = 149 sites), and Rio Grande do Sul (n = 54 sites) (Figure 2.2, Table 3 in Supplementary Material). Interestingly, Paraná has the most archaeological sites, but it is the state with the lowest amount of studies, especially with quantitative data (Figure 2.2, Table 2 in Supplementary Material). This scenario sparks interest for future research to fill this knowledge gap about the archaeofauna of the region, contributing to a more comprehensive understanding of past biodiversity and ecosystems in this area.

The sites were dated by radiocarbon dating from 8800 ± 40 years BP (Sangão - DIAS, 2003) to 280 years ± 50 BP (RS-LC-80 - ROGGE, 2006) and were associated with distinct cultural traditions, including non-ceramic foragers from the early to late Holocene (Umbu), late Holocene fishermen and horticulturists (Sambaquis, Cerritos, Taquara/Itarare, Tupiguarani, and Guarani). Given the variable nature of archaeological deposits (collective cemeteries, ceremonial areas, residential areas) and the differences between these socio-ecological systems (demographic, social organisation, economic orientation), faunal remains partially reflect distinct human-environmental perceptions and interactions with local faunal diversity.

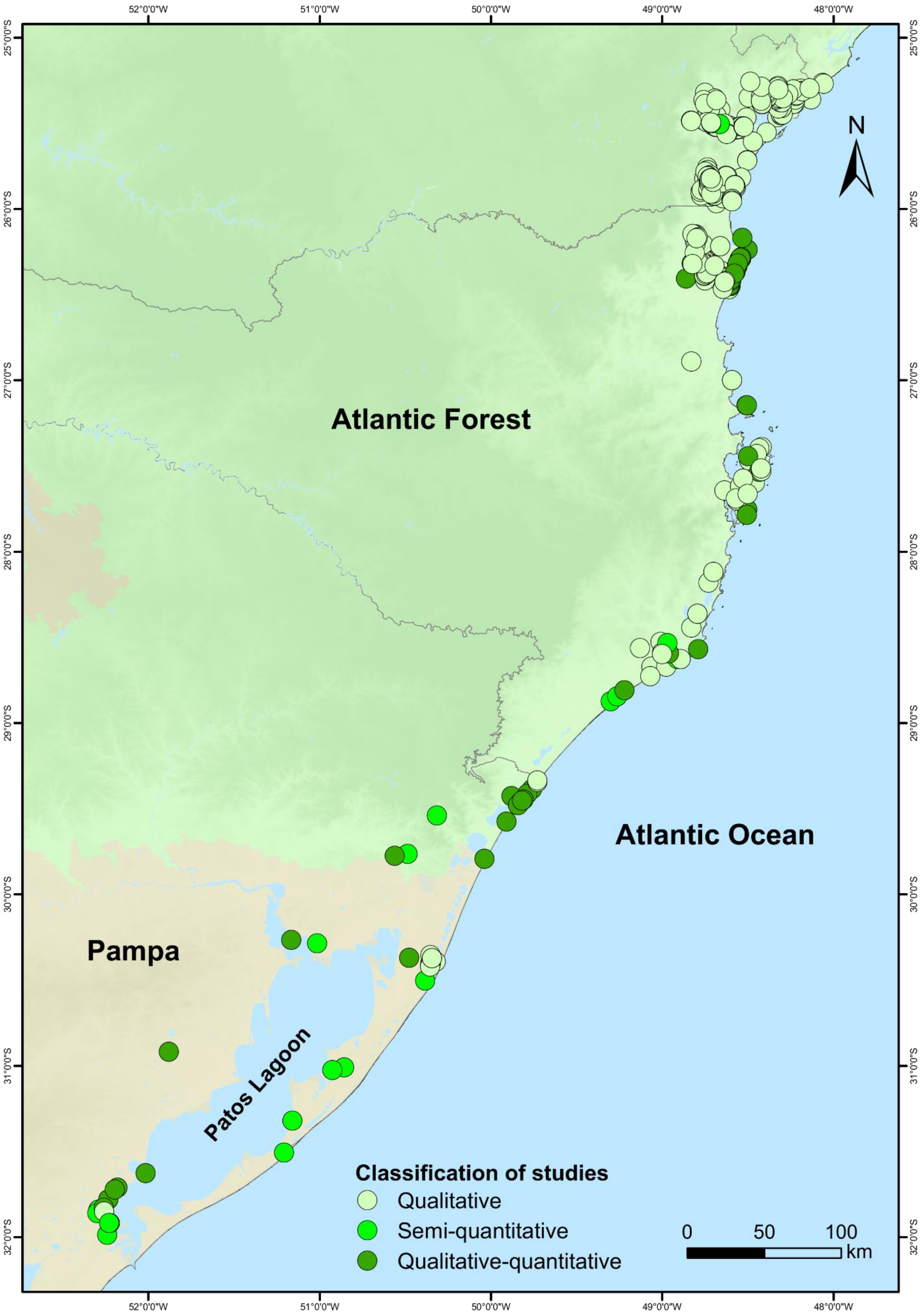

Figure 2.2. Distribution of mapped archaeological sites and their respective classifications for the presentation of zooarchaeological data.

2.3.2. Species Richness and Abundance

A total of 569 taxa were identified in nine different taxonomic groups: Mollusca (n = 205), Actinopterygii (n = 128), Mammalia (n = 106), Elasmobranchii (n = 47), Aves (n = 41), Reptilia (n = 23), Crustacea (n = 14), Echinodermata (n = 3), and Amphibia (n = 2) (Table 4 in Supplementary Material). When considering the MLTI, the species richness of the archaeofauna is 366 species. In general, the database is dominated by invertebrates (160 species; 44%), followed by aquatic vertebrates (143 species; 39%) and terrestrial vertebrates (63 species; 17%). Invertebrates are predominantly represented by mollusks with 151 species, followed by crustaceans (eight species) and echinoderms (one species) (Figure 2.3A). Among vertebrates, bony and cartilaginous fishes dominate with 109 species, followed by mammals (n = 63), birds (n = 21), reptiles (n = 12), and amphibians (one species) (Figure 2.3B). Regarding abundance, a total of 1,601,147 identified specimens (NISP) were found at 74 sites (n = 20% of the mapped sites). These sites are distributed among Santa Catarina (n = 38), Rio Grande do Sul (n = 35), and Paraná (n = 1) (Table 5 in Supplementary Material).

In terms of the frequency of occurrence, mollusks also represent the most frequent taxonomic group, with *Anomalocardia flexuosa* occurring in 71% of sites (n = 267), followed by *Phacoides pectinatus* (38%; n = 141 sites), *Mytella guyanensis* (26%; n = 97 sites), among others. Bony fishes come next, with *Micropogonias furnieri* (10%; n = 37 sites), *Pogonias courbina* (9%; n = 34 sites), both Sciaenidae, followed by Ariidae (8%; n = 30 sites), among others. Bird remains were found in 8% of sites (n = 30). The class of mammals (Mammalia) occurs in 7% of sites (n = 27), represented by *Cavia aperea* (6%; n = 23 sites), *Hydrochoerus hydrochaeris* (5%; n = 20 sites), and Cervidae (5%; n = 19 sites), among others. Among marine mammals, Delphinidae occurs in 3% of sites (n = 10), followed by Otariidae (2%; n = 9 sites) and Cetacea (2%; n = 9 sites), among others. Sharks and rays (Elasmobranchii) appeared in 5% of sites and are represented by Myliobatidae (3%) and *Carcharias taurus* (3%), among others. Reptiles, crustaceans, amphibians, and echinoderms were identified with a frequency of less than 2.5%. Although some taxa have been reported in hundreds and dozens of sites, 43% of the fauna (n = 246 taxa) occur in less than 1% of sites (n ≤ 3 sites) (Table 4 in Supplementary Material).

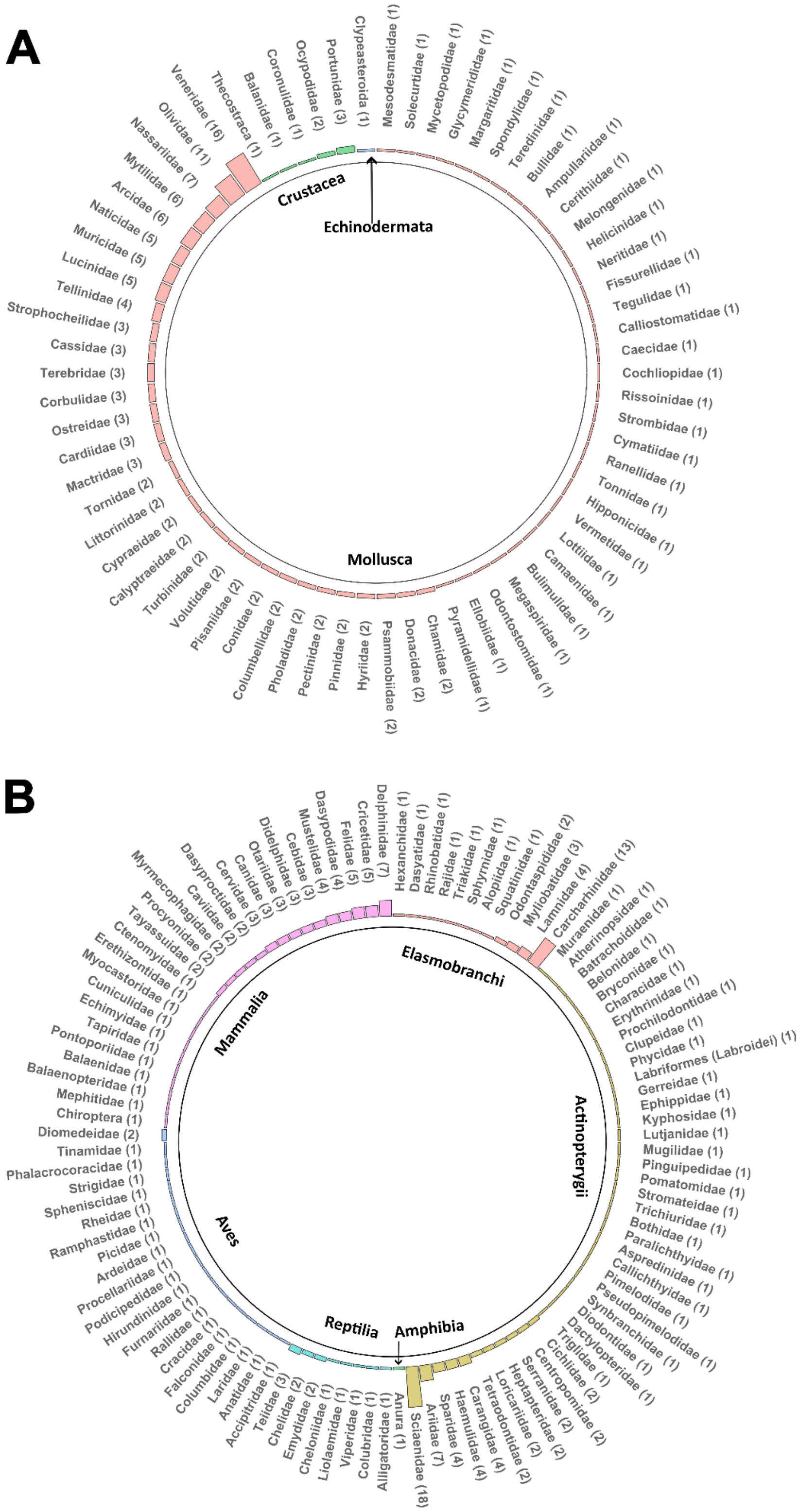

Figure 2.3. Specific richness of (A) invertebrates and (B) vertebrates separated by class, order, or taxonomic family.

2.4. Discussion

2.4.1. Contributions of ZooarchBR to archaeology and the promotion of scientific production

Given the distribution of publications and the mapped archaeological sites on the southern coast available in ZooarchBR, it is possible to map regions that require further zooarchaeological studies, generate and review scientific hypotheses, reflect on the methodologies for the recovery and analysis of faunal remains, promote collaborations between research groups, and assist funding agencies in directing public resources. For example, Paraná has the highest number of archaeological sites in the database (n = 171 sites), yet it has the lowest number of publications (n = 5). Of these publications, four present qualitative data, and only one presents semi-quantitative data. Next are Santa Catarina (n = 149 sites) and Rio Grande do Sul (n = 54 sites), with a significant total of 42 and 26 publications, respectively (Figure 2.1A and B).

Discrepancies in the methodology for recovering faunal remains are also observed, which inevitably influence the quality of data and archaeological interpretations. It is well-known that different sieve sizes have an effect on the quantity and type of faunal remains recovered (GRAYSON, 2014; REITZ; WING, 1999), which in the analysed studies range from 5 to 2 mm (between References A and B), potentially distorting faunal spectra to varying degrees. In quantitative terms, the absence of associated sediment volume with faunal remains (e.g., NISP/m3 and NISP/L) in several studies makes it impossible to make absolute quantitative approximations, compromising the ability to infer the contribution of various animals to the construction processes of some sites, diet, and other aspects of daily life. The data collected, therefore, allow us to understand the potential and weaknesses of the faunal record produced in southern Brazil over the past almost 50 years and invite important scientific reflections in the face of the ethical challenge of working with a non-renewable resource like archaeological heritage.

Additionally, the data from ZooarchBR are essential for other emerging research areas in Brazilian archaeology, such as stable isotope analyses, paleoproteomics, and paleogenetics. For example, stable isotope analyses of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) in human collagen can be used to identify their dietary preferences, such as the environments (marine, freshwater, or terrestrial) and the trophic position of species exploited by them in the past (herbivores, omnivores, and carnivores) (TOSO, et al. 2021; BASTOS et al., 2022; PEZO-LANFRANCO; COLONESE, 2022). However, this type of analysis requires a foundation in zooarchaeology to assist in interpreting the results. Paleoproteomic analysis based on collagen peptide sequences (ZooMS – BUCKLEY et al., 2014) requires a reference database with amino acid sequencing of species, which currently focuses predominantly on European and Asian species, with some from North America. In this way, ZooarchBR provides guidance for expanding this database with species from Latin America.

2.4.2. Establishing Baselines for Biodiversity

A concept that has received increasing attention since the late 20th century is the Shifting Baseline Syndrome. The baseline is a fundamental reference point for assessing changes over time and space (PAULY, 1995; KLEIN; THURSTAN, 2016), and it is essential in ecology for understanding patterns of distribution, abundance, food chains, and community structure (JACKSON; JACQUET, 2011). Studies have sought to understand pristine fauna, assisting in the sustainability and revitalization of species impacted by environmental changes (ERLANDSON; RICK, 2008; MCKECHNIE et al., 2014). In this regard, archaeological sites provide valuable information about past biodiversity and environmental changes, allowing for a comprehensive perspective on alterations that have occurred in nature over time.

Invertebrates exhibit high diversity and abundance in the archaeological record. The majority of publications have also focused on invertebrates, which, along with better preservation and visibility, may have contributed to their higher frequency compared to other taxonomic groups. Among mollusks, *Anomalocardia flexuosa* stands out, showing the highest frequency of occurrence and abundance. This species had its shells intentionally used as raw material in the construction of mounds, often monumental ones, known as shell middens (sambaquis) (VILLAGRAN et al., 2011). Additionally, paleoenvironmental studies conducted on the coast of Santa Catarina indicate that this species was abundant during the middle and recent Holocene (CANCELLI et al., 2017).

Among vertebrates, fish predominate in the assemblage, likely due to the intensification of fishing conducted in most of the traditions recorded in the database. For example, groups from the Taquara-Itararé ceramic tradition and the Sambaquis culture have the highest number of site records, and they extensively exploited fishing resources (FOSSILE et al., 2020; TOSO et al., 2021). Notable among the recorded species are the significant occurrences of *Micropogonias furnieri*, *Pogonias courbina*, and Ariidae. These species are common along the southern coast and are also targeted by current fishing activities, serving as a primary food resource for marine mammals and resident seabirds in the region (HAIMOVICI; CARDOSO, 2016; GERHARDINGER et al., 2020). Regarding mammals, the species found in the archaeological record are among the most frequent species in contemporary times (SOUZA et al., 2019; FIGUEIREDO et al., 2017). This may indicate that pre-colonial peoples were exploiting the species available in the environment without necessarily having a specific dietary preference. For example, rodents like *Cavia aperea* and *Hydrochoerus hydrochaeris* inhabit various types of environments near water bodies and form groups of up to 14.8 individuals per hectare, with the potential for up to two litters per year in favourable conditions (REIS et al., 2006). There is also a notable frequency of birds in the archaeological record. Although they are challenging to identify taxonomically at the species level (e.g., genus and species) due to their fragility and, in many cases, the lack of specialised reference collections, birds represent 6% of the identified species (n = 21).

It is essential to note that some spatial and temporal variations are likely attributed to differential taphonomic processes operating on a local scale and/or research biases (e.g., processing by different cultural affiliations and variations in excavation and sampling methodologies), which can significantly influence comparisons between sites. Therefore, when considering approaches to the composition of the archaeofauna, it is recommended to take into account the various collection methods and techniques, as well as their cultural context. Nonetheless, the available zooarchaeological data can contribute to and engage with Conservation

Biology, filling biogeographical gaps and providing valuable information about endangered species and those classified with insufficient data for threat assessment.

2.4.3. Integrating zooarchaeology with conservation biology

Zooarchaeological data have a significant role to play in environmental conservation and restoration discussions and public policies. Critical environmental issues can only be effectively addressed if both anthropogenic and natural factors are understood from a historical perspective (Jackson, 2010; Roberts, 2003). The lack of such long-term temporal perspectives can lead to misunderstandings about the extent and rate of ecosystem changes (Soga; Gaston, 2018; Pauly, 1995). This is particularly important in biodiversity hotspots, which are regions experiencing exceptional habitat and biodiversity loss (Myers et al., 2000), such as the Atlantic Forest and the Pampa biome. Faunal remains from archaeological sites become a possible, useful, and often unique tool for obtaining historical data on target species, environments, patterns and methods of capture (e.g., fishing and hunting), and the body size of individuals. These data serve as valuable sources of ecological baselines (Jackson et al., 2001).

According to the Red Lists of the International Union for Conservation of Nature (2022) and the Chico Mendes Institute for Biodiversity Conservation (BRASIL, 2018), at least 57 species recovered in 14% of the mapped sites (n = 54) are currently threatened within the Vulnerable (VU), Endangered (EN), and Critically Endangered (CR) categories (Figure 2.4, Table 4 in Supplementary Material). In addition to these, teeth of *Carcharhinus isodon*, a species classified as Regionally Extinct (RE) on the Brazilian coast (BRASIL, 2016a, 2016b), were found in sambaquis of Baía Babitonga (Itacoara and Bupeva II) on the northern coast of Santa Catarina (BANDEIRA, 2004). This correlation with the current conservation status of species is of utmost importance for assessing the temporal and spatial history of a particular species in the paleoenvironment and correlating it with its current occurrence. As an example of the potential use of ZooarchBR in Conservation Biology, we selected *Tayassu pecari*, a threatened mammal species recorded in various sites that allowed us to develop a distribution map of this species in past times and compare it with its current occurrence based on the data available from the IUCN (Figure 2.5). In addition to the threatened species (VU, EN, and CR), ZooarchBR can contribute to the assessment of the extinction risk of at least 16 species classified as Data Deficient (DD) by ICMBio (BRASIL, 2018) and IUCN (2022). A species is classified in this category when more information (e.g., distribution and abundance) is needed for a proper assessment.

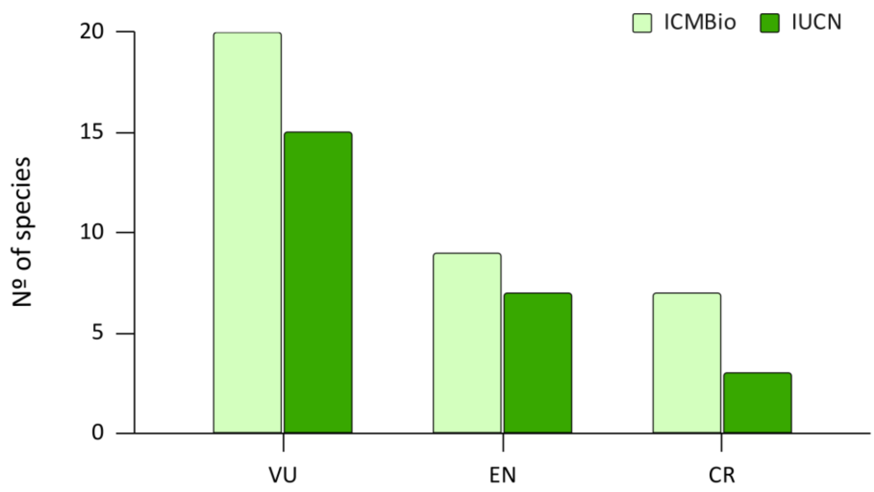

Figure 2.4. Threatened species on the Red Lists of the Chico Mendes Institute for Biodiversity Conservation - ICMBio (BRASIL, 2018) and the International Union for Conservation of Nature - IUCN (IUCN, 2022).

In addition to threatened species, there are exotic species, such as *Subulina octona*, *Rattus norvegicus*, and *Bos taurus*, which likely reflect post-depositional processes related to later occupations and urban development in coastal areas. Data like these can also spark discussions about recent anthropogenic impacts on archaeological sites and assist in mapping the distribution of invasive species in Brazil (ROSA et al., 2020). Furthermore, information about exotic species can contribute to discussions about whether certain species should be classified as exotic or not, such as the mussel *Perna perna*, which is found in archaeological sites but is considered an invasive organism (PIERRI; FOSSARI; MAGALHÃES, 2016; SILVA et al., 2018).

Finally, ZooarchBR can also serve as a basis for promoting socioeconomic policies. ZooarchBR includes 18 species of fish, mollusks, and crustaceans recorded as having socioeconomic importance in the National Action Plan for the Conservation of Threatened Species and Species of Socioeconomic Importance in the Mangrove Ecosystem (PAN Manguezal), developed with the support of representatives from traditional peoples and communities (BRASIL, 2015). By mapping the distribution of these species of socioeconomic importance, it is possible to initiate discussions and actions aimed at creating conservation units that encompass sustainable resource use (THOMPSON, et al. 2020; REEDER-MYERS et al., 2022).

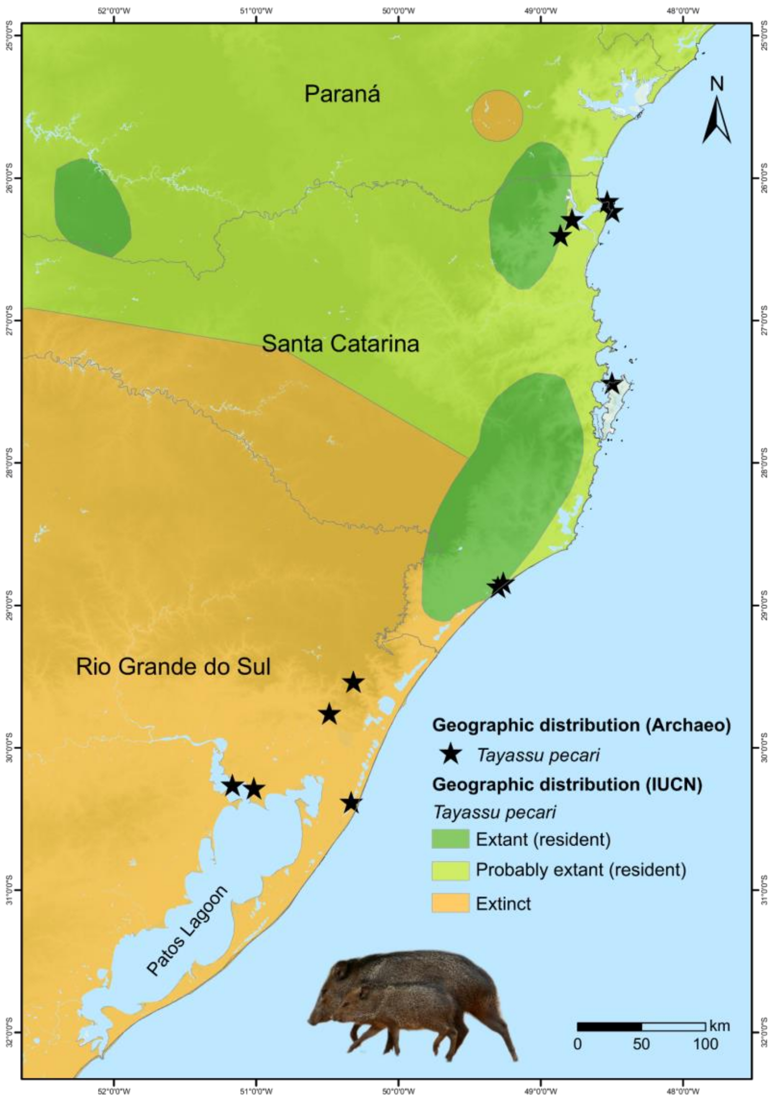

Figura 2.5. Archaeological (black stars) and current geographic distribution of the peccary *Tayassu pecari* on the southern coast of Brazil.

2.5. Final considerations

We are just beginning to understand the ecological consequences of species collapse, depletion, and habitat loss in coastal ecosystems, particularly estuaries, rocky shores, bays, coastal lagoons, and sandy beaches. These areas are considered a fundamental basis for marine productivity that has sustained human societies for thousands of years (ERLANDSON; RICK, 2008). However, based on the information compiled in ZooarchBR, we may be one step closer to answering questions such as: Does the Brazilian territory hold the title of the world's greatest biodiversity only in modern times? Can archaeological records maintain the country's biodiversity status in the Holocene? To what extent can the diversity of pre-colonial and colonial peoples influence the composition of the current biological reserve? While we do not have the answers to these questions, ZooarchBR may be the only tool for disseminating knowledge about biodiversity existing since the Holocene paleoenvironment, promoting the integration of Brazilian zooarchaeology data and contributing unique and integrative data to archaeology and conservation biology.

2.6. Supplementary material

Available on https://zenodo.org/records/8198809:

Table 1. Collaborative Table
Table 2. Archaeological References
Table 3. Archaeological Sites
Table 4. Zooarchaeological Qualitative Data
Table 5. Zooarchaeological Quantitative Data

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CHAPTER 3

Bridging archaeology and marine conservation in the Neotropics

This chapter corresponds to the published article:

Fossile T, Herbst DF, McGrath K, Toso A, Giannini PCF, Milheira RG, et al. (2023) Bridging archaeology and marine conservation in the Neotropics. PLoS ONE 18(5): e0285951. DOI: https://doi.org/10.1371/journal.pone.0285951.

3.1. Introduction

The rapid decline of global biodiversity is one of the most severe and escalating issues of our time [1, 2], increasing at an alarming rate in coastal and ocean ecosystems through overexploitation, habitat degradation, and pollution, among other stressors [3, 4]. Because taxonomic diversity (richness and abundance of species) and ecosystem function and services (the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly, [5]) are positively correlated [6], biodiversity loss (e.g. taxonomic and functional diversity) as well as changes in species distribution, composition, and abundance, have potentially dramatic consequences, altering ecosystem functions and compromising food provisions and the livelihoods of people around the world [2, 7, 8]. Scholars have sought to measure the scale of Anthropocene defaunation through modern observations for decades [9, 10]; questions remain, however, about conservation and restoration targets as establishing reference baselines is complex in marine ecosystems impacted by long-term human activities [11–13], particularly in regions with conspicuous biological knowledge shortfalls, such as Brazil [14].

Brazil is a megadiverse country [15], with the majority of its population and economic activities concentrated along its ~7,500 km coastline. In 2015, coastal and marine economies contributed to nearly 20% of the country's annual GDP [16]. In the south, the coastal strip of the Atlantic Forest and Pampa biomes support large marine biodiversity [17] and numerous ecosystem services for human populations [18]. In particular, the Atlantic Forest is a global biodiversity hotspot [19, 20] and a priority region for efforts of ecosystem restoration and biodiversity adaptation to climate change [1, 21]. However, in the last decades, population growth, increasing urbanisation, industrialisation, tourism and agricultural expansion have caused significant impacts on coastal environments in these regions [22–24]. The southern region, comprising the states of Paraná, Santa Catarina, and Rio Grande do Sul, has historically been the largest territory of fish exploitation in Brazil [25], and thus is a strategic area for marine conservation within the context of a sustainable blue economy and blue growth. Yet several economically important demersal fish species are currently threatened by overfishing, bycatch and habitat degradation [26, 27]. Recent studies revealed that some of these stressors have been in action for over a century [28], potentially distorting perceptions about the degree to which local organisms and environments have been altered over time [29, 30]. As a consequence, a thorough understanding of the scale of marine biodiversity loss and population decline requires knowledge of species composition, distribution and relative abundance predating the anthropogenic impacts of the past centuries [31, 32].

Although typically limited to decadal and centennial timescales, archaeological sites retain information on past biological diversity that is becoming central in debates about long-term anthropogenic impacts on ecosystems [33, 34]. South America, however, has received only cursory attention. In this region, archaeological faunal remains are some of the few sources of information on pre-colonial vertebrate and invertebrate diversity and relative abundance, from single species to several taxonomic and functional groups [35]. Moreover, because Indigenous environmental stewardship is considered an example of sustainable resource use [36] and key to biological conservation in tropical and subtropical regions of South America [37, 38], studies of archaeological faunal remains also offer a window into the origin and changing nature of these longstanding practices.

Indigenous groups have exploited coastal environments in the Atlantic Forest and Pampa biomes of southern Brazil since at least the Middle Holocene [39, 40], leaving behind thousands of archaeological sites containing large amounts of fish remains [41]. Archaeological fish remains are largely the product of economic strategies and related cultural practices, and thus provide the most direct evidence of which species have been selectively (e.g. due to food preferences, taboos, technology) exposed to fishing pressures in the past and over long timescales. Systematic zooarchaeological studies in these regions began in the 1970s and it is now possible to perform regional syntheses on published records for dozens of sites, obtaining snapshots of fish landings over ca. 9500 years of pre-colonial occupation, prior to the 16th century AD.

This work presents an extensive review of the published data on marine and freshwater fish stocks exploited by Middle and Late Holocene Indigenous coastal populations in southern Brazil (Fig 3.1A). We assessed species composition and relative abundances through space and time, and compared fish functional traits (trophic level, maximum body size and maximum body mass) between archaeological and modern catches. We show that socially and economically important species for present day small-scale and industrial fisheries were extensively targeted by pre-colonial Indigenous groups. Narrowing our analysis to sites in Babitonga Bay, one of the largest estuarine systems in the Southern Atlantic and the region with the largest concentration of pre-colonial archaeological sites in coastal Brazil (Fig 3.1B), our study revealed that species of high trophic level and large body size and body mass were commonly exploited in the past, suggesting they were more abundant and easily encountered. Only in recent times have fisheries moved to small-bodied and lower trophic level species. We hypothesise that increasing fishing efforts and other coastal stressors have contributed to the decline in abundance of some of these high trophic level and large bodied species in modern fisheries. Our study offers a pre-market baseline to assess changes in species abundance, composition and function through time that is currently absent in one of the largest fish producing regions of the South Atlantic.

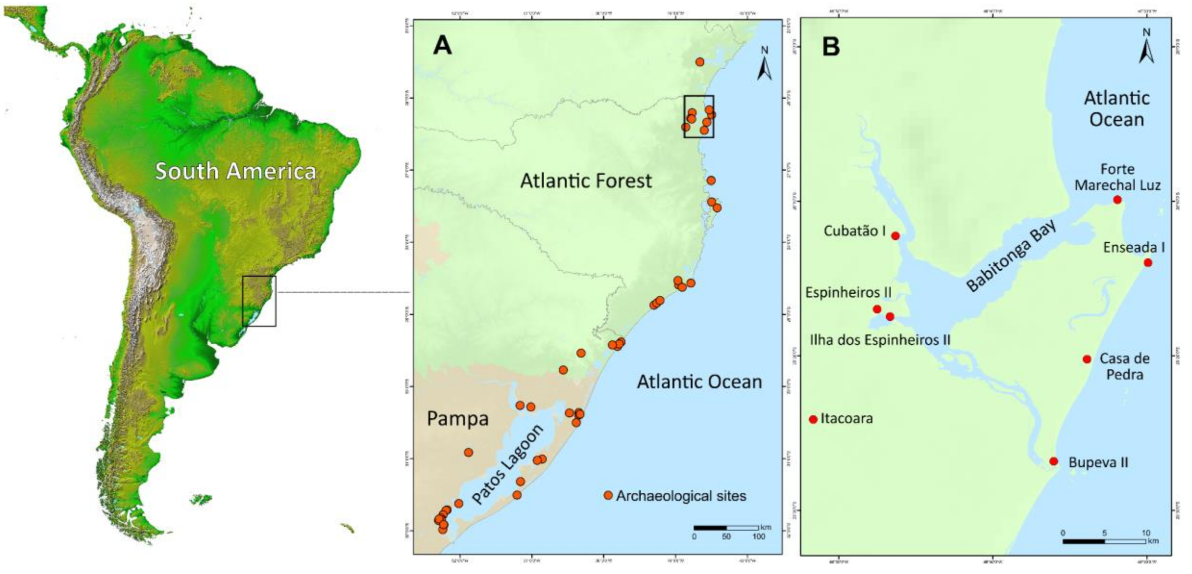

Fig 3.1. (A) Archaeological sites with fish remains, and (B) archaeological sites with fish remains in Babitonga Bay. Maps generated using ArcGIS 10.7 ([42]), CGIAR Consortium for Spatial Information ([43]) and NASA/JPL-Caltech (adapted from https://www.jpl.nasa.gov/images/pia03388-south-america-shaded-relief-and-colored-height).

3.1.1. Environmental and archaeological setting

The study area is located between 25°S and 31.5°S latitude and encompasses nearly 1000 km of coastline between the southern Atlantic Forest and the grassland Pampa biomes. The region includes several ecosystems supporting a great diversity of fish [17], including stocks of economic importance to both small-scale and industrial fisheries [25–27], such as Sciaenidae (e.g. *Micropogonias furnieri, Pogonia courbina*), Ariidae (*Genidens* sp.), Mugilidae (*Mugil liza, Mugil curema*), Paralichthyidae (*Paralichthys* sp.) and Pomatomidae (*Pomatomus saltatrix*), among others, as well as several species of sharks and rays [26, 27]. Most of these ecosystems evolved to their modern configurations during the Late Holocene [44–47]. Currently, the southernmost sector extends from Patos Lagoon (31.5°S) to the Santa Marta Cape (28.6°S) and is characterised by a wide continental shelf (120 to 230 km), with a gentle slope. The NE structure of the basement, subparallel to the coast, favoured the presence of continuous beaches of hundreds of kilometres and the development of the most extensive pairs of sandy barriers and lagoons in Brazil [48, 49]. This area includes large choked lagoons, such as Patos Lagoon, with salt marshes occurring in most tidal flats. Moving north, the change in coastline orientation favours coastal upwelling [50], and mangrove systems become dominant. From the Laguna lagoonal system (Mirim, Imaruí, and Santo Antônio lagoons) (28.1°S) to Babitonga Bay (26.7°S), the coastal sector has a narrower and steeper inner shelf and a more restricted coastal plain than neighbouring sectors, with headlands, rocky shores, pocket beaches and small embayments [49]. The coastal sector north of Babitonga Bay and adjacent to Santos Basin has a gentle slope, dominated by beaches over ten kilometres long with NE orientation, mostly separated by relatively small headlands and wide estuaries, such as the bays of Laranjeiras, Guaratuba and Paranaguá.

Estuaries and coastal lagoons were of primary importance for Indigenous populations in the study area before and during the earliest phases of contact with Europeans in the 16th century AD [51]. Marine resources were also exploited in a range of coastal habitats, including rocky shores [52] and oceanic islands [53], with considerable chronological and cultural variability. The earliest evidence of marine fish exploitation is associated with the Umbu cultural tradition, beginning around 9000 years ago [54, 55]. Contemporary to these groups, other populations depended largely on marine resources and raised monumental shell mounds locally known as sambaquis between 7000 and 500 years ago [56]. Along the Pampa biome and the La Plata basin in southern Brazil, Uruguay, and Argentina, groups known as Cerritos exploited fish and wetland resources between 4700 and 200 years ago [57]. From 1200 to 500 years ago, groups who produced ceramic artefacts attributed to the Taquara-Itararé cultural tradition also exploited fish as the main source of dietary protein in the southern Atlantic Forest coast [58, 59]. Finally, Tupiguarani and Guarani groups who settled in these coastal areas from around 1000 years ago until European contact [60], complemented their plant-based economies with fish from coastal environments [61].

3.2. Material and methods

3.2.1. Literature survey and data compilation

Faunal information was obtained from 71 reports produced between 1975 and 2022 on faunal assemblages recovered from Middle and Late Holocene sites along the southern coast of Brazil (S1 and S2 Tables). We limited our review to coastal sites, using a maximum distance from the current shoreline of 100 km, following Small and Nicholls [62]. This was also motivated by the fact that the high relative position of the sea level (ca. +3 m 5000 years ago [45, 63]) shifted the coastline further inland in areas with gentle slopes. Faunal reports included research articles (55%), academic dissertations and theses (38%), and book chapters (7%) available as physical and electronic copies in institutional repositories (universities, museums, public libraries) and publishers' websites.

Reports were categorised according to qualitative and quantitative criteria proposed by Fossile et al. [64]: Source A (qualitative-quantitative) - presented detailed taxonomic identifications, and absolute and relative abundance for all taxa (Number of Identified Specimens (NISP) and/or Minimum Number of Individuals (MNI)); Source B (semi-quantitative) - presented detailed taxonomic identifications, and absolute and relative abundance for selected taxa; Source C (qualitative) - presented taxonomic identification with no quantitative information (S1 Table). Of the 71 documents listing fish remains, Source A (qualitative-quantitative), Source B (semi-quantitative) and Source C (qualitative) accounted for 60.6% (n = 43), 26.8% (n = 19) and 12.6% (n =

9), respectively. Data in sources A and B were used to calculate and compare relative taxonomic abundances within and among faunal collections, while data in sources A, B and C were used to derive species richness and their relative frequency distribution among sites. Whenever possible, taxonomic information was recorded to the species level, but for most sites only genus, and often classes, orders, and/or families were available. The nomenclature and ecological attributions follow WoRMS [65] and Eschmeyer's Catalog of Fishes [66] (S3 and S4 Tables). Species richness (SR) was calculated using the Minimal Level of Taxonomic Identification, considering only the minimum hierarchical level for particular taxa. The conservation status of species was compiled from the IUCN Red List of Threatened Species [67] and the updated Red List of Threatened Species of the Chico Mendes Institute for Biodiversity Conservation (Instituto Chico Mendes de Conservação da Biodiversidade - ICMBio) [68]. The socioeconomic importance of species was compiled from the National Action Plan for the Conservation of Endangered Species and of Socioeconomic Importance in the Mangrove Ecosystem - PAN Mangrove [69].

We used NISP values and, in a few cases, MNI (Espinheiros II, RS-LS-11 and Itapoã; S4 Table) to express the absolute and relative abundances of taxa. NISP was reported in 77.4% of the analysed sites with fish remains, while MNI (with no corresponding NISP data) was reported in 5.7% of the sites. For sites where faunal assemblages were analysed for distinct areas, the absolute abundance of each taxa was aggregated. In the case of faunal assemblages that were published more than once, the most detailed study in both taxonomic and quantitative terms was considered. Total NISP values include all identified remains regardless of their taxonomic levels (from class to species). However, relative abundance of taxa was performed using NISP values after removing the number of remains generically identified as Actinopterygii (bony fish) and Elasmobranchii (cartilaginous fish). Trophic levels of exploited organisms (excluding class level and above) were attributed according to FishBase [70]. For order, family and genus we used the average values of species present in archaeological records in the region, or the average values of the species reported in the Brazilian Biodiversity Information System (SiBBr) [71]. One-way Analysis of Variance (ANOVA) followed by Tukey's HSD tests (stats package in R) was used for comparing NISP and SR according to excavation mesh size (95%

family-wise confidence interval). A Pearson correlation coefficient (stats package in R) was employed for measuring linear correlations between SR and NISP.

3.2.2. Cultural and chronological assignments of pre-colonial fish assemblages

Faunal assemblages were compiled by archaeological sites taking into account their cultural phases and radiocarbon dates (calibrated years before present, cal BP). Cultural phases consist of well-established "traditions" based on site typology (e.g. shell mounds, earth mounds), the presence and type of key artefacts (e.g. stone tools, ceramics), and their "absolute" chronology based on radiocarbon dates. The latter allows the general assignment of cultural phases to the formal subdivisions of the Holocene based on natural climatic/environmental events (Early, Middle and Late) [72]. For example, faunal assemblages from Enseada I were separated by two distinct cultural phases including a Sambaqui (4050 cal BP) phase and a Taquara-Itararé (1050 cal BP) phase, both dated to the Late Holocene [73]. Fauna from the site of Sangão, instead, were computed separately for Early (8950 cal BP) and Late (4650 cal BP) Holocene occupations [54].

Radiocarbon dates for the analysed sites were obtained from the Brazilian Radiocarbon Database [74], on dates generated from a range of archaeological materials (marine shells, human and faunal bones, charcoal). Conventional radiocarbon dates were calibrated and modelled using OxCal v. 4.4 [75]. For sites with multiple dates (e.g. Forte Marechal Luz, Cubatão I, Jabuticabeira II, RS-PSG-07), the conventional dates were summed (Sum function) according to main cultural attributes, for example by grouping dates obtained from Sambaqui occupations, or from layers with ceramic artefacts of Taquara-Itararé tradition. In doing so, we estimated the median age of a particular "cultural" occupation (group median). Terrestrial samples were calibrated using the 100% atmospheric calibration curve for the southern hemisphere, SHCal20 [76]. Marine organisms were calibrated using the 100% Marine20 curve [77], applying an estimated average local marine radiocarbon reservoir correction value (ΔR) of -126 ± 29 for the coasts of São Paulo, Paraná, Santa Catarina and Rio Grande do Sul, generated from eight reference points between latitudes 32.0°S and 23.7°S [78–80], according to the Marine Reservoir Correction database. Given the high contribution of marine carbon to bone collagen of human individuals in this region, the radiocarbon dates on human bone collagen were modelled using a mixed curve (SHCal20 and Local Marine curve) adopting the same ΔR value reported above. We considered the average relative contribution of marine carbon to collagen of 52 ± 9%, which is the average estimated contribution recently obtained from dozens of human individuals from archaeological sites in Babitonga Bay [40]. Calibrated and modelled radiocarbon dates were rounded to 50 years (S5 Table).

3.2.3. Comparing fish traits across time periods in Babitonga Bay

Fish data were compiled for three distinct chronological periods (and cultural phases) in Babitonga Bay: 4500–1150 cal BP (Sambaqui), 1050–600 cal BP (Taquara-Itararé), and AD 1994–2015 (modern fisheries). Fish assemblages dated to 4500–1150 cal BP were recovered from the Sambaqui phases of the sites Cubatão, Espinheiros II, Ilha dos Espinheiros II, Forte Marechal Luz, Enseada I, Bupeva II and Itacoara; fish assemblages dated to 1050–600 cal BP included the Taquara-Itararé phases documented in the sites of Forte Marechal Luz, Enseada I, Bupeva II and Itacoara (Fig 3.1B); modern fish assemblage composition (241 species) were obtained from surveys conducted in Babitonga Bay from AD 1994 to 2015 [81, 82] (S6 and S7 Tables). A total of 124 species were documented as fisheries targets for Babitonga Bay across the three studied periods. Of these, 62 species were recorded for the Sambaqui cultural phase, 34 for the Taquara-Itararé cultural phase [41, 73, 83–86], and 94 for the modern period (Projeto de Monitoramento da Atividade Pesqueira em Santa Catarina - PMAP/SC, available at: http://pmap-sc.acad.univali.br/index.html) (S6 and S8 Tables).

For each species recorded, we compiled trophic level, trophic group, maximum body size (cm) and maximum body mass (g). Fish trophic level was taken from FishBase (see above) and ranged between 2.0 to 4.9. Trophic group categories were compiled from Quimbayo et al. [87] and complemented with information from other literature [88–107]. The categories were invertivores, herbivores, macrocarnivores, omnivores, piscivores and planktivores. Maximum body size and body mass were also obtained from Quimbayo et al. [87] and from other literature [70, 108–111]. Fish species were categorised into body size classes based on their maximum body sizes. These categories were: <7 cm, 7–15.0 cm, 15.1–30.0 cm, 30.1–50.0 cm, 50.1–80.0

cm, and >80 cm. Body size categories and trophic groups were combined for each species to define fish functional entities (FEs).

Differences in fish species' trophic levels, maximum body sizes, and maximum body masses were assessed using a null model approach, under which the observed traits in each period (4500–1150 cal BP, 1050–600 cal BP and AD 1994–2015) were contrasted against null values obtained from randomly sampling the total species pool [112]. The total species pool corresponds to all fish taxa caught across the different study periods (n = 124) combined with those that were not targeted but compose the regional fish assemblages (n = 241). This total pool (n = 365) is, therefore, equivalent to the total species richness and trait variability in the region, regardless of the time period. For each trait and time period, we contrasted the distribution of observed values with the distribution of 1000 random samples of the total pool. The observed trait values were compared to those of random assemblages (null values) for each time period using two-sided t-tests. Box plots and violin plots were used to explore the distribution and differences between observed and null values. To test for differences in fish traits caught across time periods we used One-way Analysis of Variance (ANOVA) followed by Tukey's HSD tests. Fish maximum body size and maximum body mass were positively and significantly correlated ($r^2 = 0.67$; $p < 0.005$), and log-transformed before analysis. We opted to maintain both traits in our analysis to explore differences across periods (S1 Text).

We further explored differences in the proportion of fish species belonging to body size categories, trophic group categories, as well as functional entities (FEs) across time periods. These would indicate whether certain body sizes, fish trophic groups and functional groups corresponded to a greater proportion of fisheries targets in particular time periods. Also, such analysis can reveal changes and fisheries characteristics across time. To test the statistical significance in the proportions of fish body sizes and trophic categories across time periods we used a two-tailed Binomial test ($p < 0.05$). All analyses were conducted in R Studio Software [113].

Finally, the data presented is part of the Brazilian Zooarch Database (ZooarchBR) and is stored at the Brazilian Biodiversity Information System (Sistema de Informação sobre a Biodiversidade Brasileira - SiBBr) [71]. SiBBr consists of a set of data and information on Brazilian biodiversity and ecosystems linked with the Global Biodiversity Information Facility (GBIF), providing subsidies for government management related to conservation and sustainable use [71]. This platform is developed by the Brazilian Ministry of Science, Technology and Innovation (Ministério da Ciência, Tecnologia e Inovações - MCTI), with technical support from ONU Environment (UNEP) and financial support from the Global Environment Facility (GEF). The data presented here is registered in the SiBBr in the category Occurrence Records (inventories and/or research projects) through the TRADITION Project, following the Darwin Core (DwC), an international standard recognized by the scientific community for metadata. The data is also available in https://doi.org/10.5281/zenodo.7925975.

3.3. Results

3.3.1. Quantitative and qualitative data assessment

Faunal information (marine, freshwater and terrestrial animals) was compiled for 374 archaeological sites (71 reports) distributed along the southern Atlantic Forest (89%) and the Pampa (11%) biomes, from publications produced over the last 47 years (Fig 3.1 and S1 and S2 Tables). Fish remains were reported in 53 sites (14.4%, sources A, B and C) (S3 Table). Of these, 44 sites (83%, sources A and B) contained information on the absolute and relative abundance of taxa (S4 Table). Recovery and analytical techniques differed considerably among sites. For example, of the 44 sites with the absolute and relative abundance of taxa, fish remains were retrieved through sieving sediments in 73% (n = 32), but using distinct mesh sizes: 2 mm (31.2%, n = 10 sites), 3 mm (31.2%, n = 10 sites), 4 mm (9.4%, n = 3 sites) and 5 mm (28.1%, n = 9 sites). The volume of sediment was reported, or could be estimated from excavated areas, for 84% of the sites with fish remains (n = 37), and ranged from 0.06 to 13.8 m^3. In the majority of sites (98%, n = 43) both bones and otoliths were used for specimen quantification (NISP), while in 80% of sites (n = 35) otoliths and bones were used for taxonomic identification (S4 Table).

Archaeological assemblages in sources A and B were dominated by bony fish (total NISP = 876,622; 98.8% of total remains), followed by cartilaginous fish (total NISP = 10,603; 1.2%). Among bony fish, 17% of the remains could be identified beyond the class level (Actinopterygii), while for cartilaginous fish 56.7% were identified beyond the Elasmobranchii class. These proportions remained substantially comparable across the sites, regardless of their geographic location and chronology. When considering the Minimum Level of Taxonomic Identification in sources A, B and C, 109 taxa were reported, of which 79 belonged to bony fish and 30 to cartilaginous fish (S3 Table). Differences in recovery and analytical methods (sometimes referred to as second-order changes [114]) can dramatically affect fundamental and derived measurements of faunal remains such as the taxonomic abundance (NISP) and richness (SR) [114–116]. Here we explored the effect of sieving with distinct mesh sizes (2–3 mm, 4 mm and 5 mm) on both total NISP and SR (Fig 3.2A and 3.2B). For this purpose we combined data from 2 and 3 mm (2–3 mm) mesh because both are considered adequate for the recovery of fish remains [117, 118]. NISP was normalised for the volume of sediment (NISP/m^3) to account for additional size-effect. SR was also normalised for contextual total NISP values (SR/NISP). Surprisingly, the results reveal no significant statistical differences between NISP/m^3 produced by using 2–3 and 4 mm mesh ($p = 0.2936$), nor between 2–3 and 5 mm mesh ($p = 0.6817$), or 4 and 5 mm mesh ($p = 0.6032$). Similarly, derived SR/NISP were statistically indistinguishable between 2–3 and 4 mm mesh ($p = 0.6902$), and between 2–3 and 5 mm mesh ($p = 0.5218$). Again, SR produced through the use of 4 and 5 mm mesh were statistically comparable ($p = 0.9796$).

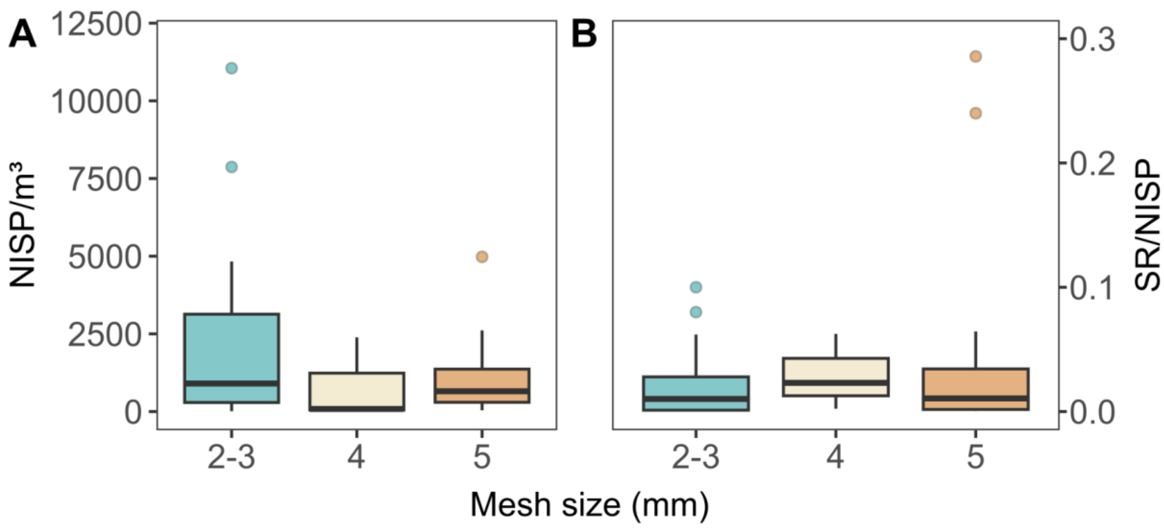

Fig 3.2. Boxplot showing the distribution of A) NISP/m^3 versus mesh size and B) SR/NISP versus mesh size.

We also assessed the sample size-effect by comparing SR with NISP/m³ [115, 116], under the theoretical proposition that, all things being equal, SR positively correlates with NISP/m³. The results revealed no significant correlations ($p = 0.9033$, $r = -0.02$, $n = 28$) between SR and NISP/m³ for the entire dataset (sources A and B) including distinct recovery (all mesh sizes) and identification (otoliths and/or bones) methods (Fig 3.3A). By contrast, when selecting data associated with 2–3 mm mesh size and identified using both bones and otoliths, a significant positive correlation ($p = 0.0008$, $r = 0.75$, $n = 14$) emerged between SR and NISP/m³ (Fig 3.3B). This correlation, however, depended on a single endmember with the highest SR and NISP/m³ (site of Rio do Meio), which when removed dissolved the positive correlation ($p = 0.9165$, $r = 0.03$, $n = 13$) (Fig 3.3C). In conclusion, although distinct recovery techniques may have affected the quality of the data in terms of SR and taxonomic abundances, the magnitude of these second-order changes remains unclear.

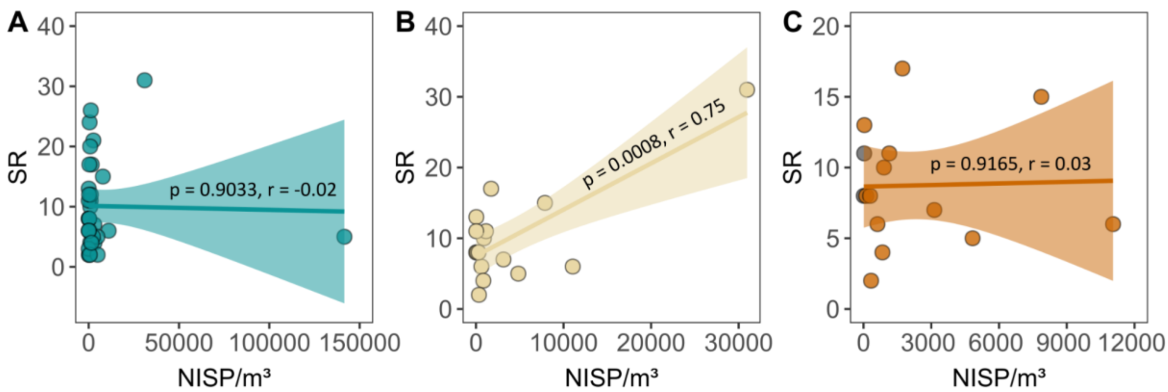

Fig 3.3. Correlation between SR and NISP/m³ for A) the entire dataset (sources A and B), B) faunal remains recovered with 2-3 mm mesh size and identified using both bones and otoliths, and C) the same data in B after removing a single outlier (site of *Rio do Meio*) with the highest SR and NISP/m³.

3.3.2. Pre-colonial fish compositions

Sites with fish remains had median calibrated dates mostly concentrated between 5402 and 200 cal BP. The only exceptions are the Early Holocene deposits of Sangão, which had two modelled median radiocarbon dates of 8150 and 9750 cal BP (S5 Table). Among bony fish species belonging to Sciaenidae (e.g. *Micropogonias* *furnieri, Umbrina sp., Pogonias courbina*) and Ariidae (e.g. *Genidens barbus, Bagre bagre, Notarius grandicassis*) accounted for ca. 50% and 23% of the identified remains, respectively (Fig 3.4A). They were also widely distributed in the archaeological record, with remains of Ariidae reported in 92% (n = 49) of the sites, and Sciaenidae in 79% (n = 42) (Fig 3.4B). At the species level, the marine-brackish, demersal and oceanodromous *Micropogonias furnieri* (whitemouth croaker) emerged as the most abundant and broadly captured species, representing 33% (NISP = 50,327) of the identified remains, and occurring in 70% (n = 37) of the archaeological sites (Fig 3.5A). Its capture appears to have increased significantly with time, most notably from ca. 2000 cal BP (Fig 3.5B) around Patos Lagoon (ca. 31°S), a key reproductive and feeding ground for this species in southern Brazil [26].

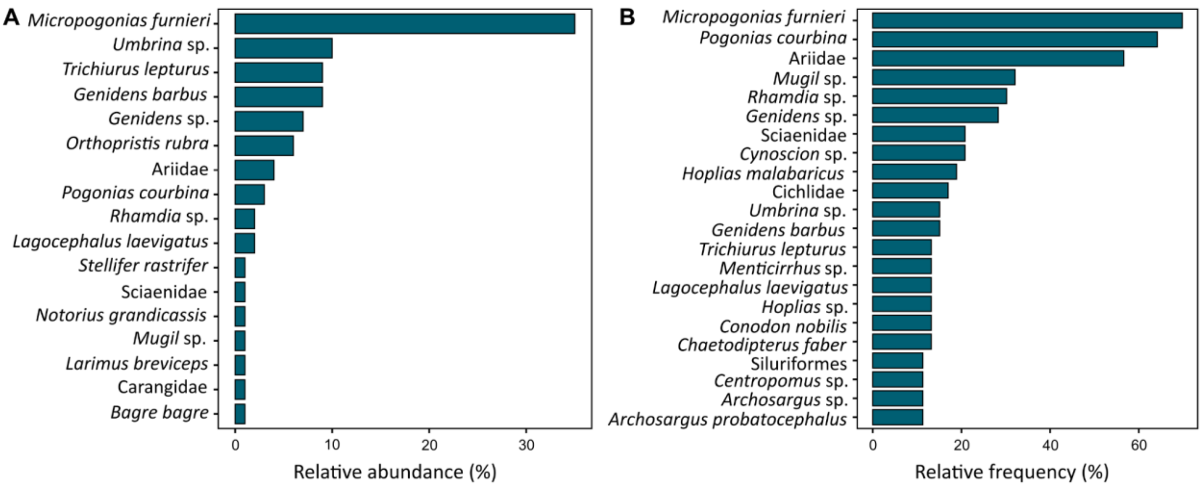

Fig 3.4. (A) Relative abundance of bony fish taxa above 1% in pre-colonial assemblages, and (B) relative frequency of bony fish taxa above 10%.

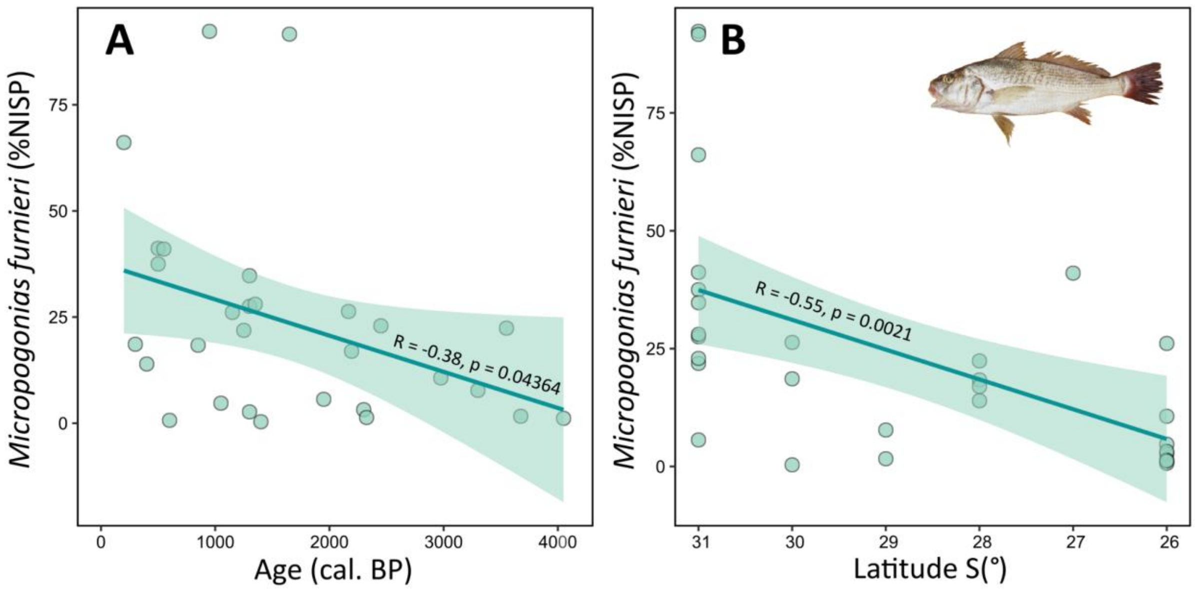

Fig 3.5. Relative abundance of *Micropogonias furnieri* as a function of (A) the median radiocarbon age of sites (modelled cal BP), and (B) latitude in pre-colonial assemblages. Green band represents the 95% confidence interval.

In terms of relative frequency, *Micropogonias furnieri* was followed by *Pogonias courbina* in ca. 64% of sites (n = 34), and unidentified Ariidae species (57%), *Mugil* sp. (32%), *Rhamdia* sp. (30%) and *Genidens* sp. (28%). With the exception of *Rhamdia* sp. (freshwater catfish), the taxa reported above are commonly distributed in near-shore coastal waters, including estuaries, tidal flats and mangrove systems [82]. Freshwater fish contributed to 0.6% of the remains, and were represented by *Rhamdia* sp., *Hoplias malabaricus*, *Hypostomus* sp., and *Synbranchus marmoratus* (S4 Table). Cartilaginous fish were mostly represented by remains of *Sphyrna* sp. (28.3%) and *Rhizoprionodon* sp. (18.5%), followed by *Carcharias taurus* (9.5%), *Carcharhinus* sp. (9.3%), *Pseudobatos* sp. (8.9%), Myliobatidae (5.6%) and others (Fig 3.6A). Overall, sharks and rays occurred in 53% (n = 28) of the sites with fish remains. Of these, Myliobatidae (rays) and *Carcharias taurus* were reported in 19% (n = 10) of the sites, followed by unidentified rays (infraclass Batoidea and order Rajiformes) and sharks (Selachii) in 11.3% and 9.4%, respectively, and finally by several species including *Carcharhinus* sp., *Galeocerdo cuvier, Carcharodon carcharias, Rhinoptera* sp., and *Negaprion brevirostris* (Fig 3.6B). Currently, these species are reported along the southern coast of South America (e.g. *Carcharias taurus, Notorynchus cepedianus,* *Lamna nasus*), while others, such as *Negaprion brevirostris, Sphyrna mokarran* and *Carcharhinus porosus*, are not found or are less frequent in southern Brazil [119–121].

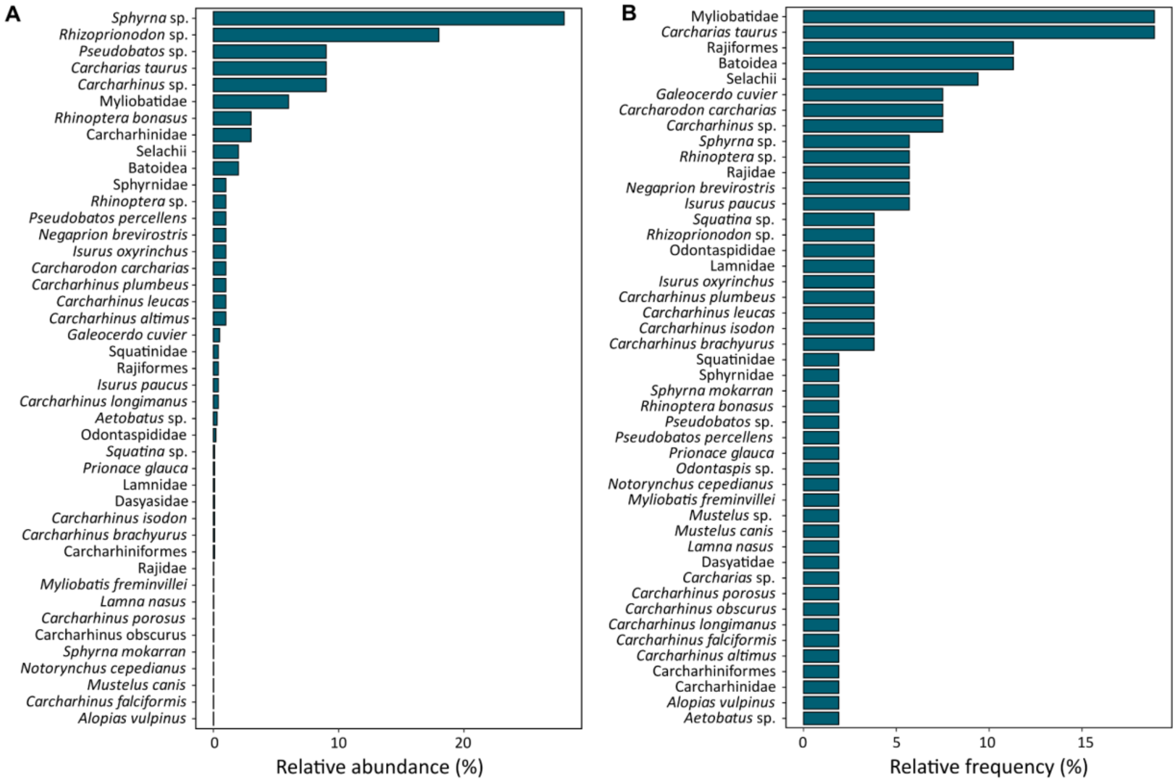

Fig 3.6. A) Relative abundance and B) relative frequency of cartilaginous fish taxa in pre-colonial assemblages.

Bony and cartilaginous fish diversity significantly decreased southwards (Fig 3.7A), but remained stable over time (Fig 3.7B). The latitudinal gradient in species diversity is consistent with studies showing a similar pattern in modern fish communities in the southwestern Atlantic Ocean [122–124]. By contrast, the weighted average trophic level (WATL) of fish assemblages did not correlate with latitude (Fig 3.7C) nor with site chronology (Fig 3.7D). Interestingly, sharks and rays increased in sites postdating 2200 cal BP (Fig 3.7F), particularly in areas located between Babitonga Bay (26°S; Bupeva II, Forte Marechal Luz) and Santa Catarina Island (27°S; Rio do Meio) (Fig 3.7E). Even though their relative abundance was not significantly correlated with age or latitude, the results are consistent with stable isotope analyses of human bone collagen indicating that from ca. 2200 years ago groups in Babitonga Bay and north of Santa Catarina Island secured most of their dietary proteins from high trophic level fish species [40]. Cartilaginous fish also accounted for more than 60% of the fish remains at the sites of Rua 13 and Sambaqui do Papagaio, both located in the aforementioned region, but lacking absolute chronology. The presence of adult, juvenile and neonate specimens [58, 125] suggests that humans were exploiting sharks and rays in a range of habitats, including nursery areas such as mangrove systems [126], as documented in other areas further north [127]. While it is plausible that some shark teeth could indicate trading networks, it is important to note that they are consistently found alongside a significant quantity of shark vertebrae and other fish remains. This suggests that the presence of shark teeth in most sites reflects local fishing activities. Together, these results suggest that captures along the Pampa (31.5°S) and southern Atlantic Forest coasts (28°S) were generally less diverse compared to more northern sites (27 to 26°S), as in the northern Santa Catarina coast (Fig 3.8). However, as discussed above, the diversity and abundance of the catches must have been higher than reflected in the collected data. High fish diversity, incomplete reference collections and disparity in recovery techniques, elevated fragmentation and lack of diagnostic features in archaeological bones are some of the common challenges that prevent the successful identification and adequate quantitative representation of fish remains in the regional archaeological record.

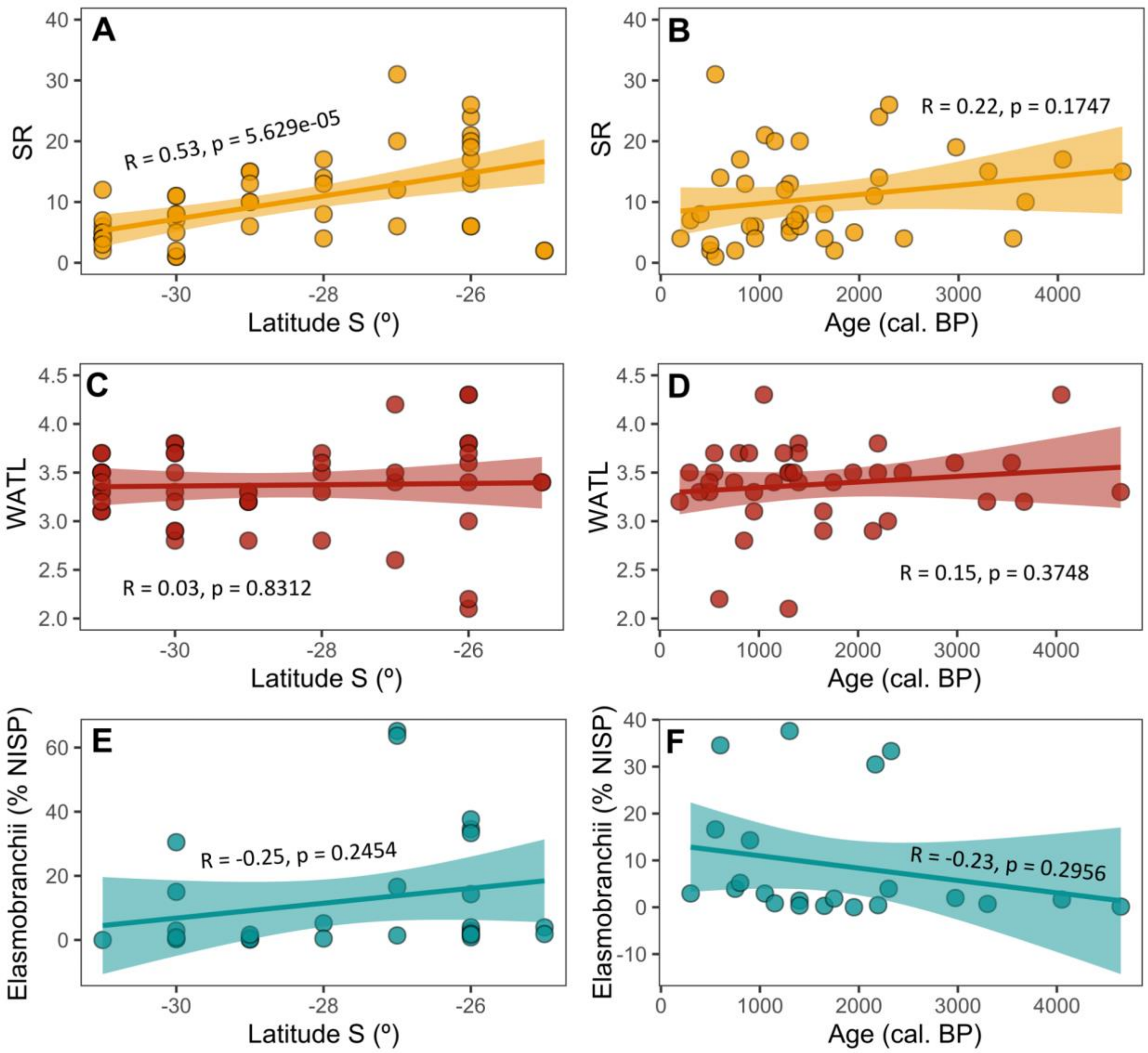

Fig 3.7. Species Richness as a function of A) the latitude and B) the median radiocarbon dates of the sites; C) weighted average trophic level per latitude and D) chronology; E) relative abundance of Elasmobranchii remains in relation to latitude and F) chronology of the sites. The bands represent the 95% confidence interval.

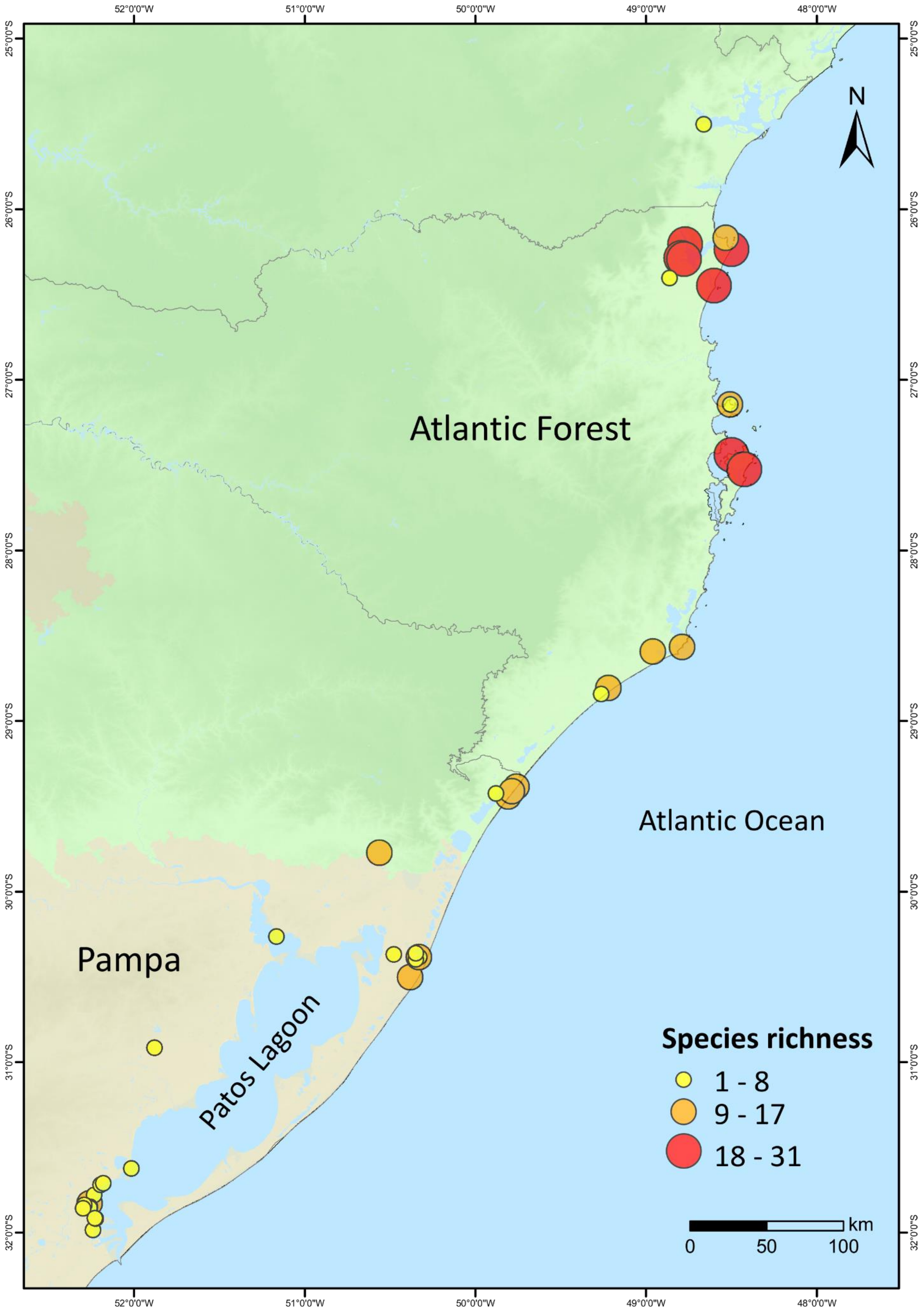

Fig 3.8. Latitudinal changes in Species Richness. Maps generated using ArcGIS 10.7 ([42]) and CGIAR Consortium for Spatial Information ([43]).

3.3.3. Trait variation of fish caught in Babitonga Bay across time periods

Babitonga Bay has the largest concentration of pre-colonial archaeological sites in coastal Brazil. Previous studies have indicated that high trophic level and large-bodied fish species were commonly targeted by Sambaqui (4500–1150 cal BP) and Taquara-Itararé (1050–600 cal BP) groups in pre-colonial times [40], which contrasts with modern catches reported by the Projeto de Monitoramento da Atividade Pesqueira em Santa Catarina ([81, 82] in the region. We tested this hypothesis by comparing fish functional traits for three distinct time periods (4500–1150 cal BP, 1050–600 cal BP and AD 1994–2015). We assessed differences in fish species trophic levels, maximum body sizes, and maximum body masses using a null model approach, under which the observed traits in each period were contrasted against null values obtained from randomly sampling the total species pool [112].

Our results suggest that catches in the periods of 4500–1150 cal BP and 1050–600 cal BP were composed of individuals of larger body size and body mass relative to modern fish catches (Fig 3.9A–3.9C). Between time periods, there were no significant differences in the trophic level of fish caught, but a slight decrease was detected in the minimum trophic level of fish species reported for the modern period (AD 1994–2015; MinTL = 2.9) compared to 1050–600 cal BP (MinTL = 3.3). Significant differences were instead only observed for the maximum body size and body mass of catches between 1050–600 cal BP and the modern period (p < 0.005 for both). Catches from 4500–1150 cal BP and 1050–600 cal BP were statistically indistinguishable for maximum body size and maximum body mass.

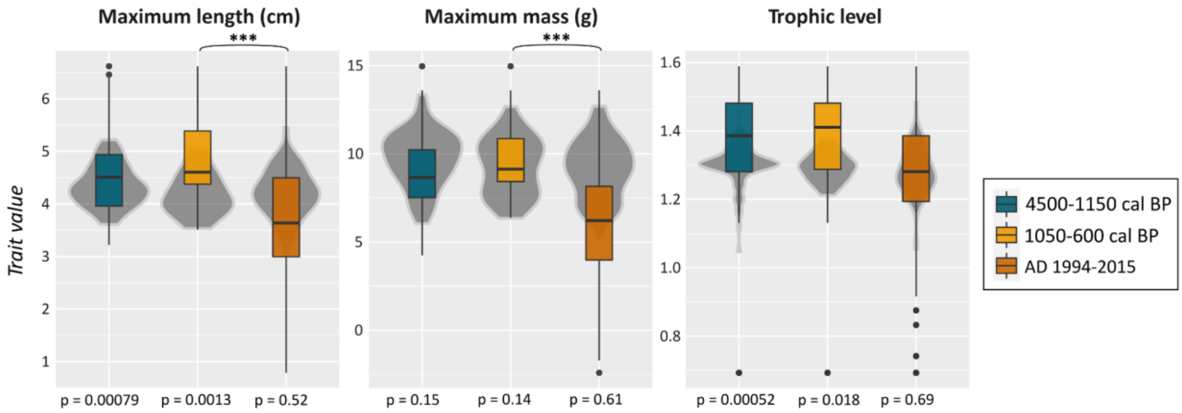

Fig 3.9. Fish traits exploited between 4500-1150 cal BP, 1050-600 cal BP and the modern period (1994-2015) for A) maximum body sizes, B) maximum body masses and C) trophic levels. Box plots represent observed values from fisheries catches across 4500-1150 cal BP, 1050-600 cal BP and the modern period (AD 1994-2015). Vertical black line denotes the median observed values, and black points are data outliers. Grey violin plots on the back represent the density distribution of null model values from random samples of the total species pool. P-values for pairwise comparisons of observed traits versus randomised data are shown below the boxes. Asterisks mark significant differences between time periods as indicated by Tukey HSD.

Within time periods, the maximum body sizes of fish in pre-colonial catches (time periods of 4500–1150 cal BP and 1050–600 cal BP) differed significantly from randomly generated assemblages (t-tests, $p = 0.0007$, samples from the total species pool), while modern catch (AD 1994–2015) body sizes were within those predicted at random (t-test, $p = 0.52$). The trophic levels of fish caught in periods 4500–1150 cal BP and 1050–600 cal BP were greater than that from the random assemblages ($p = 0.00052$ and 0.018 respectively); while the trophic level of species in modern catches did not differ from the random expectations ($p = 0.69$). For body mass, there were no significant differences from observed to null trait values (Fig 3.9A–3.9C).

Overall, the composition of captured species was dominated by large-bodied fish (> 50 cm) throughout the studied periods (4500–1150 cal BP ~90%; 1050–600 cal BP ~76% and modern ~58% of species). Modern populations included species with a broader range of body size categories, varying from fish < 15 cm in total length to large bodied species > 80 cm (Fig 3.10A). Fish maximum body sizes ranging from 15.1 to 30 cm corresponded to 14% of the species in modern catches, which was significantly different ($p < 0.001$) to catches in the period 4500–1150 cal BP, with only 3.2% of species identified (*Cathorops spixii* and *Isopisthus parvipinnis*) within this body size category. Medium and small-bodied fish species corresponded to a minor proportion of catches in pre-colonial times (3–20% for species up to 50 cm total length). Species with total length > 80 cm accounted for 45.7% of modern species composition, while they represented 59.6% and 73.5% of catches dated to 4500–1150 cal BP and 1050–600 cal BP, respectively (e.g. *Trichiurus lepturus, Caranx latus*).

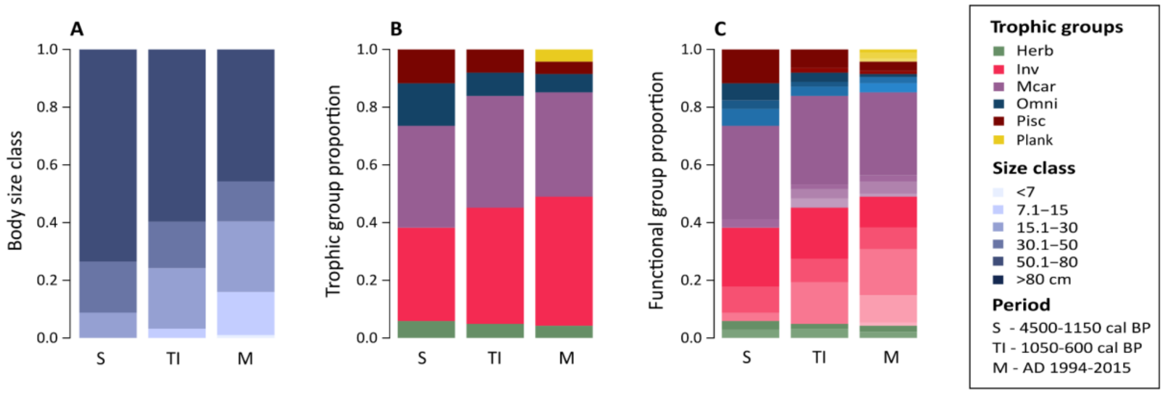

Fig 3.10. Fish traits and functional groups across time periods. A) The proportion of fish species within different body size categories, B) trophic groups, and C) functional entities between pre-colonial (4500-1150 cal BP and 1050-600 cal BP) and modern (AD 1994-2015) periods. In C, functional entities represent the combination of fish trophic groups and body size classes, and darker tones represent larger body size categories within the same trophic group. Two-tailed Binomial tests reveal significant (p < 0.05) differences in the proportions of 15.1 - 30 cm species between the 4500-1150 cal BP and modern (AD 1994-2015) periods.

Compared to modern assemblages, pre-colonial catches were characterised by a greater contribution of piscivore and omnivore species (Fig 3.10B). Piscivores accounted for 8.1% to 11.7% of species in fish remains from periods 4500–1150 cal BP and 1050–600 cal BP, respectively (e.g. *Bagre bagre, Pomatomus saltatrix, Trichiurus lepturus*), compared to 4.2% in modern assemblages. The proportion of macrocarnivores was similar across all periods (~35% of species). The contribution of invertivore fish slightly increased across periods, accounting for 40.3% and 32.3% in catches from periods 4500–1150 cal BP and 1050–600 cal BP (e.g. *Genidens barbus, Lagocephalus laevigatus, Micropogonias furnieri*), respectively, and reaching up to 44.6% in the modern period (AD 1994–2015). Planktivores were only documented in modern assemblages (4.2%). Finally, the proportion of fish functional entities reveals that it is the addition of fish within larger body size classes that greatly characterises pre-colonial catches (Fig 3.10C). Modern assemblages have a much greater contribution of small and medium-sized invertivores, as well as a lower contribution of large bodied (> 80 cm) piscivore species. While in catches from the period 4500–1150 cal BP, macrocarnivores were mostly large bodied (50.1–80 cm and > 80 cm), in catches from 1050–600 cal BP and in modern assemblages (AD 1994–2015) there is an increase of smaller macrocarnivore species (15.1–30 cm and 30.1–50 cm).

3.4. Discussion

3.4.1. Variations in pre-colonial fish compositions

Our review of the literature shows that several species of high social and economic value today were exploited by coastal societies in southern Brazil over the last 9500 years [128–130]. We acknowledge that the discrepancies in recovery and analytical techniques among reports complicate attempts to interpret data across distinct sites, and over spatial and temporal scales. Moreover, the faunal record presented here reflects dietary preferences, food processing, site function (e.g. cemeteries, residences), symbolic and ritual practices, and taphonomic factors that may have varied in time and space. Nevertheless, archaeology remains one of the few sources of information available to elucidate species distribution and relative abundance in the past, and particularly in data-deficient countries such as Brazil. Even though the relative abundance and distribution of species in archaeological contexts may be distorted due to the combination of first-order and second-order changes to the archaeological record (see [114]), the zooarchaeological data produced over the last 47 years in Brazil offer a unique approximation of which species were targeted in this region over time scales surpassing those of modern observations. Integrating methodologies such as geometric morphometrics, stable isotopes, archaeogenomics, and proteomics in neotropical zooarchaeology studies can significantly enhance its relevance to marine conservation.

The diversity of the catches are similar to those reported for modern small-scale commercial landings in the region [131–133], even though only 8% (n = 13) of the species accounted for the majority of the identified fish remains (NISP > 1%). Of these, a few demersal and estuarine-dependent species belonging to Sciaenidae (e.g. *Micropogonias furnieri, Umbrina sp., Pogonias courbina*) and Ariidae (e.g. *Genidens barbus, Bagre bagre, Notarius grandicassis*) were predominantly targeted in the past. They possibly formed large populations in coastal lagoons and estuaries, providing humans with an abundant and reliable supply of marine proteins year-round [39, 40].

Several lines of evidence indicate that pre-colonial coastal communities were able to extract volumes of fish comparable to or greater than subsistence catches in recent times [41]. Stable isotopes analyses also revealed that fish consumption per capita (contribution of marine protein to individual diet) was higher among pre-colonial communities [40] compared to local modern populations in coastal Brazil [134–136]. Nevertheless, the archaeological faunal record does not provide evidence for measurable human impacts on coastal organisms in this region. While most of these groups exploited crucial habitats for species reproduction and conservation (mangroves, salt marshes [126]), and targeted juvenile individuals in nursery grounds (e.g. sharks [137]), compelling evidence for ecological impacts are still lacking. If such detrimental impacts occurred, they were likely limited or localised, possibly permitting stock recovery over relatively short periods of time. For example, *Micropogonias furnieri* dominated fish assemblages in Patos Lagoon, with catches increasing in the last 2000 years in relation to human population growth [138] and stabilisation of environmental conditions, notably sea level, in the region [47]. Yet, there is no evidence that this species was affected by overfishing, such as could be indicated by a declining number in catches [139, 140]. By contrast, the targeting of *M. furnieri* by small-scale and industrial fisheries in recent times have led to a decrease in abundance to the point that it is now considered overexploited [25, 26]. However, further studies are required for conclusive interpretations to be drawn.

It is particularly striking that *Mugil* sp., despite occurring in 32% of sites with fish remains, represented only 0.7% of combined NISP values (excluding remains generically identified as Actinopterygii and Elasmobranchii). At least one species of Mugilidae (*Mugil liza*) is abundantly captured by communities along the southeastern coast of southern Brazil during austral autumn and winter, from May to July, and constitutes a cultural seasonal keystone seafood in this region [141]. The artisanal catches are obtained through the use of distinct fishing gear, but large catches are mostly secured by means of beach seine [142]. It could be argued that the relatively low abundance of *Mugil* sp. in pre-colonial catches reflect a lack of mass-capture fishing technology, such as large nets. Archaeological evidence for the use of fishing nets has been found in this region, such as stone sinkers and weights [143], as well as plant-based cordage and other artefacts [144], but their effectiveness for capturing large schools of Mugilidae remains a matter of debate. Significantly, Indigenous culinary practices described in some 16th century European chronicles provide some insight into the complexity of the taphonomic processes potentially affecting fish assemblages in this region. For example, Hans Staden in the first half of the 16th century reported that Guarani groups of the southern coast of Brazil processed fish (possibly Mugilidae) to make flour [145]. Although the origin and details of such practices are unknown, fish drying and grinding would imply that some species may have undergone selective taphonomic processes that conditioned their recovery and identification in the archaeological record [146].

The evolution of local fishing technology also played a role in species variation through time and among sites. For example, increased remains of pelagic species in sites containing ceramic artefacts of the Taquara-Itararé tradition coincided with the appearance and spread of single-piece baited fishing hooks manufactured from mammal bones from 1200 years ago [40]. Groups producing/using ceramic artefacts attributed to Taquara-Itararé tradition also had the technology to colonise oceanic islands in southern Brazil, such as Arvoredo Island located more than 10 km off the mainland [147, 148]. This evidence supports the emerging consensus that some coastal populations intensified fishing in the Late Holocene [40, 127], and pursued offshore resources. In addition to fishing technology, the evolution of coastal ecosystems in southern Brazil over the last 5000 years (a period covering 98% of the analysed data) potentially affected species distribution and local relative abundances, and hence subsistence models through time. As recently discussed by Toso et al. [40], the decrease in relative sea level and the silting of some estuarine-lagoonal water bodies in southern Brazil in the Late Holocene may have disrupted access to key lagoonal resources in the Atlantic Forest coast, forcing some human populations (e.g. Taquara-Itararé groups) to intensify the capture of open sea and pelagic species in more recent times.

3.4.2. Fishing up marine food web in pre-colonial times?

Top marine predators (sharks and rays) were particularly targeted in southern Brazil from ca. 2200 years ago. Our null model approach based on the frequency of species in Babitonga Bay also revealed that pre-colonial fisheries predominantly captured species of relatively higher trophic position, in addition to larger body size and body mass, compared to modern fish catches and to local fish assemblages. The results thus suggest that past coastal environments supported more complex food webs than currently exist in the region. High trophic level and large-bodied species were possibly more abundant in the past, allowing for their periodic exploitation by Indigenous populations with relatively simple fishing technology for thousands of years [40].

Compared to pre-colonial assemblages, modern fish catches in Babitonga Bay have a smaller contribution of key functional groups such as top predators (large-bodied piscivores and macrocarnivores) and a higher abundance of lower trophic level and small-bodied species. Notably, it is only in modern catches that we see planktivores being exploited, as well as the increasing contribution of small-bodied species to catch composition. Although there were no significant differences in trophic levels across periods to suggest the occurrence of fishing down the marine food web (gradual decrease in the mean trophic level of fish in fisheries catches due to preferential removal of top predators, [149]), the identified pattern reveals a significant decrease in the encounter rate with large-bodied and high trophic level species in modern catches. The causes are possibly attributed to overfishing, bycatch and other detrimental impacts on top predators, even though the effects of taphonomic processes and recovery techniques on modelled outputs remain unclear.

3.4.3. Implications for marine biological conservation

Significantly, Brazil is one of the world's largest elasmobranch fishing industries, with over 90% of the catches in Brazil obtained by fisheries in Santa Catarina and Rio Grande do Sul [150]. Until the last three decades, southern Brazil's continental shelf supported a high diversity and large populations of coastal elasmobranchs that were exploited by subsistence, recreational and commercial fisheries [151–153]; however, many of these species are now considered endangered [154]. Other environmental stressors, such as industrial and urban activities [155], including the closure of the Linguado channel in the 1930's and its impact on migratory species [156, 157], have aggravated local ecological conditions.

Similarly, several species of demersal and pelagic sharks and rays reported in the archaeological record [86, 158–160], have seen reductions in population sizes over the last decades [161, 162], and are currently listed in the Vulnerable (VU), Endangered (EN), Critically Endangered (CR) and/or Regionally Extinct (RE) categories [68]. Long-living species of Sciaenidae and Ariidae are currently considered overexploited with risks of significant catch reduction in the near future, while others have collapsed [26, 163]. A large number of species reported in the archaeological record are currently categorised as Data Deficient (DD) in terms of their distribution and abundance [67, 68] (cartilaginous fish - *Rhinoptera bonasus, Carcharhinus altimus, Carcharhinus brachyurus, Isurus paucus, Lamna nasus*; bony fish - *Sardinella brasiliensis, Trachinotus cayennensis, Anisotremus surinamensis, Menticirrhus americanus, Menticirrhus littoralis,* and *Pagrus pagrus*). Given their socio-economic importance, notably for the food security and livelihood of local coastal communities (PAN Mangrove [69]), an understanding of species and population responses to long-term fishing pressure is critical for their sustainable management.

Coastal and ocean ecosystems have fuelled subsistence fisheries for thousands of years along the Brazilian coasts. As a result, hundreds of archaeological sites preserve information of past biological diversity of potential interest for fisheries management and conservation debates. Here, we have directed our analyses towards bony and cartilaginous fish, as they represent some of the most commonly occurring and abundant faunal remains in the archaeological sites under examination. Other organisms such as molluscs, echinoderms and crustaceans are also untapped sources of information on long-term human-coastal interaction in this region. Future studies that combine these proxies may enhance our understanding of past Indigenous coastal adaptation.

Our study revealed that demersal species contributed to most of the catches and thus played an important role in past Indigenous food security. Compared to present day fish catches, our study indicates that past encounter rates were possibly greater for species of high trophic level, large body size and body mass to enable their persistent capture and consumption, which invites us to rethink the antiquity of the human footprint on ocean ecosystems in the region. Some of these species are currently threatened by overfishing and habitat degradation, while others are surrounded by uncertainties regarding their modern distribution and abundance. The results presented here provide the most direct evidence of what species have been subjected to long-term fishing efforts, and offer benchmarks of species relative abundances and distributions prior to fish commoditization in the Southwestern Atlantic Ocean.

3.5. Supplementary material

Available on https://doi.org/10.1371/journal.pone.0285951:

S1 Table. Archaeofauna references.
S2 Table. Archaeological sites data.
S3 Table. Ichthyo-archaeofauna qualitative data.
S4 Table. Ichthyo-archaeofauna quantitative data.
S5 Table. Radiocarbon chronology of archaeological sites.
S6 Table. References for modelling fish traits across time periods in Babitonga Bay.
S7 Table. Modelled fish traits across time periods in Babitonga Bay. Absence and presence of fish for time periods: 4500–1150 cal BP (Sambaqui), 1050–600 cal BP (Taquara-Itararé), and AD 1994–2015 (modern).
S8 Table. Modelled fish traits across time periods in Babitonga Bay. Absence and presence of fish for time periods: 4500–1150 cal BP (Sambaqui), 1050–600 cal BP (Taquara-Itararé), and AD 1994–2015 (modern). Data from Projeto de Monitoramento da Atividade Pesqueira em Santa Catarina (PMAP/SC).
S9 Text. R script for modelling fish traits across time periods in Babitonga Bay.

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CHAPTER 4

The Onset of Deep-Water Fishing in Southern Brazil

This chapter corresponds to the published book chapter:
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4.1. Introduction

Humans have taken advantage of the biological diversity and other ecosystem services of the Brazilian coast for at least 6000 years (Toso et al., 2021). Early evidence of marine fishing along the Brazilian coast for subsistence and ritual practices is documented mainly in the form of shell mounds, locally known as sambaquis, and shallow archaeological sites with abundant faunal remains (Prous, 1992; Gaspar et al., 2008). Sambaquis are the most visible and well-known coastal sites, constructed through various cultural activities resulting in the vertical accumulation of faunal remains together with complex sedimentary matrices, numerous human burials, and stone, bone and plant artefacts (Lima, 2000; Villagran et al., 2011; Wagner et al., 2011; Colonese et al., 2014; Fossile et al., 2019). These sites constitute a cultural heritage of national and international interest and expand our understanding of pre-colonial Indigenous interaction with, and transformation of, coastal environments.

Faunal remains (Klokler, 2014, 2016; Fossile et al., 2019) and stable isotope (Toso et al., 2021; Bastos et al., 2022) analysis indicate that aquatic organisms, and notably fish, were the primary source of dietary proteins to pre-colonial Indigenous populations. Beyond their nutritional value, fish and shellfish also played a role in the symbolic and ritual spheres (Prous, 2006; Gaspar et al., 2008; Klokler, 2014), as alluded to by the production of a very particular class of stone (zooliths) and bone (zoosteos) artefacts representing a wide variety of terrestrial and aquatic animals (Milheira, 2014; Prous, 2018), and sometimes associated with human burials (Garcia, 2018). Fish were also a common item in funerary rituals, again reinforcing their relevance in the social fabric and long-term identity of these communities (Klokler, 2014, 2016; Fossile et al., 2019). Some regional variability can be observed in the funerary record. For example, the zooarchaeological data from Babitonga Bay (Santa Catarina state) indicate that most of the catches used in funerary rituals were medium-high trophic level species (Fossile et al., 2019, 2020), which contrasts with the view that lower trophic level species were preferentially used in these ceremonial activities (Klokler, 2014, 2016).

Recently, Brazilian archaeologists have started to explore the untapped potential of sambaquis and other coastal sites as archives of biological diversity, species abundance and distribution prior to European contact (Mendes et al., 2018; Fossile et al., 2019, 2020). This is of particular significance in biodiversity hotspots, which are regions undergoing exceptional loss of habitats and biodiversity (Myers et al., 2000), such as the Atlantic Forest of Brazil. In fact, it is becoming increasingly clear that environmental issues can only be effectively addressed if anthropogenic and natural drivers of change are understood from a historical perspective (Jackson, 2001, 2010; Roberts, 2003). The lack of such long-term view can cause misconceptions about the extent and rate of ecosystem alterations (Soga & Gaston, 2018). Within this broad conceptual framework, faunal remains become valuable sources of ecological baselines (Erlandson et al., 2009; Erlandson & Rick, 2010; Braje et al., 2017), and when associated with archaeological artefacts such as fishing and hunting gear, they enable the exploration of the origin and changing nature of historical anthropogenic footprints on past ecosystems (Erlandson et al., 2009; Bettinger, 2015).

Babitonga Bay, located on the northeast coast of the state of Santa Catarina, has over 200 archaeological sites, hosting the largest concentration of sambaquis on the Brazilian coast (DeBlasis et al., 1998; Fish et al., 2000; Lopes et al., 2016; Bandeira et al., 2018). The region holds a prominent position in studies regarding early coastal adaptations in eastern South America (Fig. 4.1). Independent lines of evidence point to fundamental changes in fishing strategies from ca. 2000 cal BP in Babitonga Bay and adjacent coastal areas. Firstly, studies involving bulk collagen stable isotope analysis of human remains show an increase in consumption of high trophic level marine organisms from ca. 2000 cal BP, notably in human individuals associated with Taquara-Itararé ceramics (Toso et al., 2021). Secondly, single-piece baited fishing hooks appear in numerous sites containing ceramic artefacts of the TaquaraItararé tradition (Tiburtius & Bigarella, 1953; Bryan, 1993; Schmitz et al., 1993). Interestingly, the extent to which the emergence and/or spread of new fishing technology allowed past coastal societies to pursue new marine resources remains a matter of debate. For example, the relation between baited fishing hooks and species of high trophic level in the region has never been explored.

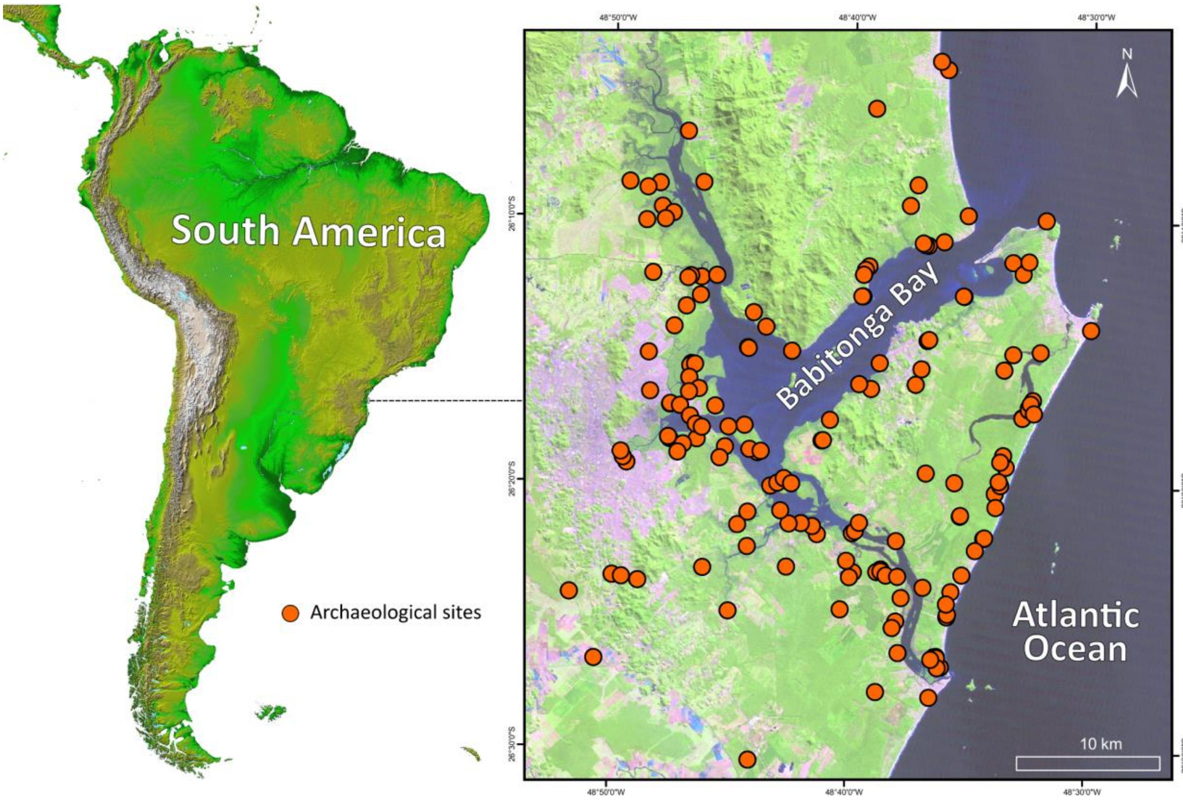

Fig. 4.1 Distribution of pre-Columbian archaeological sites in Babitonga Bay, Santa Catarina, Brazil.

Here, we address some of these enquiries by reviewing the evidence of portable fishing gear and faunal remains in Babitonga Bay from the Middle to the Late Holocene. Our review of the literature shows an apparent association between fishing technology and marine fish catch composition in Babitonga Bay. The results expand our knowledge about marine resource acquisition by Indigenous populations that inhabited the southern coast of Brazil before European contact, while reinforcing the hypothesis that from ca. 2000 years ago Indigenous groups were “fishing up the food web”, and exploiting deeper marine habitats of the southwestern Atlantic Ocean.

4.2. The Study Area: Babitonga Bay

Pre-Columbian occupations in Babitonga Bay are dated between ca. 6600 and 400 cal BP, with most of the sites formed between ca. 5500 and 2200 cal BP (Toso et al., 2021). These groups depended on coastal systems affected by variations in sea level and coastal morphology (Martin et al., 1988; Vieira, 2015; Sá, 2017) occurring since the Middle Holocene, which are thought to have affected resource procurement strategies and settlement patterns (Toso et al., 2021). During the Holocene Climate Optimum (ca. 5500 BP) the sea level of the southern Brazilian coast was ca. 3 m above the current level (Angulo et al., 2006; Toniolo et al., 2020). During its regression towards modern values, ecosystems such as mangroves and coastal lagoons were formed and/or expanded, likely affecting the distribution of coastal and estuarine fauna (Angulo & Müller, 1990; Angulo et al., 2009). This time interval coincides with an increase in the number of archaeological sites, suggesting a period of greater human population density that lasted until 2200 years ago (Toso et al., 2021), after which shell mound formation was minimal and many sites were abandoned. It is possible that pre-colonial population growth at this time suddenly exceeded environmental carrying capacity, forcing major socio-ecological reorganisations (Lima, 2000; Toso et al., 2021). From ca. 1200 years ago several sambaquis were occupied by groups producing, or using through exchange/adoption, ceramic artefacts attributed to the Taquara-Itararé tradition (also defined as Proto-Jê) of the Brazilian highlands. The spread of ceramics to the coast is possibly associated with the demographic increase of Proto-Jê groups in the southern Brazilian highlands (Robinson et al., 2018) and the decline of shell mound cultures on the coast (Toso et al., 2021). Groups using ceramic artefacts attributed to the Taquara-Itararé tradition also produced shallow sites with abundant faunal remains (Toso et al., 2021; Gilson & Lessa, 2021b) and human burials (Lessa, 2006)

4.3. Regional Changes in Fishing Technology

Although few sites were systematically excavated in Babitonga Bay, a total of 781 artefacts potentially associated with fishing have been recovered from Middle and Late Holocene archaeological contexts. These included projectile points (n = 589, 75.4%), single-piece baited fish hooks (n = 104, 13.3%), fishing net weights (n = 88, 11.3%) and cordage made of plant fibres (Tiburtius et al., 1951, 1954; Tiburtius & Bigarella, 1953; Beck, 1972, 2007; Goulart, 1980; Fossari, 1984; Bryan, 1993; Afonso & DeBlasis, 1994; Tiburtius, 1996; Bandeira, 2004; Peixe et al., 2007; Bandeira et al., 2009; Sá, 2015) (Fig. 4.2a–d). Arguably, some of these artefacts may not have been exclusively used for fishing. Projectile points could have been used for hunting and/or in warfare (Tiburtius & Bigarella, 1953; Fossari, 1984), while cordage could have been employed in a range of activities (Ribeiro, 1986; Gaspar, 1998; Peixe et al., 2007;

Bandeira et al., 2009). However, their close association with abundant fish remains suggests a strong link between these portable technologies and fishing practices.

Fishing artefacts were documented in eight sites. Of these, projectile points were recovered in all sites with the exception of Espinheiros II; fish hooks were found mainly in sites near the coast (Forte Marechal Luz, Enseada I, Bupeva II, and Rio Pinheiros). An exception is the recovery of dozens of single-piece fish hooks from Itacoara, located ca. 30 km from the current coastline, but still at close distance to the estuary and small rivers. Net weights were recovered from sites in the inner part of the bay (Morro do Ouro and Itacoara) (Fig. 4.3a).

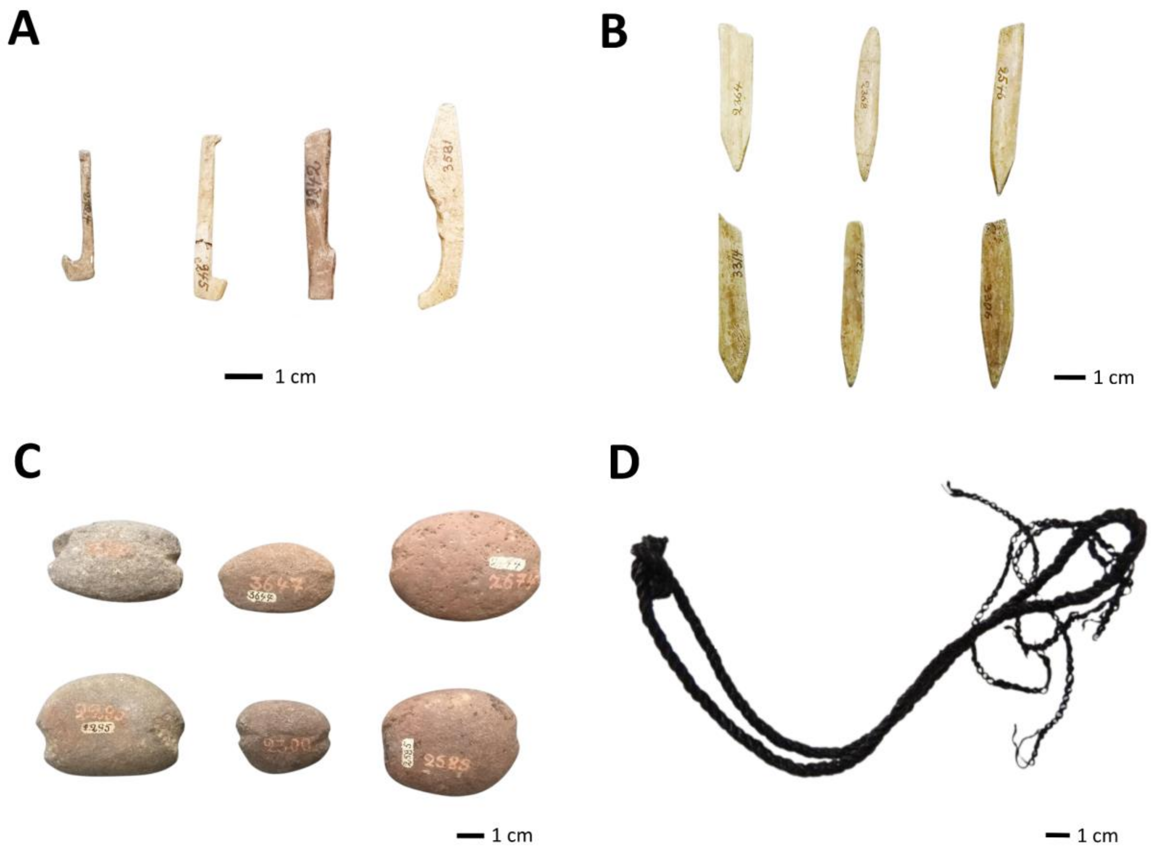

Fig. 4.2. Artefacts recovered in sambaquis from Babitonga Bay, - Museu Arqueológico de Sambaqui de Joinville (MASJ) collection. (a) Single-piece baited fish hooks from Itacoara; (b) Projectile points from various sites; (c) Net weights from various sites; (d) Cordage (Araceae – Philodendron sp.) from Sambaqui Cubatão I. Cordages are exceptionally well preserved in Cubatão I and Espinheiros II due to anaerobic conditions. (a, b and c were adapted from Ferreira et al. (2019), and d by the authors).

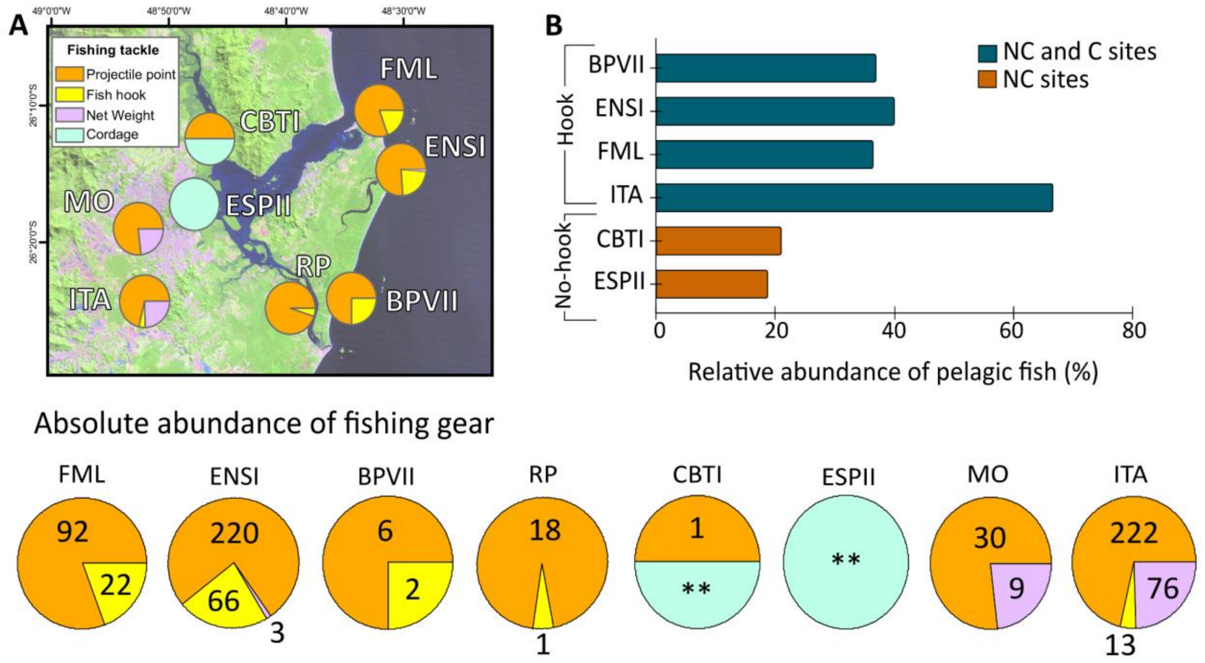

Fig. 4.3. (a) Distribution and relative abundance of fishing technology; (b) Relative abundance of pelagic fish according to the presence and absence of single-piece baited fish hooks in non-ceramic (NC) and ceramic (C) archaeological sites. MO and RP are not included as they lack systematic faunal analysis. Quantitative data is not available for cordage (**). Abbreviation of sites: RP Rio Pinheiros, MO Morro do Ouro, FML Forte Marechal Luz, ENSI Enseada I, CBTI Cubatão I, ESPII Espinheiros II, BPVII Bupeva II, ITA Itacoara

Significantly, 97% of single-piece baited fish hooks (n = 93) and 86% of projectile points (n = 295) were recovered from sites with Taquara-Itararé ceramics (Enseada I, Itacoara, and Forte Marechal Luz), in deposits dated between 1390 and 620 BP (Table 9.1). Using faunal data from Fossile et al. (2019, 2020) from 110 archaeological sites in Babitonga Bay, we derived that high trophic level species (Trophic Level value ≥4.0), including *Trichiurus lepturus* (largehead hairtail), *Lagocephalus laevigatus* (smooth puffer) and *Carcharias taurus* (sand tiger shark), were relatively more abundant in ceramic sites with fishing hooks (91% of NISP), compared to non-ceramic sites with no fishing hooks (44% of NISP). Similarly, pelagic species (e.g. *Galeocerdo cuvier* (tiger shark), *Sphyrna* sp. (hammerhead sharks), *Trichiurus lepturus* (largehead hairtail), *Pomatomus saltatrix* (bluefish) and *Lagocephalus laevigatus* (smooth puffer)) were relatively more abundant in sites containing ceramic artefacts and fishing hooks than in non-ceramic sites (Fig. 4.3b).

At Bupeva II, elasmobranchs (Rajiformes (rays), *Carcharhinus isodon* (finetooth shark), *Galeocerdo cuvier* (tiger shark), *Carcharodon carcharias* (great white shark), *Isurus oxyrinchus* (shortfin mako), *Carcharias taurus* (sand tiger shark), and *Sphyrna* sp. (hammerhead sharks)) represented 27% of the fish remains in nonceramic contexts, while in ceramic deposits it rose to 42% (Bandeira, 2004). At Enseada I, elasmobranchs (Rajiformes (rays), *Galeocerdo cuvier* (tiger shark), *Prionace glauca* (blue shark), *Carcharodon carcharias* (great white shark), *Carcharias taurus* (sand tiger shark), and *Sphyrna* sp. (hammerhead sharks)) contributed to 1.6% and 3% in non-ceramic and ceramic contexts, respectively (Bandeira, 2004). At Itacoara, elasmobranchs are found only in the ceramic context, representing 14% of the remains (Bandeira, 2004). At Forte Marechal Luz, the remains of elasmobranchs accounted for 38% and 35% of fish remains in nonceramic and ceramic contexts, respectively (Bryan & Gruhn, 1993). It is worth noting though, that the later non-ceramic phases of Forte Marechal Luz have radiocarbon dates comparable with the earliest sites with Taquara-Itararé ceramics in this region (e.g. Itacoara, Enseada I; Table 4.1).

Table 4.1. Conventional radiocarbon dating of pre-Columbian archaeological sites with fishing artefacts in Babitonga Bay.

Archaeological site	**Key cultural feature**	**Lab. code**	**Material**	**Conventional date (BP)**
Rio Pinheiros II	Ceramic	Beta_443872	Bone (unidentified species)	860 ± 30
Rio Pinheiros II	Non-ceramic (sambaqui)		Marine Shell	3850 ± 140
Rio Pinheiros II	Non-ceramic (sambaqui)		Marine Shell	4580 ± 120
Morro do Ouro	Non-ceramic (sambaqui)		Human bone collagen	3870 ± 40
Morro do Ouro	Non-ceramic (sambaqui)	AA_104770	Human bone collagen	3938 ± 55
Morro do Ouro	Non-ceramic (sambaqui)	Beta_93152	Human bone collagen	4030 ± 40
Morro do Ouro	Non-ceramic (sambaqui)	AA_104768	Human bone collagen	4086 ± 42
Morro do Ouro	Non-ceramic (sambaqui)	Beta_444034	Human bone collagen	4200 ± 30
Morro do Ouro	Non-ceramic (sambaqui)		Human bone collagen	4300 ± 50
Morro do Ouro	Non-ceramic (sambaqui)	AA_104767	Human tooth	4425 ± 39
Forte Marechal Luz	Ceramic	M_1203	Charcoal	620 ± 100
Forte Marechal Luz	Ceramic	M_1200	Charcoal	640 ± 100

Forte Marechal Luz	Ceramic	M_1202	Charcoal	880 ± 100
Forte Marechal Luz	Non-ceramic (sambaqui)	M_1205	Charcoal	850 ± 100
Forte Marechal Luz	Non-ceramic (sambaqui)	M_1204	Seed	1100 ± 100
Forte Marechal Luz	Non-ceramic (sambaqui)	M_1206	Charcoal	1440 ± 110
Forte Marechal Luz	Non-ceramic (sambaqui)		Human bone collagen	1550 ± 40
Forte Marechal Luz	Non-ceramic (sambaqui)	M_1207	Sea mammal bone collagen	2060 ± 120
Forte Marechal Luz	Non-ceramic (sambaqui)	M_1208	Charcoal	3660 ± 130
Forte Marechal Luz	Non-ceramic (sambaqui)		Sea mammal bone collagen	4290 ± 130
Enseada I	Ceramic		Human bone collagen	1390 ± 40
Enseada I	Non-ceramic (sambaqui)		Human bone collagen	3920 ± 40
Cubatão I	Non-ceramic (sambaqui)	Beta_268526	Charcoal	2250 ± 40
Cubatão I	Non-ceramic (sambaqui)	Beta_268518	Human bone collagen	2430 ± 40
Cubatão I	Non-ceramic (sambaqui)	Beta_268523	Human bone collagen	2460 ± 40
Cubatão I	Non-ceramic (sambaqui)	Beta_268525	Human bone collagen	2460 ± 40

Cubatão I	Non-ceramic (sambaqui)	Ly_ 4524	Human bone collagen	2460 ± 30
Cubatão I	Non-ceramic (sambaqui)	Ly_4527	Human bone collagen	2495 ± 30
Cubatão I	Non-ceramic (sambaqui)	Beta_268524	Human bone collagen	2510 ± 40
Cubatão I	Non-ceramic (sambaqui)	Beta_259519	Human bone collagen	2520 ± 40
Cubatão I	Non-ceramic (sambaqui)	Ly_4528	Human bone collagen	2520 ± 40
Cubatão I	Non-ceramic (sambaqui)	Beta_259823	Marine shell	2560 ± 40
Cubatão I	Non-ceramic (sambaqui)	Ly_4526	Human bone collagen	2620 ± 30
Cubatão I	Non-ceramic (sambaqui)	Beta_259821	Human bone collagen	2630 ± 40
Cubatão I	Non-ceramic (sambaqui)	Beta_259824	Marine Shell	2660 ± 40
Cubatão I	Non-ceramic (sambaqui)	Beta_259820	Human bone collagen	2670 ± 40
Cubatão I	Non-ceramic (sambaqui)	Beta_259827	Charcoal	2890 ± 70
Cubatão I	Non-ceramic (sambaqui)	Beta_259825	Charcoal	2970 ± 60
Cubatão I	Non-ceramic (sambaqui)	Ly_4525	Charcoal	2975 ± 30
Cubatão I	Non-ceramic (sambaqui)	Beta_259829	Charcoal	3040 ± 60

Cubatão I	Non-ceramic (sambaqui)	Beta_259826	Charcoal	3110 ± 70
Cubatão I	Non-ceramic (sambaqui)	Beta_259828	Marine shell	3480 ± 60
Espinheiros II	Non-ceramic (sambaqui)	Gif_9415	Charcoal	1160 ± 45
Espinheiros II	Non-ceramic (sambaqui)		Charcoal	1270 ± 60
Espinheiros II	Non-ceramic (sambaqui)	Gif_9416	Charcoal	2970 ± 60
Bupeva II	Non-ceramic (sambaqui)	Kia_22262	Sea mammal bone collagen	2325 ± 25
Itacoara	Ceramic		Human bone collagen	1250 ± 30
Itacoara	Non-ceramic (sambaqui)	Kia_21796	Wood and burned seed	1570 ± 20

Results from Babitonga Bay are broadly supported by zooarchaeological studies from adjacent coastal areas. Remains of top predators such as fur seals (*Arctocephalus australis* (South American fur seal)), dolphins (*Delphinus delphis* (short-beaked saddleback dolphin), *Tursiops truncatus* (bottlenose dolphin)) and sharks (*Carcharias taurus* (sand tiger shark), *Carcharodon carcharias* (great white shark), *Galeocerdo cuvier* (tiger shark)), among others, were found in archaeological deposits containing Taquara-Itararé ceramics at Praia das Laranjeiras II (Camboriú), which also preserved remains of single-piece baited fish hooks (Schmitz et al., 1993). At the Taquara-Itararé site of Rio do Meio (Florianópolis), a large variety of fish, including a large diversity of sharks (*Carcharhinus plumbeus* (sandbar shark), *C. obscurus* (dusky shark), *C. leucas* (bull shark), *C. brachyurus* (copper shark), *Rhizoprionodon* sp. (sharpnose sharks), *Carcharodon carcharias* (great white shark), etc.) were exploited by groups using single-piece baited fish hooks (Gilson & Lessa, 2020, 2021a, b).

The observed correlations between the capture of pelagic and high trophic level species and the presence of fishing hooks and spears has been documented in other archaeological records in the Americas. Erlandson et al. (2009) have shown a substantial increase of fish bones in California’s northern Channel Islands after the appearance of curved, single-piece fish hooks from about 2500 years ago. Remains of pelagic fishing including large species such as tunas, swordfish, and sharks increased notably after 1500 years ago. This trend resembles the one documented in Babitonga Bay after the introduction of single-piece baited fish hooks.

Single-piece baited fish hooks and spears are particularly effective for catching larger predators and pelagic species (Misund et al., 2002; He et al., 2021). Moreover, fish hooks can be effectively employed in deep water and areas with low visibility (Toso et al., 2021). In support of the arguments presented above is the presence of Taquara-Itararé ceramic artefacts in an archaeological site on Arvoredo Island, an oceanic island located more than 10 km from the southern Brazilian coast (Rohr, 1984; Segal et al., 2017). Moreover, stable carbon and particularly the nitrogen isotopic values of bone collagen of humans found at several coastal sites containing Taquara-Itararé ceramic artefacts broadly support the idea of “fishing up the marine food web” (Toso et al., 2021). The results presented here thus support the growing evidence that offshore fishing was practised by Late Holocene Indigenous groups who used Taquara-Itararé ceramics on the southern coast of Brazil.

4.4. Implications for Biological Conservation

Tracking the origin and changing nature of offshore fishing has implications beyond the boundaries of archaeology (Erlandson et al., 2009; Erlandson & Rick, 2010; Braje et al., 2017). Data from Fossile et al. (2020) suggest that top marine predators must have been abundant in the region in the past to permit their recurrent exploitation (high encounter rate) through relatively simple fishing technology. For example, species with trophic levels ranging between 3.5 and 4.5, including bony (e.g. *Chaetodipterus faber* (Atlantic spadefish), *Trichiurus lepturus* (largehead hairtail)) and cartilaginous fish (e.g. *Carcharias taurus* (sand tiger shark)) were relatively abundant and widespread in the archaeological record. Cartilaginous fish (n = 14 taxa), such as *Carcharias taurus* (sand tiger shark), rays (Batoidea), and *Carcharodon carcharias* (great white shark) occurred in ca. 60% of the sites with fish remains in Babitonga Bay (n = 7). Given the ecological and social importance of these species – some as key functional players in the ecosystem and others as sources of food and livelihood to local coastal communities – an understanding of species and population responses to long-term fishing pressure is critical for their modern-day sustainable management.

Several species documented by Fossile et al. (2020), and revised in this study, are currently threatened, falling into the Critically Endangered (CR), Endangered (EN), or Vulnerable (VU) categories of the International Union for Conservation of Nature – IUCN (IUCN, 2022) and the Instituto Chico Mendes de Conservação da Biodiversidade – ICMBio (Brasil, 2018a). These include *Pomatomus saltatrix* (bluefish), *Cynoscion acoupa* (acoupa weakfish), *Alopias vulpinus* (common thresher shark), *Isurus oxyrinchus* (shortfin mako), *Hyporthodus niveatus* (snowy grouper), *Pogonias courbina* (black drum), *Carcharias taurus* (sand tiger shark), *Carcharodon carcharias* (great white shark) and *Genidens barbus* (white sea catfish). Moreover, *Carcharhinus isodon* (finetooth shark), found at the sites of Itacoara and Bupeva II, is considered regionally extinct (RE) on the Brazilian coast (Brasil, 2018b). Other species lacking sufficient data (DD) for extinction risk assessment are also documented in the archaeological record, including for example, *Pagrus pagrus* (red porgy), *Menticirrhus* *americanus* (southern kingfish), *Gymnothorax ocellatus* (Caribbean ocellated moray), *Pomacanthus paru* (French angelfish), *Mugil liza* (blueback mullet) and *Anisotremus surinamensis* (black margate).

4.5. Final Considerations

The archaeological sites of Babitonga Bay provide unique insights into pre-colonial Indigenous knowledge, and trends in marine species composition and relative abundance in the Atlantic Forest coast of Brazil. The archaeological faunal record, although still deficient in chronological resolution and often affected by discrepancies in recovery techniques, show that pre-colonial indigenous groups intensified the capture of pelagic and high trophic level species from ca. 2000 years ago. Key to this process was the adoption of efficient and sophisticated fishing (baited hooks) and maritime (boats) technologies that allowed them to pursue resources offshore, marking the onset of deep-water fishing in the region. The archaeological faunal record also holds significant information on past species distribution and relative abundance, which can be used to track changes in ecosystem structure, composition and function through time. The information gained can potentially contribute to establishing more accurate reference baselines and aid in ambitious and more informed conservation initiatives.

4.6. References

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CHAPTER 5

Long-term perspective on fishing and mammal defaunation in the Atlantic Forest coast of Brazil using archaeological faunal remains

This chapter corresponds to the accepted article:
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5.1. Introduction

Tropical and subtropical regions of South America are facing significant environmental and ecological challenges which parallel the global trends resulting from the rapid economic expansion of recent decades (Bogoni et al., 2020; Steffen et al., 2015; Verba et al., 2020). Brazil's renowned biodiversity hotspots of the Amazon and the Atlantic Forest (Colombo & Joly, 2010; Rezende et al., 2018) are currently undergoing rapid biodiversity and population loss due to overexploitation and habitat degradation (Ceballos et al., 2017; de Lima et al., 2020; Galetti et al., 2015, 2017; Scarano & Ceotto, 2015; Verba et al., 2020). Recent studies suggest a staggering loss of over 60% of mammals in the Atlantic Forest (Bogoni et al., 2020); unfortunately, such figures are likely an underestimation if reference baselines can be extended to include Pre-colonial and historical periods.

Studies have shown that certain anthropogenic stressors responsible for impacting animal diversity and abundance in recent decades have been present for over a century. As early as the mid-18th century, intellectual elites in colonial Brazil were already expressing increasing concern regarding the adverse environmental impacts of colonial economies, especially deforestation (Pádua, 2000). Similarly, in his seminal work the Destruction of the Brazilian Atlantic Forest, Dean discussed the persistent human impact on plants and animals in extensive regions of the Atlantic Forest since, at least, the European colonisation (Dean, 1997). Others have shown that colonial and post-colonial fisheries were also capable of overexploiting local organisms, causing a noticeable decline in fish and coral populations (Fogliarini et al., 2022; Sandoval Gallardo et al., 2021). Our understanding of these historical processes has predominantly relied on administrative documents, letters and accounts of European travellers and naturalists who began visiting the region in the 16th century (da Rocha, 2022; Russell-Wood, 2001; Whitehead, 2012). While certain historical sources, such as newspapers and archives, provide valuable descriptions of local plants and animals, along with their broad societal significance (Herbst et al., 2023; Sandoval Gallardo et al., 2021), many written documents produced into the late 18th century lack specific details concerning the relative abundance, distribution, and extent to which several native animals were used (Pádua, 2000). Nevertheless, these studies reinforce the growing consensus that a comprehensive understanding of current biodiversity and environmental threats necessitates information that predates the anthropogenic impacts of the most recent decades (Jackson & Hobbs, 2009; McClenachan et al., 2012).

Archaeology emerges as a discipline with the potential to illuminate the past daily experiences of vulnerable groups and minorities, as well as their interactions with the surrounding environments (Funari, 1994; Symanski, 2009; Symanski & Zarankin, 2014). Currently, Historical Archaeology in Brazil remains heavily biassed towards the analysis of ceramic artefacts, shipwrecks, infrastructure, and housing and settlement patterns (Lima, 1993; Symanski, 2009; Symanski & Zarankin, 2014), while faunal remains have received only superficial attention (Nobre, 2004). Analysis of terrestrial mammal remains can provide insights into species composition, distribution and relative abundance, as well as their function (food sources) and perceived value (economic, symbolic, etc.) to past human societies, and species responses to anthropogenic activities (Barnosky et al., 2017; Lyman & Cannon, 2017; Stahl, 2008). This last point is particularly relevant in conservation debates due to well known effects of subsistence hunting on tropical forest composition, most notably through the removal of medium- and large-bodied terrestrial mammals with low population densities (Bogoni et al., 2020; Dirzo et al., 2014; Galetti et al., 2017; Peres, 2000). Yet, little is known about these processes in historical times, nor the extent to which they may have contributed to the increasing rates of defaunation in the Atlantic Forest in recent decades (Galetti et al., 2017).

To address this knowledge gap, we present the results of zooarchaeological analyses conducted on faunal remains from colonial (prior to 1822) and post-colonial archaeological sites located in Babitonga Bay, Santa Catarina state (southern Brazil) (Figure 5.1). The region preserves numerous historical archaeological sites spanning from the 18th to the 20th centuries (Bandeira & Alves, 2012), whose economies depended on manioc, rice and livestock production, along with hunting and fishing in forest and mangrove ecosystems (Saint-Hilaire, 1936). Of these sites, only 15 have been excavated to date, five of which presented faunal remains. Marine and terrestrial vertebrate remains from the archaeological sites of Morro Grande 1 (MG1) and Praia Grande Unidade 21 (PG-U21) were analysed herein using an integrated approach of conventional zooarchaeological (morphological traits) analysis and collagen peptide mass fingerprinting, known as Zooarchaeology by Mass Spectrometry (ZooMS). Both sites were extensively excavated and have the largest collection of faunal remains of all the historical sites. Changes in hunting strategies through time and their putative ecological impacts were studied by comparing the historical fauna with faunal data from Pre-colonial sites in the region (Enseada I, Bupeva II, Forte Marechal Luz, Itacoara, Ilha dos Espinheiros II and Cubatão I) and from contemporary traditional coastal communities in southern Brazil, known as Caiçaras. The overarching aim of this study was to improve our understanding of the ecological footprint of colonial and post-colonial societies, and provide a historical perspective to the ongoing debates on vertebrate defaunation in the Atlantic Forest. More specifically, we aimed to understand the socioeconomic importance of marine fish and native terrestrial mammals during the historical occupation in Babitonga Bay.

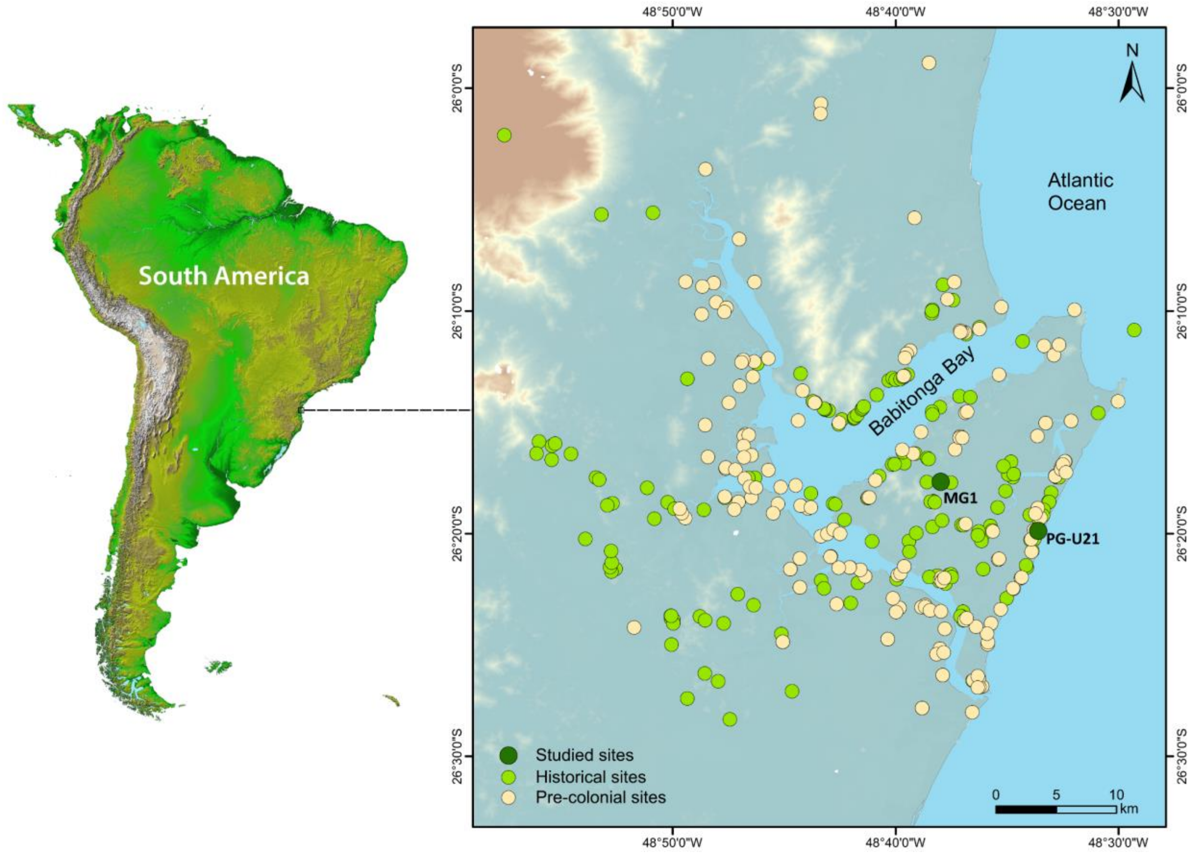

Figure 5.1. Location of Babitonga Bay in southern Brazil, including Pre-colonial and Historical sites in the region, and the two historical sites analysed herein, Praia Grande Unidade 21 (PG-U21) and Morro Grande 1 (MG1). Map generated on data publicly available from NASA/JPL-Caltech (adapted from https://www.jpl.nasa.gov/images/pia03388-south-america-shaded-relief-and-colored-height), Brazilian Agricultural Research Corporation - EMBRAPA (Embrapa, 2021),

Natural Earth (https://www.naturalearthdata.com/), Brazilian Institute of Geography and Statistics - IBGE (https://www.ibge.gov.br/geociencias/todos-os-produtos-geociencias.html) and National Institute for Space Research - INPE (Assis et al., 2019).

5.2. Methods

5.2.1. Archaeological contexts

MG1 and PG-U21 are situated within the municipality of São Francisco do Sul (Figure 5.1). Located ~10 km from the coast, MG1 holds historical significance as it is located in one of the earliest non-Indigenous colonial settlements in Babitonga Bay (Pereira, 2004). Written and oral historical records indicate that the region was primarily dedicated to cultivating manioc for flour production (Santos, 2004; Silva et al., 2001). Excavations in 2001 covering an area of 374m^2 found one homogeneous stratigraphic deposit with evidence of residential spaces, ceramic artefacts and coins dated to the 19th century, and faunal remains. On the other hand, PG-U21 is considered a coastal site located in Praia Grande which exhibits a clear association with fishing. Historical accounts describe fishing and fish processing (drying) in the area, along with manioc cultivation in more recent times (Alves & Oliveira, 2002). Archaeological excavations conducted in 2002 over an area of 166m^2 uncovered abundant faunal remains, ceramic artefacts dating to the 20th century, and other artefacts likely associated with residential activities (Figure 5.2). The stratigraphic sequence at the site encompassed six distinct layers (layers 1 to 6, with 1 being the most recent and 6 being the earliest). These layers form over time, one superimposed on the other as a result of human activities, natural processes, or a combination of both, allowing for the establishment of a chronological sequence of events and providing insight into the activities of the people who used the site.

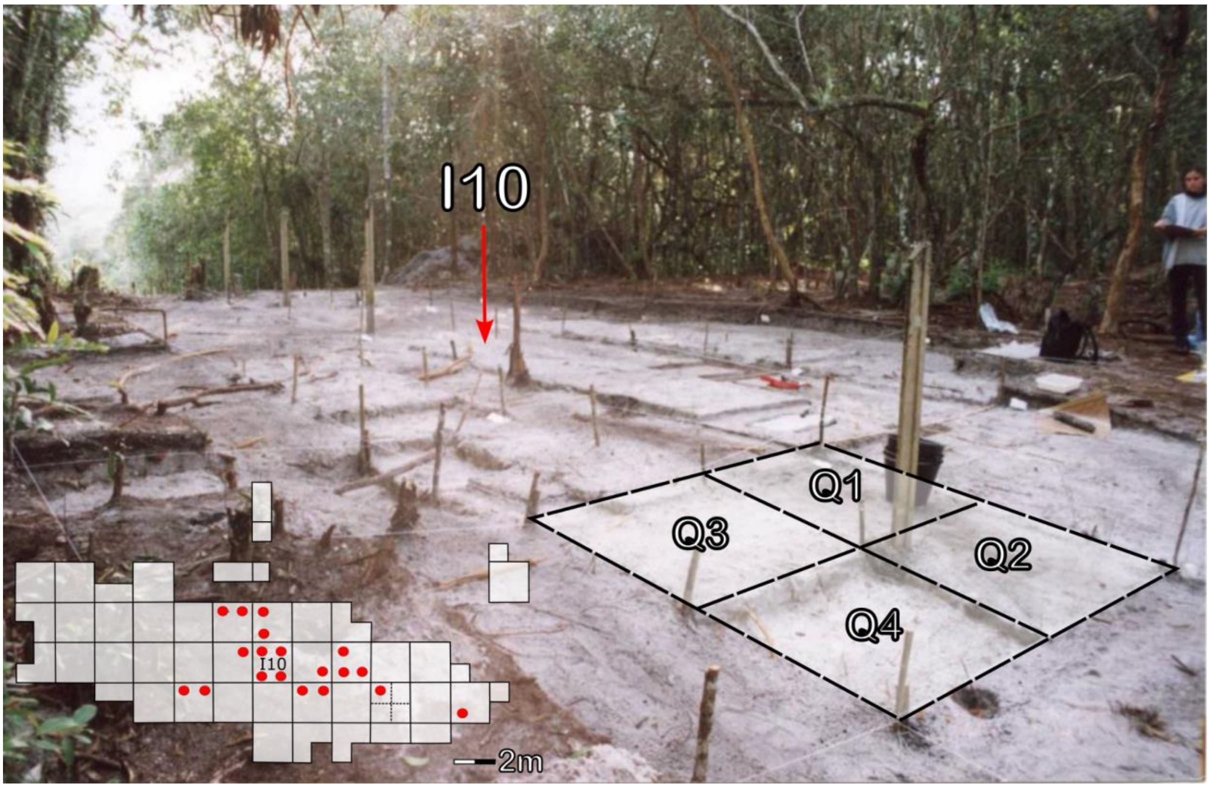

Figure 5.2. Overview of Praia Grande Unidade 21 (PG-U21) showing the excavation area (bottom left) and specific grid (I10) analysed in this study. Red points in the excavation area (bottom left) indicate the distribution of faunal remains at the site (Alves & Oliveira, 2002). The quadrants Q1, Q2, Q3 and Q4 have been depicted in grid H13 for reference to the excavation grid system used.

5.2.2. Sampling strategy and site chronologies

Analysed faunal remains from MG1 were recovered from 77 grids, corresponding to 15.4 m^3 of sediment, which was sieved using a 3 mm mesh size (Silva et al., 2001). Analysed faunal remains from PG-U21 instead derived from one grid (I10) located in the centre of the excavation, accounting for 1.66 m^3 of sediment, which was sieved using a 2.5 mm mesh size (Alves & Oliveira, 2002). Although only vertebrate remains were analysed from both sites, a significant number of marine mollusc shells (e.g. *Anomalocardia flexuosa*) were also recovered at PG-U21 (Alves, 2003; Alves & Oliveira, 2002) and are currently undergoing analysis.

In order to improve the chronological attributions of MG1 and PG-U21, bones of terrestrial mammals (n = 4) were selected for radiocarbon dating (AMS) at CEDAD, Università di Salento (Italy). Bones from MG1 (one deer and one cattle bone) were sampled from layer 1 (grids A12 [LTL22552] and C13 [LTL22553]). Bones from PG-U21 (one armadillo and one cattle bone) were sampled from layer 2 (LTL22550) and layer 3 (LTL22551) in grid I10. Conventional radiocarbon dates were calibrated using OxCal v. 4.4 (Ramsey, 2009), using the 100% atmospheric calibration curve for the southern hemisphere, SHCal20 (Hogg et al., 2020). Calibrated dates were rounded to 10 years.

5.2.3. Archaeological faunal identification

The vertebrate faunal remains were identified through side-by-side comparison with reference collections from the Museu Arqueológico de Sambaqui de Joinville (MASJ, Brazil), the Laboratório de Arqueologia e Patrimônio Arqueológico at the Universidade da Região de Joinville (LAPArq/Univille, Brazil) and the Laboratory of Archaeozoology at the Universitat Autònoma de Barcelona (Spain); along with specialised literature (Adams & Crabtree, 2012; France, 2009; McLelland, 1991; Sebben et al., 2019; Tercerie et al., 2022; Wensing, 2009). The scientific names followed the World Register of Marine Species (Horton et al., 2020) and the Animal Diversity Web (Myers et al., 2020). The abundance of species was represented by the Number of Identified Specimens (NISP), a quantitative unit frequently used in zooarchaeological studies (Grayson, 1984; Lyman, 2008a, 2018). The Number of Specimens (NSP), which represents the total of all analysed specimens (identified or unidentified), and the Number of Unidentified Specimens (NUSP) were also quantified. Fragments of the same specimen that could be refitted were counted as one. Species richness (SR) was calculated using the Minimum Level of Taxonomic Identification, considering only the minimum hierarchical level for a particular taxa. In order to account for variations in the excavation areas and in the volume of archaeological deposits between the sites, as well differences in the number of bones and taphonomic processes that may variably affect distinct taxonomic groups (Lyman, 2008b; Reitz & Wing, 2008), the NISP was standardised for the volume of sediment (NISP/m^3). This index provides an independent density measurement for each taxonomic class.

Fish remains were separated between postcranial (posterior to the first precaudal vertebrae) and cranial (neurocranium and viscerocranium) bones for skeletal frequency analysis, which provides insight into processing techniques (e.g. parts removed during fish processing for storage, trade, etc.) (Lyman, 1994; Zohar et al., 2001). Other taphonomical features such as fragmentation, heat exposure, and cut marks were also recorded (Costamagno et al., 2019; Egeland, 2003; Fernandez-Jalvo & Andrews, 2016; Yravedra, 2013). Remains that were slightly broken (e.g. vertebra without spinous and transverse processes) were considered whole.

5.2.4. Faunal identification using collagen peptide mass fingerprinting (ZooMS)

According to historical records both cattle (*Bos taurus*) and buffalo (*Bubalus* spp.), as well as peccary (Tayassuidae) and domestic pig (Suidae), were exploited in the region. Chickens (*Gallus gallus*) were also commonly exploited along with other native birds. The remains of these morphologically similar species are complex to set apart using conventional morphological analysis, requiring additional analytical approaches to achieve accurate identifications. As such, the remains of 57 mammals and birds from MG1 (n = 30) and PG-U21 (n = 27) were selected for analysis with Zooarchaeology by Mass Spectrometry (ZooMS) to confirm the morphological taxonomic identification. ZooMS is a method of peptide mass fingerprinting that takes advantage of interspecies differences in the amino acid sequences of collagen to make taxonomic identifications (Buckley et al., 2009; Welker et al., 2015).

Bone samples, ranging from 10-30 mg, were sampled from each of the 57 remains and put in 250 µl of 0.6M hydrochloric acid (HCl) at 4°C to demineralize. The acid was then removed and the samples were rinsed once in 0.1 M sodium hydroxide (NaOH) to remove humic contaminants, followed by three washes with 200 µl of 50mM ammonium bicarbonate buffer (AmBic, NH4HCO3, pH 8). After the final rinse, 200 µl of AmBic was added and the samples were gelatinized for 1 hour at 65°C. 125 µl of each sample was transferred to a 96 well plate and the samples were digested overnight at 37°C with the addition of 0.4 µg of trypsin. Samples were acidified to 0.1% trifluoroacetic acid (TFA) to stop the trypsin, then purified using C18 resin ZipTip pipette tips (Pierce™ Thermo Scientific) via an Opentrons OT-2 pipetting robot using an in-house Python script. The in-house Python script used the Opentrons Gen 1 300 µL multichannel pipette, three 96 well plates and a 12 reservoir plate in order to purify peptides using the C18 Zip Tips. The dimensions of the C18 Zip Tips and accompanying tiprack were added to the robot as a custom labware definition to allow the robot to recognise and use the C18 Zip Tips. 1 µl of the extracted peptides was spotted onto a Bruker target plate and combined with 1 µl of matrix solution (α-cyano-hydroxycinnamic acid) then analysed in triplicate along with calibration standards on a Bruker ultrafleXtreme MALDI TOF/TOF mass spectrometer at the University of York. Spectra were averaged and analysed using mMass software (Strohalm et al., 2008) and species were determined based on published m/z markers (Buckley et al., 2009, 2014, 2017; Eda et al., 2020, 2023; Kirby et al., 2013; Welker et al., 2015) and in some cases using known reference material (unpublished data, see SM4 Table 3).

5.2.5. Comparing native terrestrial mammal functional traits across time periods

Differences in mean body weight classes (body mass), population density, and trophic groups of targeted non-volant terrestrial mammal species were compared across three time periods: Pre-colonial (4500–1150 cal BP), Historical (1750-1950 AD) and Contemporary (1998-2000 AD). These differences were also compared with the current composition of native terrestrial mammals in the region, against which we assessed the degree of selection in past hunting activities. Pre-colonial assemblages (4500–1150 cal BP) were compiled from archaeological sites located in Babitonga Bay: Enseada I, Bupeva II, Forte Marechal Luz, Itacoara, Ilha dos Espinheiros II, and Cubatão I (Bandeira, 1992, 2004; Benz, 2000; Bryan, 1993; Fossile et al., 2019). Historical assemblages (1750-1950 AD) included species recovered from MG1 and PG-U21, both located in Babitonga Bay. We also compared the Pre-colonial and Historical faunal assemblages with hunted animals among three Caiçara communities on the southeastern coast of Brazil (~150 km from Babitonga Bay) between 1998 and 2000 (Hanazaki et al., 2009). This Contemporary assemblage (1998-2000 AD) derived from interviews with Caiçara groups who descend from Indigenous, African and European populations, and thus may serve as a modern analogue for assessing patterns of animal exploitation in historical times (Begossi, 2006; Begossi & Richerson, 1993; Hanazaki & Begossi, 2003). Present day Caiçara communities value native terrestrial mammals such as deer (*Mazama* spp.), lowland paca (*Cuniculus paca*), agouti (*Dasyprocta azarae*), armadillo (*Dasypus novemcinctus*), opossum (*Didelphis aurita*), capybara (*Hydrochoerus hydrochaeris*), tamandua (*Tamandua tetradactyla*), and peccary (*Pecari/Dicotyles tajacu*) as dietary sources (Begossi & Richerson, 1993;

Hanazaki et al., 2009). Certain species, including deer, capybara, peccary and also ocelot (*Leopardus pardalis*), are also exploited for medicinal purposes (Hanazaki et al., 2009). Data on native non-volant terrestrial mammals was obtained from surveys performed in Babitonga Bay between 1909 and 2016 (Carvalho-Junior, 2022; Cherem et al., 2004; Dornelles et al., 2017; Ima, 2009) and complemented by the aforementioned archaeological data, resulting in a total of 53 species.

Mean body weights were determined for each species based on data from the literature (e.g. Myers et al., 2020), and categorised into small (<1 kg), medium (1-15 kg), and large mammals (>15 kg) following Galetti et al. (2017) and Vynne et al. (2022). Population density (individuals/km^2) and trophic groups were compiled from Robinson & Refford (1986) and, when required, complemented with information from other literature (Duarte et al., 2012; Faria-Corrêa, 2004; Galante & Cassini, 1994; Myers et al., 2020; Reis et al., 2006; Tomas & Desbiez, 2004). Density data was obtained for a total of 46 species. The average density was calculated following Galetti et al. (2017), using game species found in each analysed period.

Species were divided into trophic categories of Carnivore, Myrmecophagy, Insectivore-omnivore, Frugivore-omnivore, Frugivore-granivore, Frugivore-herbivore, Herbivore-browser, Folivore-herbivore, and Herbivore-grazer (Reis et al., 2006; Robinson & Redford, 1986). The statistical significance in the proportions of analysed traits across time periods was tested using a two-tailed Binomial test ($p < 0.05$) in RStudio Software (RStudio Team, 2020).

5.3. Results

5.3.1. Site chronologies

Terrestrial mammal samples from MG1 and PG-U21 provided calendar ages ranging from 1510-1800 to 1690-1950 AD (68.4% confidence interval), with medians ranging from 1650 to 1850 AD (Table 5.1, Figure 5.3A). Overall, the calibrated radiocarbon dates were older than the associated material culture from both sites (coins, tin cans and ceramic artefacts), which have been assigned to the 19th and 20th centuries (Alves & Oliveira, 2002; Silva et al., 2001). For example, fragments of English pottery produced by J&G Meakin Ltd. with a distinguishing “SOL” stamp, were found in layers 1 and 2 of PG-U21 (Figure 5.3B). This particular make of pottery appears to have been produced from the 1910's, thus offering a terminus post quem for the uppermost part of the site. Similarly, diagnostic pottery remains and coins found at MG1 indicate that some occupations took place from 1821 AD. Although it is possible that the radiocarbon dates detected earlier occupations (i.e. 1700 AD), their large probabilistic distributions combined with the plateau-reversals in the 14C calibration curve around 1700-1800 AD and 1820-1920 AD (Manning et al., 2018; Taylor et al., 1996), complicate the radiocarbon interpretation and impinge upon our ability to precisely constrain the site chronologies (Figure 5.3A). The combination of radiocarbon and relative material-based chronologies, therefore, led us to assign a parsimonious age for both sites of 1750-1950 AD.

Site	CEDAD Lab code	Material	Context	^{14}C yr. BP	^{14}C yr. cal AD (2σ)	Median cal AD
PG-U21	LTL22550	Bovidae	Grid I10-Q1, Layer 2	281 ± 45	1510 – 1800	1660
PG-U21	LTL22551	Dasypodidae	Grid I10-Q3, Layer 3	139 ± 40	1690 - 1950	1850
MG1	LTL22552	Cervidae	Grid A12, Layer 1	282 ± 40	1510 - 1800	1650
MG1	LTL22553	Bovidae	Grid C13, Layer 1	175 ± 40	1670 - beyond calibration range	1810

Table 5.1. Radiocarbon chronology and contextual information of archaeological bone samples.

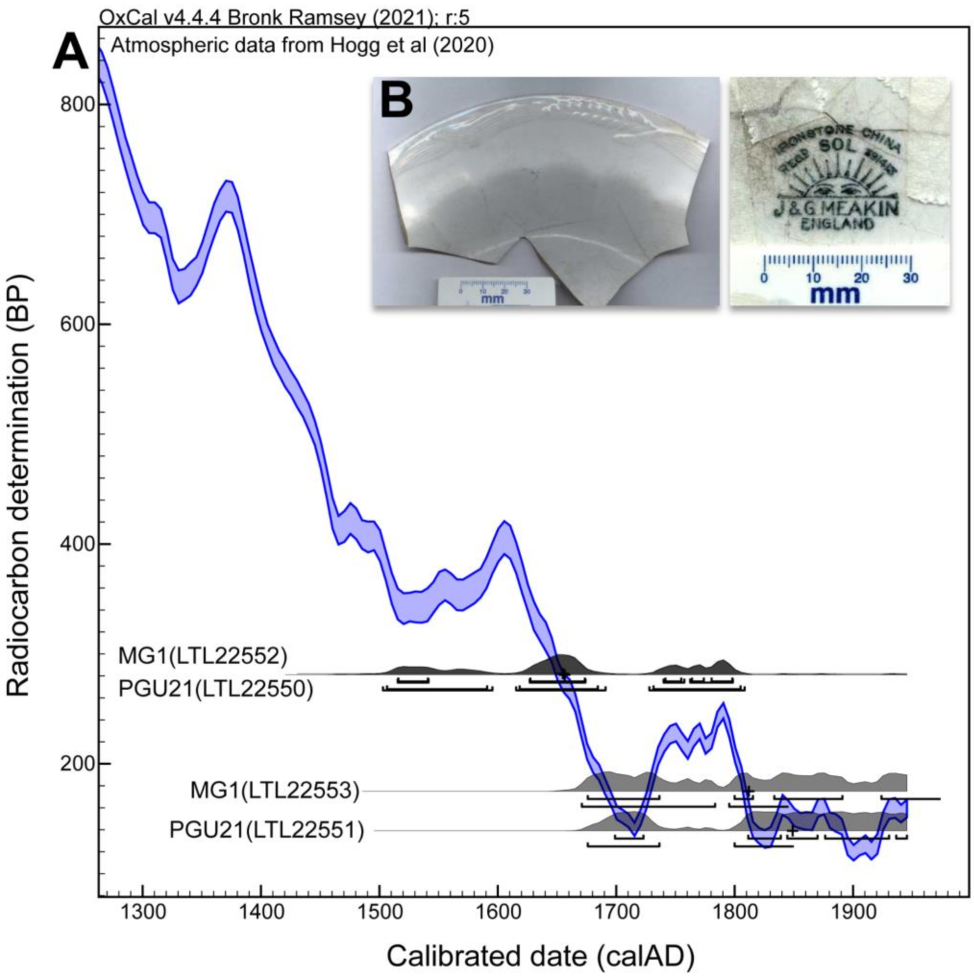

Figure 5.3. A) Radiocarbon chronology and B) associated material culture (fragment of J&G Meakin Ltd. pottery from PG-U21 with the distinctive impression dated to the 1910's).

5.3.2. Species composition, distribution and relative abundance

A total of 11262 bone remains (NSP) were analysed from MG1 and PG-U21, of which 10960 (97.32%) could be identified using distinct taxonomic levels (NISP) and 302 (2.68%) could not be identified (NUSP) (SM1), due to pre- and/or post-depositional alterations (SM2). 57.90% of the remains analysed from MG1 were fragmented, and 52.43% of remains were fragmented from PG-U21. Cutmarks were identified on 76.92% of native terrestrial mammal bones (excluding osteoderms and teeth), ranging from 4.92% in *Didelphis* spp. (opossum) and *Cuniculus paca* (lowland paca) to 12.30% in Dasypodidae (armadillo). Cutmarks were also found on 80% of domesticated animal bones (excluding teeth) from MG1 and PG-U21, including

Bovidae (36.81%) and Ovicaprid (1.39%). While Suina (pig and/or peccary) presented cutmarks in 90.91% of the remains. In both cases, the cutmarks were mostly located on limb bones (e.g., tibiae, metapodial and phalange), which can be related to carcass skinning, defleshing and disarticulation (Costamagno et al., 2019; Egeland, 2003). Cutmarks confirm that native terrestrial mammal remains from both sites resulted from anthropogenic activities (e.g. hunting) rather than being a natural death assemblage.

Bony fish (NISP = 9002 remains) from MG1 and PG-U21 together accounted for 82.13% of the faunal remains, including *Genidens barbus* (white sea catfish), *Conodon nobilis* (barred grunt), *Centropomus* spp. (snook), *Cynoscion* spp. (weakfish), *Cynoscion leiarchus* (smooth weakfish), *Larimus breviceps* (shorthead drum), *Micropogonias furnieri* (whitemouth croaker) and *Pogonias courbina* (black drum). Fish remains were mostly represented by postcranial bones in both MG1 (n = 180, 84.11% fish remains) and PG-U21 (n = 3552, 71.35% fish remains) in relation to cranial bones (MG1, n = 34, 15.89%; PG-U21, n = 1426, 28.65%). The cranial/postcranial (C/P) ratio from aggregated archaeological layers differed between MG1 (0.19) and PG-U21 (0.40) (SM3; Figure 5.4).

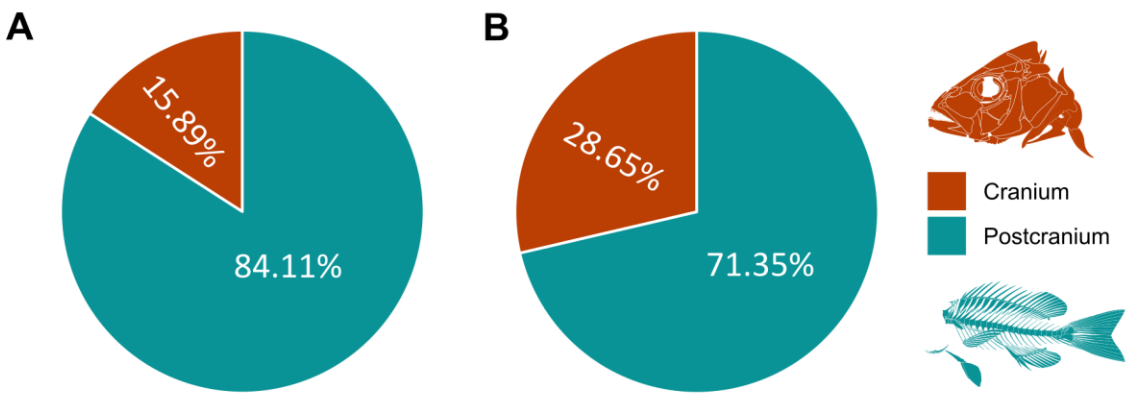

Figure 5.4. Aggregated relative frequency of cranial and postcranial fish bones from (A) MG1 and (B) PG-U21. Figure generated on data publicly available from ArchéoZoo.org (https://www.archeozoo.org/archeozootheque/).

Fish remains were followed by mammals (16.45%, NISP = 1803), with medium-bodied mammals represented by *Didelphis* spp. (opossum), Dasypodidae (armadillo), Cebidae (capuchin monkey) and *Cuniculus paca* (lowland paca), while large mammals were represented by Suina (Tayassuidae (peccary) and/or Suidae (domestic pig)), Cervidae (deer) and Bovidae (cattle). Birds (1.41%; NISP = 154) were represented by Aves (cf. *Gallus gallus* [chicken]). The sole species of cartilaginous fish (0.01%; NISP = 1) recorded was *Carcharhinus* spp. (shark) (SM1).

5.3.2.1. MG1

When assemblages were analysed individually MG1 had a total of 1136 identified remains (74/m^3), of which 53.26% (NISP = 605) corresponded to indeterminate mammals (Mammalia), followed by indeterminate bony fish (Actinopterygii; 16.11%; NISP = 183), then cattle (6.78%; NISP = 77), pig (peccary and domestic pig) (6.25%; NISP = 71), deer (2.73%; NISP = 31), rodents (2.73%; NISP = 31), bird (cf. *Gallus gallus*; 2.02%; NISP = 23) and others (<2%) (SM1).

The highest species richness in MG1 was represented by mammals (SR = 10), including both native (deer, lowland paca, armadillo, opossum, dolphin and cf. whale) and domestic (cattle and sheep) species. The remains of marine mammals (Delphinidae and cf. Mysticeti) appear mostly as artefacts, due to indications that they were intentionally polished and/or modified, such as the presence of nails in two Delphinidae remains. ZooMS analysis confirmed the overall morphological identifications at MG1 (86.7% congruence), with the exception of three Suina which ZooMS identified as two cattle and one brocket deer, and one cattle that ZooMS identified as brocket deer (SM4 Table 1). Along with confirming the exploitation of cattle (*Bos taurus*, n = 11), brocket deer (*Mazama* spp., n = 12), and probably chickens (*Gallus gallus*, n = 2, although the spectra were of poor quality so a confident identification was not possible), ZooMS also allowed us to verify that both peccary (*Tayassu pecari* and/or *Pecari/Dicotyles tajacu*, n = 4) and domestic pig (*Sus domesticus*, n = 1) were exploited at the site (SM4 Table 1). Suines can be difficult to distinguish between as different species of *Sus* spp., for example, have highly similar collagen sequences meaning it is often impossible to determine if wild or domestic pigs were being exploited. Using several known peccary (*Tayassu pecari*, *Pecari/Dicotyles tajacu*) reference bones, differences were identified in the MALDI-TOF-MS spectra compared to *Sus* spp., with peccary having peptide markers at m/z 1991 and 2959, and *Sus* spp. with markers at m/z 1961 and 2987 (SM4 Figures 1, 2 and 3). While these markers need to be confirmed with further analyses, including LC-MS/MS sequencing to identify the specific peptides, they were identified in the six Suina samples analysed herein (SM4 Figures 2 and 3), and also in several additional peccary (m/z 1991, 2959) and pig (both domestic and wild boar, m/z 1961, 2987) samples from other sites unrelated to this study. Additionally, bulk collagen isotope analysis performed on these Suina samples as part of an ongoing study (data not presented herein) provides further support that these additional peaks can be used to distinguish between *Sus* spp. and Tayassuidae, as the two identified as domestic pig (one from MG1 and one from PG-U21) had nitrogen stable isotope (δ15N) values of 11.03‰ and 8.09‰, respectively, while the samples identified as peccary (all from MG1) had significantly lower values, ranging from 1.32‰ to 1.70‰, suggestive of different trophic ecologies.

5.3.2.2. PG-U21

A total of 9825 remains (5918/m^3) were recovered from PG-U21, of which 74.19% were indeterminate bony fish (Actinopterygii, NISP = 7288), followed by armadillo (8.48%, NISP = 833 including osteoderms), barred grunt (7.99%, NISP = 785 including otoliths), whitemouth croaker (3.31%, NISP = 325 including otoliths), and others (<2%) (SM1). Several species including cattle (n = 10), chicken (n = 9), armadillo (n = 9), and domestic pig (n = 1) were all identified with ZooMS (SM4 Tables 1 and 2). This represents 96.3% consistency with morphological identifications, with the exception of one sample morphologically identified as armadillo but that could not be identified amongst the species with currently available ZooMS collagen peptide markers.

The composition, relative abundance and density of faunal remains of PG-U21 varied considerably through the stratigraphy. Fish remains were recovered from all layers, but a noticeable increase in the density of remains (NISP/m^3) was documented in layers 1 and 2, possibly reflecting fishing intensification (Figure 5.5). These were mostly represented by barred grunt and whitemouth croaker, followed by shorthead drum and others. Remains of native terrestrial mammals were also found in all layers, represented mostly by armadillo and a few remains of capuchin monkeys. Interestingly, their densities also increased in layer 2. By contrast, livestock (cattle, sheep, domestic pig) were only documented in layers 3 and 2, with the highest density in layer 3. Finally, bird (mostly believed to be chicken) remains were found in all layers, with higher densities in layers 3, 4 and 5.

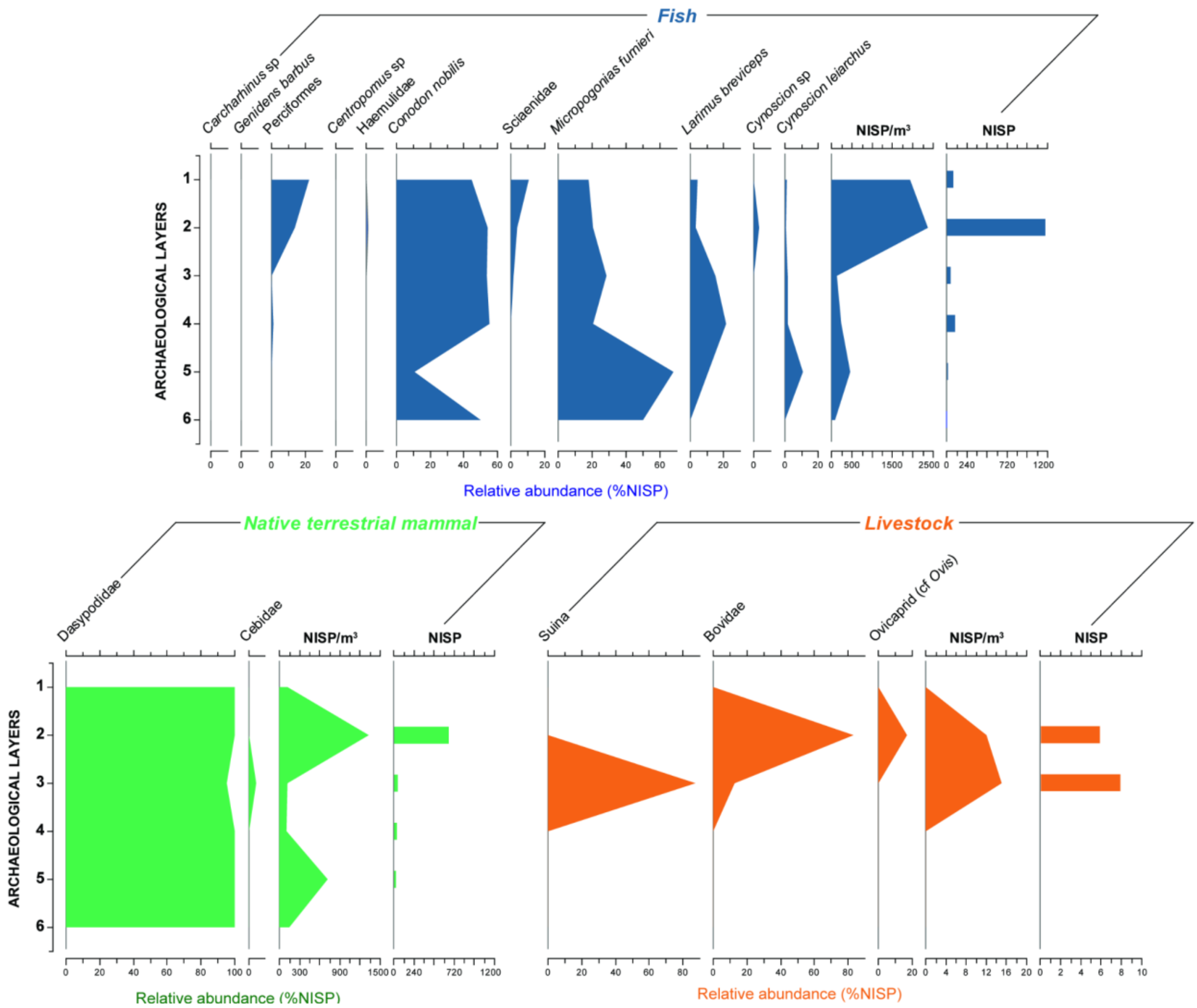

Figure 5.5. Stratigraphic variation in the relative abundance (%NISP), density (NISP/m³) and number of identified remains (NISP) for fish, native terrestrial mammals, and livestock from PG-U21, excluding the generic attributions to Actinopterygii and Mammalia, and remains of Aves. Based on the ZooMS identifications, Suina were grouped with livestock.

5.3.3. Trait variation in native terrestrial mammals across time periods

A total of 21 native terrestrial mammal species were identified across the three studied time periods, with body weight classes ranging from 0.6 kg to 200 kg (SM5; Figure 5.6A). Among these, 20 species were documented for the Pre-colonial period

(4500–1150 cal BP, SM6), six for the Historical period (1750-1950 cal AD), and 10 for the Contemporary period (1998-2000 AD). In the Pre-colonial period, the species with the largest and smallest mean body weights were *Tapirus terrestris* (Brazilian tapir, 200 kg) and *Cavia aperea* (Brazilian guinea pig, 0.6 kg), respectively. In the Historical period, MG1 exhibited a broader range of body weight classes (1.3 kg to 30.5 kg), while PG-U21 had a more restricted range (2.8 kg to 5.7 kg). Tayassuidae (peccary, 30.5 kg) had the largest mean body weight, while *Didelphis* spp. (opossum, 1.3 kg) was found to have the lowest. In the Contemporary period, the largest mean body weight was represented by *Hydrochoerus hydrochaeris* (capybara, 50.5 kg), while the species with the lowest mean body weight was *Didelphis aurita* (big-eared opossum, 1.3 kg). The current composition of terrestrial mammals from Babitonga Bay includes species with a broader range of body weight classes, ranging from the Brazilian tapir (200 kg) to *Monodelphis iheringi* (Ihering's short-tailed opossum, 0.1 kg).

Medium-bodied mammals (1.01-15 kg), accounting for 41% of the current species in Babitonga Bay, were the most exploited animals during all studied periods, ranging from 60% in the Pre-colonial and Contemporary periods, to 67% in the Historical period. These were followed by large-bodied mammals (> 15.1 kg) ranging from 30% in the Contemporary, 33% in the Historical, to 35% in the Pre-colonial period; while evidence for targeting small-bodied mammals (< 1.0 kg) was only detected in the Pre-colonial period, represented by Brazilian guinea pig. When considering the current species composition of Babitonga Bay in comparison to the three time periods and body weight classes studied, significant differences were only observed for the proportion of small-bodied mammals between the Pre-colonial period and the current composition ($p = 0.01367$).

Targeted mammals had population densities ranging from 0.1 to 65.5 individuals/km^2, with the highest density represented by the Brazilian guinea pig (65.5 individuals/km^2) and the lowest by *Puma concolor* (cougar) (0.1 individuals/km^2). In contrast, all native terrestrial mammals had estimated density values ranging from 0.1 to 400 individuals/km^2. However, the majority of targeted mammals across all periods exhibited densities ranging from 1.1 to 30 individuals/km^2. These species represented 68% of the terrestrial mammals in the Pre-Colonial period, 83% in the Historical period, and 80% in the Contemporary period. By contrast, these species represent only 39%

of Babitonga Bay's current terrestrial mammal composition, which shows density distributions ranging from 0.1 to 400 individuals/km^2 (SM5; Figure 5.6B). Although no significant differences were observed across the studied periods, the results suggest that Pre-colonial, Historical and Contemporary hunting practices selectively targeted medium- and large-bodied animals with low to medium population densities.

Regarding trophic groups, the categories ranged from Herbivore-grazers to Carnivores, with the majority of targeted mammals belonging to the Frugivore-omnivore category (SM5; Figure 5.6C). The highest diversity of trophic categories was detected in the Pre-colonial period, with a preference for Frugivore-omnivores (30%), followed by Carnivores (15%), Frugivore-granivores (15%), Frugivore-herbivores (15%), and others at less than 5%. In the Historical period, the exploitation was mainly focused on Frugivore-omnivores (n = 49%), followed then by Insectivore-omnivores, Frugivore-granivores and Frugivore-herbivores (all with n = 17%). In the Contemporary period, the most exploited category was again Frugivore-omnivores, Frugivore-granivores and Frugivore-herbivores (all with n = 20%), followed by Carnivores, Myrmecophages, Insectivore-omnivores and Herbivore-browsers (all with n = 10%). The current terrestrial mammal composition of Babitonga Bay exhibits the same trophic groups as those in the Pre-colonial and Historical periods; however, the most abundant trophic group is Frugivore-granivores (28%), followed by Carnivores (17%), Insectivore-omnivores (17%), Frugivore-omnivores (15%), Frugivore-herbivores (7%), Myrmecophages (4%), and others. Despite the preference for Frugivore-omnivore species in the Pre-colonial, Historical and Contemporary periods, there were no statistical differences between periods and current compositions.

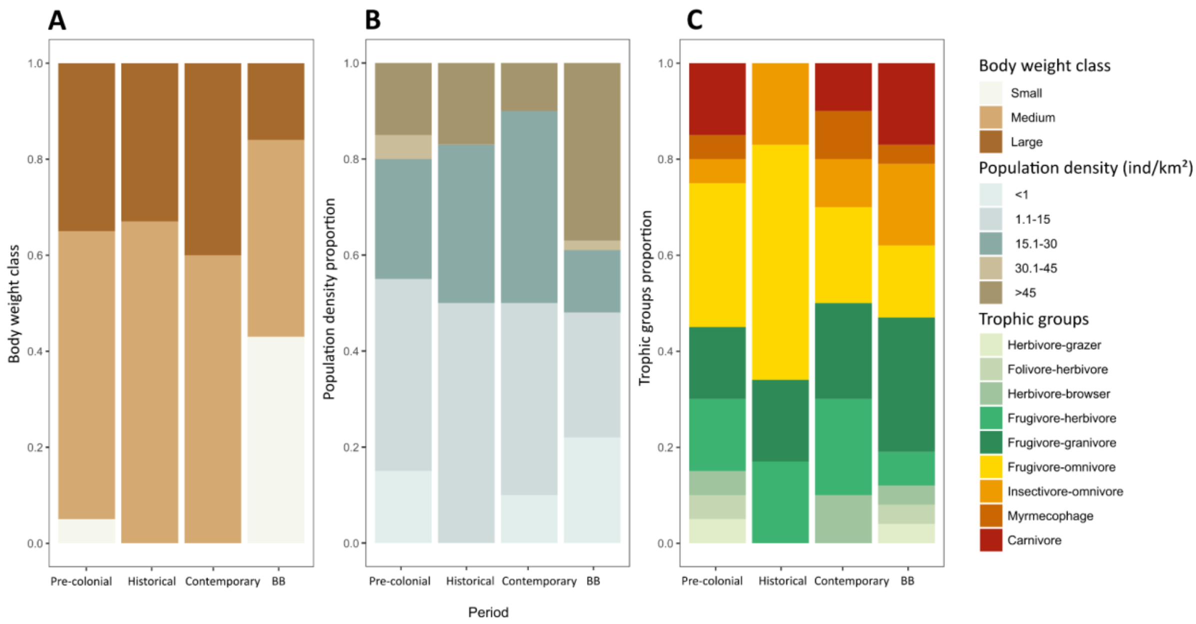

Figure 5.6. Mammalian traits and functional groups across studied time periods. The proportion of mammal species differentiated by (A) body weight classes, (B) population density (individual/km²) and (C) trophic group between Pre-colonial (4500–1150 cal BP), Historical (1750-1950 cal AD) and Contemporary (1998-2000 AD) periods, along with the current native terrestrial mammal composition of Babitonga Bay (BB).

5.4. Discussion

Radiocarbon dates and artefacts indicate that MG1 and PG-U21 were occupied from approximately 1750 to 1950 AD, one hundred years after the establishment of the village of Nossa Senhora da Graça on the São Francisco River in 1658 (Cabral, 1937; Saint-Hilaire, 1936). In 1660, the village was elevated to the status of town, and in 1665 it was designated as a parish, and then as a city in 1847, the earliest city in the state of Santa Catarina (Cabral, 1937). Faunal remains from MG1 and PG-U21 offer valuable insights into the livelihoods and the ecological footprints of these early colonial and post-colonial decades in Babitonga Bay. The information gained also allows us to reassess the often neglected role of fisheries during the early modernization of Brazil's southern coast.

The zooarchaeological data revealed noticeable differences in faunal remains between MG1 and PG-U21, both in terms of species composition, relative abundance and density (Figure 5.7A-B). We acknowledge that differences in recovery and analytical methods can affect fundamental and derived measurements of archaeological faunal remains (Grayson, 2014; Lyman, 2008a; Reitz & Wing, 1999); however, these are unlikely to explain the variations seen among the sites. Firstly, in both sites, faunal remains were retrieved using similar mesh sizes (2.5 and 3mm), which are considered adequate for the recovery of small fragments and anatomical parts, such as fish remains (McKechnie & Moss, 2016; Zohar & Belmaker, 2005). Secondly, taxonomic identification for both sites was performed using the same reference collections and by the same analyst, therefore reducing analytical biases. Moreover, the proportion of fragmented bones was similar among sites. The recovered faunal remains thus confidentially reflect fundamental differences in subsistence and economic activities between the sites.

Fish outnumbered other faunal remains at PG-U21, with an overall aggregate density (899/m^3) comparable to, or higher than, some local Pre-colonial shell mounds (known as sambaquis, with densities from 42/m^3 to 7871/m^3) produced by groups subsisting largely on fishing (Fossile et al., 2019, 2023) (Figure 5.7B). Fishing intensification, however, appears to have occurred during the later phases of the site dated to the early 20th century. This coincides with a time interval of substantial policy incentives for commercial fisheries, with increased catches and fishing efforts along the coast of Santa Catarina state (Herbst et al., 2023; Sandoval Gallardo et al., 2021); as such, this fishing intensification at PG-U21 may reflect a local response to increased market demand. The relatively low taxonomic diversity of fish remains suggests specialised fishing practices aimed at supplying both household and local markets, which is largely supported by historical accounts documenting the importance of fish as a source of food and income in Babitonga Bay since the mid-19th century (Saint-Hilaire, 1936). The most frequently caught species (whitemouth croaker and barred grunt) continue to display high economic and subsistence values today (Haimovici et al., 2016; Lima et al., 2019), and the same fish species are also consumed by contemporary Caiçara communities along the Atlantic Forest coast (Begossi, 2006; Begossi & Richerson, 1993; Hanazaki & Begossi, 2003). Extensive research has demonstrated that these communities carefully consider the costs and benefits associated with pursuing and processing food resources based on factors such as site location, environmental conditions, and the influence of urban centres and markets (Hanazaki & Begossi, 2000; MacCord & Begossi, 2006). According to this theoretical proposition, there is a stronger focus on fishing as the proximity to the coast increases, which explains the higher dependence on fishing observed in PG-U21 (coastal) compared to MG1 (inland). Overall the results highlight the significant role of fishing in Babitonga Bay between the 18th and the 20th century, which adds to the growing evidence for a heavy reliance on fishing for food security for thousands of years in the region (Fossile et al., 2019, 2023; Toso et al., 2021). This is particularly significant given that fishers were often overlooked or inadequately represented in regional historical narratives (Silva, 1988, 2001).

The species found at PG-U21 and MG1 suggest that fishing was mainly practised in coastal waters. Surprisingly, other coastal species widely captured nowadays, such as mullets (Hanazaki & Begossi, 2000, 2003; Herbst & Hanazaki, 2014; Sandoval Gallardo et al., 2021), have not been recorded at either site. *Mugil liza* (Lebranche mullet), in particular, is abundantly caught along the southeastern coast of Brazil during austral autumn and winter, from May to July (Steenbock, 2019), and this practice has been regionally documented since the early 16th century (Staden, 2020). It is possible that the species was not consumed by local residents, as observed among some contemporary communities in southern Brazil (Hanazaki & Begossi, 2003). Alternatively, processing methods involving salting and drying (locally known as cambira, (Alves, 2003; Anacleto et al., 2019)) may have prevented the survival of diagnostic bone remains in the archaeological record. Cambira involves a longitudinal incision along the dorsal region of the individual, and the removal of the head, prior to salting and drying. This method is similar to the one observed by Zohar and Cooke (Zohar & Cooke, 1997) in the northwest of Panama Bay, who demonstrated that it causes damage to, and loss of, cranial bones, precisely those bones which contain most of the diagnostic elements needed for taxonomic identification. Nevertheless, the differences in cranial/postcranial values between the two sites and the absence of otoliths in MG1 suggest that a large number of fish may have been locally processed in PG-U21, while in MG1 more fish were brought to the site already processed (with crania removed). As such, processing methods are unlikely to explain the absence of mullets at least in PG-U21, unless the species was processed and cranial bones disposed of elsewhere, with only the postcranial fraction transported to the site for consumption or trade. The absence of mullets, therefore, remains a matter deserving of further study.

Our results indicate that livestock did not play a major role as a food source (e.g. meat), nor as sources of secondary products (dairy, fur/hide) during the colonial and post-colonial periods in Babitonga Bay (Figure 5.7A-B). Rather, local food security and livelihood relied on fishing and the hunting of native terrestrial mammals, along with crop agriculture. Fish were exploited for their meat, fat and oil, while native terrestrial mammals could have also been pursued for their secondary products (fur/hide), as suggested by the number and location of cutmarks. This is supported by historical records which report that fish and native terrestrial mammals were consumed at the household level, and used as sources of income (Ribeiro & Corção, 2013; Saint-Hilaire, 1936). Among domesticated animals, chickens are an exception as they very likely played a role as a daily source of dietary protein (meat and eggs) at both sites, as documented among traditional riverine and coastal communities nowadays (Hanazaki & Begossi, 2003). Fish, native mammals and chickens appear to have contributed substantially to the overall economy of PG-U21. By contrast, the low density of faunal remains in MG1 suggests that other economic activities, such as plant cultivation and processing (e.g. manioc milling), prevailed at the site.

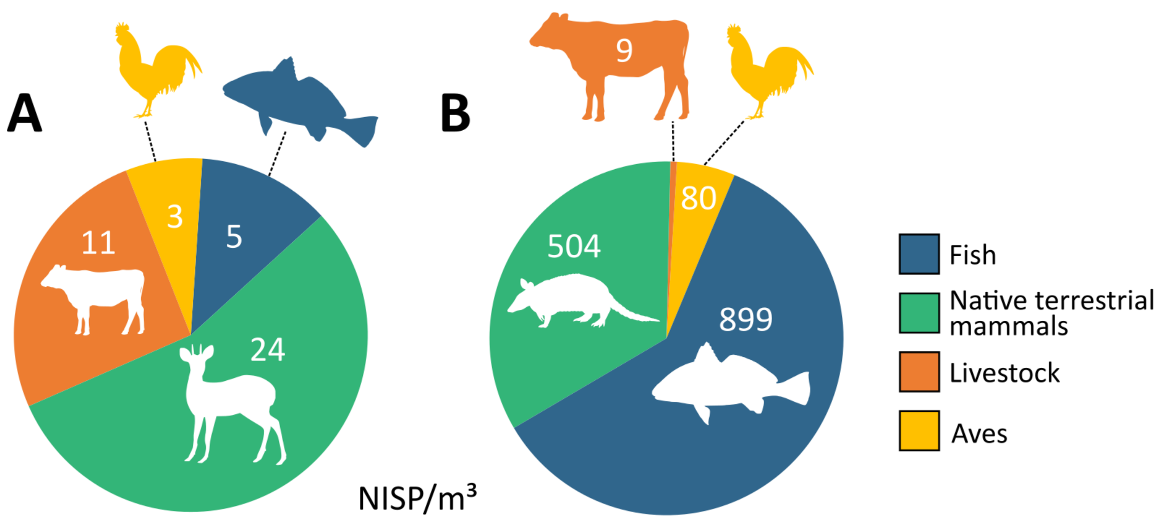

Figure 5.7. Aggregated density (NISP/m³) for fish, native terrestrial mammals, livestock and birds from (A) MG1 and (B) PG-U21, excluding the generic attributions to Actinopterygii and Mammalia. For MG1, remains of Artiodactyla and Canidae were also excluded from the analysis. Based on the ZooMS identifications, Suina were grouped with native terrestrial mammals for MG1 and with livestock for PG-U21. Figure generated on data publicly available from PhyloPic (http://phylopic.org/).

5.4.1. Long-term selective hunting in Babitonga Bay

Native terrestrial mammals made up a significant proportion of faunal remains at both sites. This suggests that species currently undergoing population declines were exploited in the region for at least the past two centuries. When comparing this data to information gathered from Pre-colonial sites, our findings show a consistent pattern of medium- and large-bodied terrestrial animal species being hunted by both Pre-colonial and historical coastal communities in Babitonga Bay (Brazilian tapir, and various species of deer and peccary). This hunting trend persists despite changes in the purpose of hunting over different study periods, such as subsistence, ritualistic, and livelihood pursuits. Such a pattern is also observed among some contemporary Caiçara communities, and has been extensively documented in tropical forests in South America and beyond (Ceballos et al., 2017; Darimont et al., 2023; de Souza & Alves, 2014; Dirzo et al., 2014; Milner-Gulland & Bennett, 2003; Peres, 2000).

Significantly, several species identified in the Pre-colonial and Historical periods, such as Pampas deer (*Ozotoceros bezoarticus*) (Bryan, 1993), Brazilian tapir, white-lipped peccary, and red brocket deer are no longer documented in the region (Carvalho-Junior, 2022; Dornelles et al., 2017). The last recorded sightings of tapirs and peccaries in Babitonga Bay date back to 1996, while the last record of a red brocket deer was in 2001 (Cherem et al., 2004). By contrast, these species have been reported between 2015 and 2019 in a Protected Area located approximately 45 km away from Babitonga Bay (Hübel et al. 2021), reinforcing the role of conservation strategies in reducing defaunation (Bogoni et al., 2020). Despite a long history of hunting, Babitonga Bay shows a notable diversity of medium and large terrestrial mammal species (n = 30, excluding volant mammals), surpassing the average observed in the Atlantic Forest from 1983 to 2017 (n = 14.7 species) (Bogoni et al., 2018). This suggests that the remaining forested areas may still be capable of sustaining levels of productivity that offset the detrimental effects of hunting and habitat degradation (Peres, 2000; Peres & Nascimento, 2006).

When considering the average density of mammals, our results suggest hunting intensity was lower in the Historical period (22.1 ind./km^2), compared to both the Contemporary (18.5 ind./km^2) and Pre-colonial periods (18 ind./km^2). These subtle differences could be attributed to the relatively smaller human population residing in Babitonga Bay from the 18th to the 20th centuries, or changes in the socio-economic nature of hunting practices through time. For example, the absence of carnivores during the Historical period may be explained by evolving social factors. Leónce Aubé (Aubé, 1857) documented that native animals in Babitonga Bay were classified into two groups by local communities in the 19th century: game species, consisting of animals hunted for their nutritional value; and "ferrous" animals (e.g. carnivores such as Panthera onca, jaguar), which were not hunted. Present-day Caiçara communities pursue different species for their food value, as well as for their medicinal value (Hanazaki et al., 2009), and both are strongly tied to cultural traditions that can be traced back to the 16th century (Camphora, 2021).

Long-term selective hunting may have had significant detrimental social and ecological consequences in the Atlantic Forest, about which our understanding remains limited (Jorge et al., 2013). Studies have shown that the selective removal of medium and large terrestrial species with low population densities, low breeding cycles, prolonged gestation periods, and extended intervals between births, not only causes a decline in the overall animal biomass, but also has far-reaching implications for forest ecosystem services (Galetti et al., 2015, 2017, 2021; Peres, 2000; Peres & Nascimento, 2006). Hunting pressure on medium and large frugivorous mammals, considered "habitat shapers" (Rumeu et al., 2020) for their capacity to disperse large seeds, may disrupt the recruitment and distribution of plant species with trophic cascade effects on plant diversity, soil regulation and structure, and forest carbon storage capacity, among others (Camargo-Sanabria et al., 2015; Galetti et al., 2015, 2017; Jorge et al., 2013; Peres, 2000; Rumeu et al., 2020; Villar et al., 2021). Moreover, native terrestrial animals play a significant role in the livelihoods of tropical and subtropical rural communities (Alves et al., 2009; Hanazaki et al., 2009; Peres &

Nascimento, 2006), and their loss risks increasing the socio-ecological vulnerability of local traditional groups, and their perceptions of forest ecosystems (Milner-Gulland & Bennett, 2003; Ponta et al., 2019).

The commoditization of natural resources, coupled with significant progress in hunting, processing, and transportation technologies in recent decades, have led to unprecedented levels of defaunation in the Neotropics (Bogoni et al., 2018, 2020; Jorge et al., 2013; Peres, 2000). Our study indicates that these ecological footprints actually have deeper historical origins, which if not recognized can lead to the establishment of inappropriate sustainability targets, weak public and stakeholder support for conservation initiatives, and generational shifts in the acceptance of systems that are considered degraded (Lovell et al., 2020; McClenachan et al., 2018; Pauly, 1995; Soga & Gaston, 2018). In order to obtain a more comprehensive understanding of local animal density and its implications, further studies are needed, including studies on past faunal assemblages. Archaeological faunal remains are some of the few available sources of information on Pre-colonial and historical vertebrate diversity, and as such can shed light on the origin and changing nature of defaunation over long timescales. We recommend the integration of historical and archaeological data into modern faunal population assessments and conservation initiatives to set more informed reference baselines.

5.5. Implications for Conservation

Influenced by a lack of historical perspective, the widespread perception of low human impact in tropical forests has led to limited conservation attention until recent decades. This historical amnesia has hindered assessments of the current environmental challenges facing the Atlantic Forest and its coastal waters, including defaunation and overfishing. A growing body of evidence indicates that the diversity of Neotropical mammals is currently under threat from various human-induced pressures, and archaeology is emerging as a key discipline for expanding our understanding of these anthropogenic pressures over long time scales. Our analysis of faunal remains from two historical sites highlights the significant role of fishing and hunting of native terrestrial wildlife during the last two centuries of human colonisation of Babitonga Bay. This study provides compelling evidence that the selective hunting of medium- and large-bodied native terrestrial mammals has persisted in the region for over 4500 years, and requires us to reconsider the idea of a heavy reliance on domestic animals during European colonisation of southern Brazil.

5.6. Supplementary Material

Available on https://doi.org/10.1177/19400829231218419:

SM1. Archaeofauna qualitative-quantitative data
SM2. Taphonomic data
SM3. Ichthyoarchaeofauna specimens data
SM4. Zooarchaeology by Mass Spectrometry (ZooMS) data
SM5. Modelled mammalian composition and functional traits across time periods in Babitonga Bay

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CHAPTER 6

The historical ecology of subsistence and early commercial fisheries in mangrove systems in Brazil

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6.1. Introduction

Brazil encompasses some of the most diverse biomes on earth, such as the Amazon and the Atlantic Forest, and one of the world's most extensive mangrove systems [1,2]. Mangroves offer numerous ecosystem services (from food provisioning to carbon storage, [2]) and provide for diverse coastal populations, including traditional communities (Indigenous, *Caboclos*, small-scale fisheries) who secure their food and livelihoods from resources therein. It has recently been estimated that ~53% of small-scale fishers in Brazil engage in either part-time or full-time fishing activities in or around mangrove systems, amounting to nearly 300,000 people [3]. Conservation and management of mangrove systems in Brazil, therefore, are of high priority and have been addressed through distinct mechanisms, including the establishment of Marine Protected Areas with varying levels of access and use [4]. Despite these efforts, mangrove conservation is the subject of continuous debate, with effective protection jeopardised by political and economic disputes [2,5]. Moreover, fisheries monitoring programs remain scarce, with irregular and geographically scattered statistics spanning just a few decades [6,7]. For several species, their ecological and conservation statuses remains uncertain [8], while significant gaps persist regarding the origin and changing nature of past anthropogenic footprints on mangrove habitats.

A number of species historically exploited in mangrove systems continue to be pursued today for both commercial and household consumption. Among these, whitemouth croaker (*Micropogonias furnieri*) and white sea catfish (*Genidens barbus*) have been subject to exploitation since pre-colonial times [9,10], with catches declining in response to overfishing over the past few decades [11,12]. By contrast, there remains a significant knowledge gap concerning various species of lesser commercial value but are vital for household consumption and local poverty alleviation, such as barred grunt (*Conodon nobilis*) [13–16]. Information on the ecology and biology of barred grunt is limited, particularly in southern Brazil [17–20]. Due to low population numbers and substantial fishing pressure from various fisheries (shrimp, artisanal, recreational), barred grunt has been identified as highly susceptible to stock collapse and overexploitation [13,21–23]. Moreover, recreational fishing has grown significantly in Brazil since the second half of the 20th century, potentially intensifying pressure on numerous species, including barred grunt and fat snook (*Centropomus parallelus*) which are commonly caught by this sector [24–26]. Information on the size and the trophic ecology of these species, however, remains scarce in the region.

For at least 7000 years, mangrove systems have supported numerous Indigenous populations along the southern Atlantic Forest coast of Brazil. Large shell mounds, locally known as sambaquis [27], and other shallow coastal sites produced by later groups using Taquara-Itararé ceramics [28], offer glimpses of past human perception and cultural value of mangrove habitats. Faunal remains from these sites hold clues to Indigenous ecological knowledge related to species diversity, distribution and habitat, as well as their provisioning (food) and cultural services (economic, symbolic, ritualistic, etc.) [9,29–31]. It has been estimated that annual captures of demersal fish by pre-colonial Indigenous groups were comparable to or higher than historical subsistence fisheries in these regions [9,32]. Their per capita intake of marine proteins remains unequalled among modern small-scale coastal fisheries [33,34], and even among those that retain some ecological knowledge rooted in Indigenous traditions [35,36]. Many questions remain, such as which fishing grounds were preferentially used by pre-colonial Indigenous populations, whether specific species or size classes were targeted or more general fish communities, and whether species-specific strategies were implemented [31,32,37]. Little is known about the potential adverse effects of thousands of years of fishing, and whether these resources were somehow managed to ensure sustainable levels of exploitation.

European colonisation from the 16th century onward brought unprecedented changes to Brazilian coastal environments. Notably, it led to the replacement of Indigenous populations, the marginalisation of their ecological knowledge, and the commoditization of natural resources, which has fundamentally reshaped human-environment interactions in the region [38]. Historical documents from the last 150 years attest to an intensification of anthropogenic pressures on Brazilian mangroves due to evolving political agendas related to industrialisation, agricultural practices, commercial fishing, and urbanisation [39,40]. Fishing restrictions and sanctions documented since at least the late 19th century (e.g. 1880-1890) indicate that some local stocks were already experiencing the effects of overfishing, with the impacts exacerbated by profit- and efficiency-seeking fisheries policies introduced throughout the 20th century [39–42]. While historical sources offer valuable insights into exploited species and the drivers of exploitation, they often lack details regarding size and feeding behaviour of targeted species [40], which are crucial for stock assessments [43,44].

Stable isotope analyses have been extensively employed to reconstruct the trophic ecology and behavioural patterns of marine species. Stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope analysis of marine vertebrates, for example, is a well-established approach for studying animal physiology, niche differentiation and trophic connections within food webs [45–47]. Bulk tissue $\delta^{13}C$ values trace the energy flow from distinct photosynthetic pathways at the base of the food web, including sources like terrestrial, freshwater and marine primary producers [48,49]. Bone collagen is typically ^{13}C-enriched by ~3.5 per mil (‰) compared to assimilated food items, thus it can complement trophic information often obtained from a consumer's nitrogen isotopic composition [49,50]. Nitrogen isotopes reflect the protein fraction in diet, and studies have shown that bone collagen $\delta^{15}N$ values in marine fish tend to increase by ~1‰ to 2.5‰ with each successive trophic level [49,50]. Stable sulphur isotopes ($\delta^{34}S$) provide additional information on energy and nutrient flow, particularly between benthic and pelagic ecosystems [46,51,52]. Sulphur in bone collagen is found in the essential amino acid methionine, and is transferred through the food web with relatively minor, but variable, isotopic fractionation [52–55]. In marine environments, planktonic algae and seaweed uptake and assimilate marine sulphates (~+21‰) producing little isotope fractionation [46,56]. By contrast, dissimilatory sulphate reduction by anaerobic bacteria/archaea causes high isotope fractionation of marine sulphates in nearshore environments (e.g. estuaries), producing ^{34}S-depleted sulphides (~-26‰) or other oxidation products that are used by plants such as mangroves and seagrasses rooted in anoxic sediments [46,51,56–59]. This results in ^{34}S-depleted organic matter at the base of the food web compared to marine algae and seaweed. Nearshore habitats are also exposed to continental waters with extremely variable $\delta^{34}S$ values (-40‰ to +20‰, [54] compared to marine sulphates [46], but their isotopic effect on food webs will be perceptible only in very low saline habitats [60]. Stable isotope analysis of archaeological faunal remains has been increasingly used to uncover the ecology of past fisheries [47,61,62], and more recently, this approach has been extended to archaeological fish records from Brazil [34,63]. However, these applications are limited to stable carbon and nitrogen isotopes, while sulphur isotopes have remained unexplored to date in the region. Furthermore, the limited isotope record for fish prevents our understanding of the evolution of food webs and coastal habitats used by past human groups in the southwestern Atlantic Ocean, as well as the extent of recent anthropogenic impacts on coastal systems.

Otolith analyses are commonly applied to estimate fish body length, age and growth rate, which are particularly important for fisheries management purposes [64,65]. Decreasing fish body length is considered an indicator of intensive fishing in stock assessments [43,66,67]. Variations in species' size can change the length at which the first maturity occurs, potentially rendering conservation measures ineffective [68]. Fish body length and age at first sexual maturity, in fact, are frequently used to determine the smallest size at which a species can be sustainably caught (Minimum Landing Size - MLS) [69,70]. Additionally, metric studies employing otoliths and fish vertebrae have been used to track the impact of early fisheries in other regions [47,71,72]. In Brazil, however, otoliths from archaeological sites have only received cursory attention for past fisheries reconstructions [31,32,37,73].

In order to address some of the gaps, here we analysed the body total length and trophic ecology of various demersal fish species retrieved from pre-colonial (prior to 1500 AD, SM1) and historical (late 19th and early 20th centuries AD, SM1) archaeological sites in Babitonga Bay, Santa Catarina state (Figure 6.1). This region is home to the largest mangrove ecosystem in southern Brazil, which hosts a large number of pre-colonial and historical archaeological sites with evidence of subsistence and commercial fishing [10,32,74,75]. Body total length of archaeological specimens captured for subsistence and commercial purposes was estimated, and the stable carbon, nitrogen, and sulphur isotopic composition of bone collagen was analysed from various species to investigate the ecology of pre-colonial and historical catches (Figure 6.2). Our objective was to explore differences in species size and fishing ground preferences between pre-colonial and historical fisheries, and to provide for the first time in the region glimpses of ecological baselines predating the onset of intensive commercial fisheries from the mid 20th century.

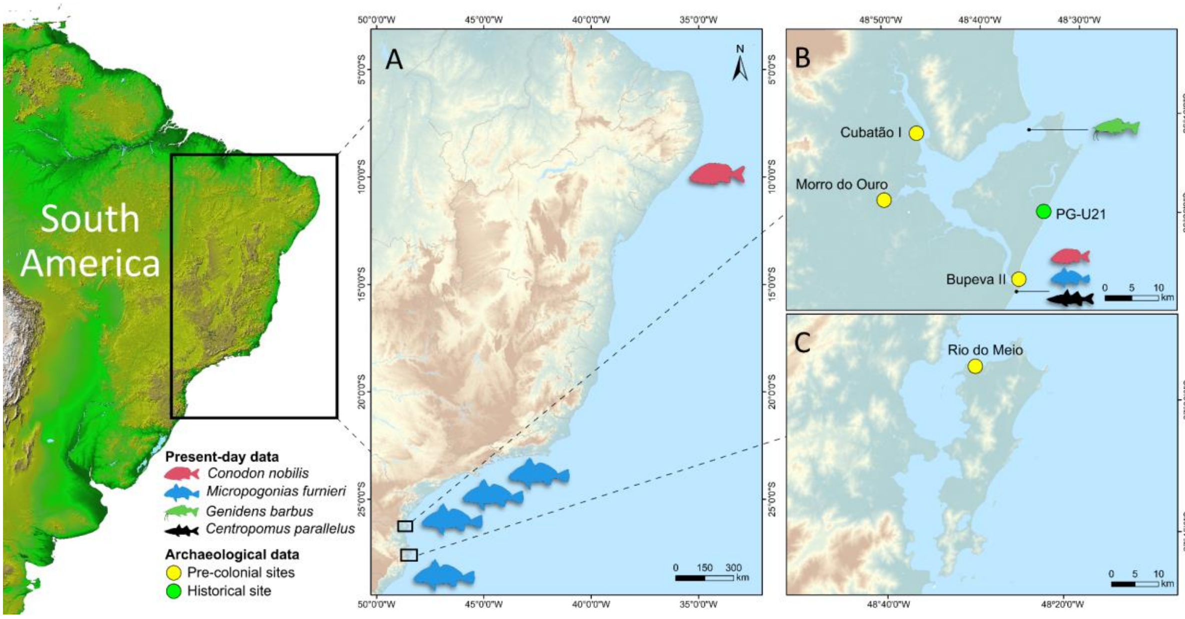

Figure 6.1. *Overview of the study area showing (A) the geographic position of measured body size in present-day populations of barred grunt and whitemouth croaker (18, 76); (B) the location of pre-colonial (Morro do Ouro, Bupeva II, Cubatão I) and historical (Praia Grande Unidade 21) archaeological sites analysed, including the catch location of present-day species used for stable isotope analysis; and (C) the location of the pre-colonial site of Rio do Meio. Maps were generated using ArcGIS 10.8 (https://www.arcgis.com) and Inkscape 1.3 (https://inkscape.org/) on data publicly available from NASA/JPL-Caltech (adapted from https://www.jpl.nasa.gov/images/pia03388-south-america-shaded-relief-and-colored-height), Brazilian Agricultural Research Corporation - EMBRAPA (77), Natural Earth (https://www.naturalearthdata.com/), Brazilian Institute of Geography and Statistics - IBGE (https://www.ibge.gov.br/geociencias/todos-os-produtos-geociencias.html), National Institute for Space Research - INPE (78) and Phylopic 2.0 (https://www.phylopic.org/).*

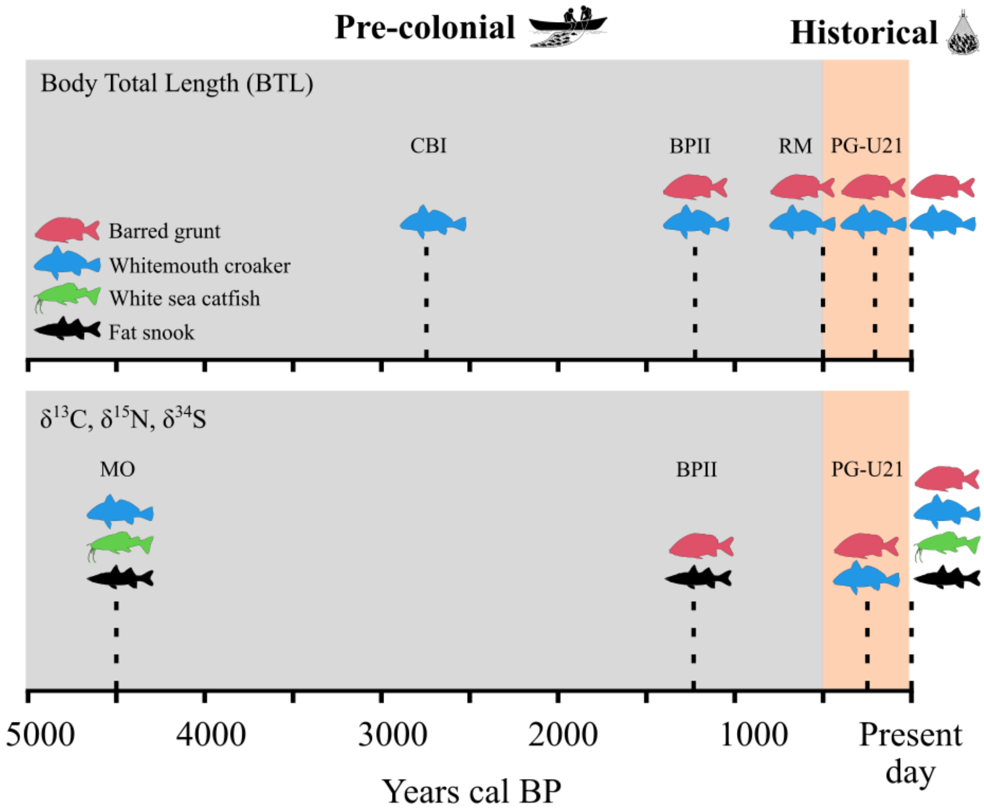

Figure 6.2. *Timeline illustrating the dates of the archaeological sites from which samples were analysed for body total length (BTL) and stable isotopes (Morro do Ouro - MO, Cubatão I - CBI, Bupeva II - BPII, Rio do Meio - RM, Praia Grande Unidade 21 - PG-U21), along with the present-day species analysed. Figure generated with Inkscape 1.3 (https://inkscape.org/) using publicly available silhouettes from Phylopic 2.0 (https://www.phylopic.org/).*

6.2. Material and Methods

6.2.1. Sample selection for stable isotope analysis

Species commonly exploited in southern Brazil since pre-colonial times were selected for stable carbon ($\delta^{13}C$), nitrogen ($\delta^{15}N$) and sulphur ($\delta^{34}S$) isotope analyses. Specifically, bones of barred grunt (*Conodon nobilis*), whitemouth croaker (*Micropogonias furnieri*), white sea catfish (*Genidens barbus*) and fat snook (*Centropomus parallelus*) were recovered from pre-colonial and historical archaeological sites in Babitonga Bay. Pre-colonial sites included the shell mound Morro do Ouro (MO), in Joinville, and the shell mound Bupeva II (BPII), in São Francisco do Sul. Bones of white sea catfish (n = 100) and fat snook (n = 23) from MO were recovered from deposits radiocarbon dated between 4800–4550 and 4500–

4100 cal BP [79]. Bones of barred grunt (n = 20) and fat snook (n = 20) from BPII were retrieved from deposits radiocarbon dated to 1000–750 and 650–500 cal BP (95.4% confidence interval [CI], SM1). Bones were also samples from the historical site Praia Grande Unidade 21 (PG-U21), a rural settlement in São Francisco do Sul [80]. There, samples of barred grunt (n = 20) and whitemouth croaker (n = 20) were selected from deposits radiocarbon dated to 1690–1950 and 1510–1800 AD (68.4% CI) [80,81]. The material culture at this site (coins and ceramic artefacts), however, constrains the chronology of the archaeological deposits to the late 19th to early 20th centuries AD [80]. Whenever possible, specimens were selected to represent individual animals by sampling the same anatomical element (dentary, premaxilla, articular, hyomandibular, pharyngeal teeth). The permits for stable isotope analysis of archaeological samples were obtained from the *Instituto do Patrimônio Histórico e Artístico Nacional* (IPHAN, protocol nº. 01510.000196/2019-63 and 01510.000823/2021-81).

For comparative purposes, bones of modern (present-day) adult individuals of barred grunt (n = 25), whitemouth croaker (n = 11), white sea catfish (n = 20) and fat snook (n = 18) were also sampled for stable isotopic analysis. Modern samples caught in Babitonga Bay and adjacent coastal waters were commercially acquired in Joinville between 2018–2019 and registered in the *Sistema Nacional de Gestão do Patrimônio Genético e do Conhecimento Tradicional Associado* (SisGen, nº. RF54A7C and R22244B) following article 22 of Decree 8.772, of 11 May 2016.

6.2.2. Collagen extraction

The bone collagen of archaeological (n = 203) and modern (n = 74) samples was extracted at the stable isotope facilities of the Institute of Environmental Science and Technology (ICTA-UAB). Archaeological bones (50 to 630 mg) were physically cleaned and immersed in 0.6M hydrochloric acid (HCl) at 4°C for several days. Bones were then rinsed with ultrapure water and immersed in 0.05M sodium hydroxide (NaOH) for 20 minutes at room temperature. NaOH wash cycles were repeated as needed, typically 1 or 2 times, until no further colour change occurred in the solution. Samples were rinsed three times with ultrapure water for 10 minutes each to ensure the complete removal of NaOH [82,83]. Samples were gelatinized in 0.001M HCl (pH3) at 80 °C for 48 h. The supernatant containing collagen was then filtered using Polyethylene Ezee filters (9 mL, pore size 60–90 μm, Elkay Laboratories Ltd.), then frozen for at least 48h at -20ºC and lyophilised. Bones from MO were relatively small in size (50% of the samples ≥ 300 mg), thus a decision was made to not treat them with NaOH in order to prevent sample loss [84,85]. A paired analysis on both treated and untreated NaOH samples from the site revealed no significant differences in both atomic and isotopic values (SM2). The same collagen extraction protocol was applied to the modern bone samples (22 to 340 mg), with the exception that lipids were first removed by sonicating samples 3 times for 15 min in a dichloromethane:methanol solution (2:1) prior to collagen extraction. The NaOH wash was applied to modern samples to aid in the removal of non-collagen proteins [86].

6.2.3. Stable isotope analysis

Stable isotope analysis of successfully extracted samples was performed at SUERC, East Kilbride (UK). 114 samples were analysed using a Delta V Advantage continuous-flow isotope ratio mass spectrometer coupled via a ConfloIV to an IsoLink elemental analyser (Thermo Scientific, Bremen, Germany) as described in Sayle et al. [87]. Bone collagen (~0.7 mg) was combusted in the presence of oxygen in a single reactor containing tungstic oxide and copper wires at 1020°C to produce N_2, CO_2 and SO_2. A magnesium perchlorate trap was used to eliminate water produced during the combustion process, and the gases were separated in a GC column heated between 70°C and 240°C. Helium was used as a carrier gas throughout the procedure. N_2, CO_2, and SO_2 entered the mass spectrometer via an open split arrangement within the ConfloIV and were analysed against their corresponding reference gases. The International Atomic Energy Agency (IAEA) reference materials USGS40 (L-glutamic acid, $\delta^{13}C$ (V-PDB) = -26.39 ± 0.04‰, $\delta^{15}N$ (AIR) = -4.52 ± 0.06‰) and USGS41a (L-glutamic acid, $\delta^{13}C$ (V-PDB) = 36.55 ± 0.08‰, $\delta^{15}N$ (AIR) = 47.55 ± 0.15‰) were used to normalise $\delta^{15}N$ and $\delta^{13}C$ values. Two in-house standards (GS2, δ34S (V-CDT) = -10.28 ± 0.18‰ and GAS2, $\delta^{34}S$ (V-CDT) = 18.56 ± 0.10‰) that are calibrated to the International Atomic Energy Agency (IAEA) reference materials IAEA-S-2 (silver sulfide, $\delta^{34}S$ (V-CDT) = 22.62 ± 0.08‰) and IAEA-S-3 (silver sulfide, $\delta^{34}S$ (V-CDT) = -32.49 ± 0.08‰) were used to normalise $\delta^{34}S$ values. Normalisation was checked using the well characterised Elemental Microanalysis IRMS fish gelatin standard

B2215 ($\delta^{13}C$ (V-PDB) = -22.92 ± 0.10‰, $\delta^{15}N$ (AIR) = 4.26 ± 0.12‰, $\delta^{34}S$ (V-CDT) = 1.21 ± 0.24‰) and/or USGS88 (marine collagen, $\delta^{13}C$ (V-PDB) = -16.06 ± 0.07‰, $\delta^{15}N$ (AIR) = 14.96 ± 0.14‰, $\delta^{34}S$ (V-CDT) = 17.10 ± 0.44‰). Precision is determined to be ± 0.2‰ for δ15N, ± 0.1‰ for $\delta^{13}C$ and ± 0.4‰ for $\delta^{34}S$ and is based on repeated measurements of Elemental Microanalysis IRMS fish gelatin standard B2215. 19% of samples were analysed in duplicate.

Samples with insufficient aliquots for sulphur isotope analysis (n = 26, 10%) had their stable carbon and nitrogen isotope values determined in the Stable Isotope Analysis Laboratory in ICTA-UAB. Duplicate collagen samples (0.5 mg) were analysed using an elemental analyser (EA) Flash (ThermoScientific, Bremen, Germany) coupled to a Thermo Delta V Advantage isotope ratio mass spectrometer (IRMS) with a Conflo IV interface (ThermoScientific, Bremen, Germany). The IAEA reference material (IAEA 600, caffeine, $\delta^{13}C$ (V-PDB) = -27.77 ± 0.04‰, δ15N (AIR) = 1.0 ± 0.2‰, IAEA, Vienna, Austria) and the United States Geological Service (USGS) reference material (USGS 62, caffeine, $\delta^{13}C$ (V-PDB) = -14.79 ± 0.04‰, $\delta^{15}N$ (AIR) = 20.17 ± 0.06 ‰, USGS, Reston, VA) were used to normalise $\delta^{15}N$ and $\delta^{13}C$ values. The analytical error (standard deviation) was determined to be 0.04‰ for $\delta^{13}C$ and 0.07‰ for $\delta^{15}N$. Results are reported as per mil (‰) relative to the internationally accepted standards V-PDB, AIR and V-CDT. Present-day collagen $\delta^{13}C$ values were corrected for the Suess effect using a $\delta^{13}C$ correction factor of +1.8‰ observed in the South Atlantic [88].

We employed standard ellipses to delineate present-day and historical ecological niches based on modern and archaeological bone collagen δ13C, δ15N, and δ34S values. Ecological niches were built using SIBER 2.1.8 (Stable Isotope Bayesian Ellipses in R, [89]) in RStudio [90]. Comprehensive information on the model parameters and assumptions can be found in Jackson et al. [89]. In brief, Bayesian methods were applied to generate standard ellipses that elucidate the isotopic and ecological niches of taxonomic species within a given community. These ellipses were individually constrained using the average isotopes values from each species, encompassing 95% of the data (p = 0.95). Subsequently, the Standard Ellipse Area correction (SEAc) was used to calculate the degree of overlap among these species' niches.

6.2.4. Otolith samples and estimated body total length

Otoliths of barred grunt and whitemouth croaker were sampled from pre-colonial (BPII) and historical (PG-U21) sites for estimating the body total length (BTL). These species were selected due to their relative abundance and the ease of taxonomic identification based on their otolith morphometric traits. Otoliths of barred grunt (n = 11) from BPII were retrieved from bulk archaeological deposits sieved with 5 mm mesh size. Otoliths of barred grunt (n = 177) and whitemouth croaker (n = 129) from PG-U21 were sieved from bulk archaeological deposits using a 2.5 mm mesh size. Otoliths were identified through side-by-side comparison with reference collections at the *Museu Arqueológico de Sambaqui de Joinville* (MASJ) and the *Laboratório de Arqueologia e Patrimônio Arqueológico* (LAPArq) of the *Universidade da Região de Joinville* (Univille). Some species were also identified by comparison with the digital Collection of Otoliths of Teleost Fishes from the Southeast-South Region of Brazil (COSS-Brasil) of the Oceanographic Institute of the University of São Paulo [91]. Otoliths were first sorted by laterality and then the length (OL) measured using a Digimess 150 mm digital calliper. OL was used to estimate body total length (BTL) according to equations for present-day populations of barred grunt [92] and whitemouth croaker [93] in the Southwestern Atlantic Ocean:

Eq. 1 Barred grunt, $BTL = 1.3292 * OL1.1623$ ($r = 0.98$, $n = 76$).

Eq. 2 Whitemouth croaker, $BTL = 24.34 + 22.57 * OL$ ($r = 0.99$, $n = 93$).

We extended our analysis to previously published OL data for barred grunt and whitemouth croaker from other pre-colonial archaeological sites in southern Brazil (Figure 6.1B-C). These included otoliths from Cubatão I (CBI, n = 37 whitemouth croaker) dated between 3550–3100 and 2350–2000 cal BP [32] and from Rio do Meio (RM, n = 911 whitemouth croaker; n = 37 barred grunt) dated between 650–500 and 550–250 cal BP [37,94]. Faunal remains from these sites were recovered from bulk deposits sieved with 5 and 2 mm mesh sizes. Otoliths from CBI and RM were measured using a Zeiss Stemi 200 magnifier with a Dino-Eye coupled camera (DinoCapture software) and Digimess 150 mm digital calliper. OL is presented with one decimal place for comparison with data previously published for Rio do Meio [37]. OL comparisons between sites were performed using statistical tests in Past 4.10 [95] and RStudio Software [90]. Since the normal distribution of OL could be rejected (Shapiro-Wilk W), the Kruskal Wallis non-parametric test followed by the Wilcoxon rank sum test (Bonferroni method) was used for OL comparisons (see SM6).

6.2.5. Measured BTL in present-day populations

The estimated BTL of archaeological individuals was compared to measured values in modern specimens collected from the Southwestern Atlantic Ocean as part of biological studies [18,76] (Figure 6.1A). Ideally, BTL data should originate from populations in similar environmental conditions to those found in archaeological contexts. In the case of whitemouth croaker (n = 357), this was achieved by using BTL data from southern Brazil, caught between latitudes 22°S and 29°S and recorded in 1989 and 1990. The fishing area corresponds to the FAO Fishing Area 41.2.1 (Santos, [96]). This includes the coastal and offshore zones of the states of Santa Catarina, Paraná, São Paulo, and Rio de Janeiro [76], which are in close proximity to the archaeological specimens.

Conversely, the lack of studies and methodological limitations related to BTL of modern barred grunts from southern and southeastern Brazil introduced uncertainties in data comparison. For example, BTL data collected by Pina and Chaves [97] were obtained from accidentally captured specimens (bycatch) and may not represent the entire population. In the case of Pombo et al. [98], the BTL data derived from specimens captured in shallow coastal waters (less than four metres deep) and therefore may be biassed toward juvenile individuals. To address these limitations, we have used barred grunt BTL data from specimens (n = 410) collected from FAO Fishing Area 41.1.2 (Natal, [96]), specifically at latitude 09°S in the state of Alagoas, between 2009 and 2012 [18]. These data include specimens captured using various methods, such as beach seines, gillnets, and trawls [18].

It is important to emphasise that the BTL of modern studies should represents the size distribution of the underlying populations, while archaeological specimens are fisheries resources, as such their BTL are largely influenced by fishing goals, gear type and market forces, among others [76,99–101], as well as recovery techniques and taphonomic processes [102–104]. Comparisons between BTL of archaeological catches and modern populations for stock size assessment, therefore, is not straightforward [105].

6.3. Results

6.3.1. Collagen composition in modern fish

Collagen extracted from all modern bones (n = 74) presented wt%C (39.22% to 45.49%), wt%N (13.87% to 16.38%), and C:N molar ratios (3.10 to 3.57) consistent with well-preserved bone collagen [82,106,107] (SM2, SM3). For eight samples (11%), the C:N was higher (>3.30) than reported for modern bony fish (3.00 to 3.30) [107]. Elevated C:N in modern samples may be produced by the presence of lipids and non-collagen proteins present in the extracts [86,107,108], but these are expected to have been adequately removed by the defatting and NaOH wash processes employed. At least in the case of lipids, the lack of a negative correlation between the $\delta^{13}C$ values and the C:N molar ratios ($r = -0.17$, $p = 0.16$, Pearson correlation, SM4) [107] assures that modern collagen samples retained their genuine $\delta^{13}C$ and $\delta^{15}N$ values. The wt%S ranged from 0.34% to 0.62% (median 0.44%), with average C:S and N:S molar ratios of 263.06 ± 30.8 (182.10 to 341.15) and 81.44 ± 10.4 (54.60 to 105.45), respectively. Some samples (n = 13) had lower wt%S than the acceptable ranges for intact archaeological (0.40–0.85%) and modern (0.52–0.83%) fish bone collagen, established primarily from cold-water species like *Gadus morhua* [109]. Our average C:S and N:S molar ratios exceeded those of Nehlich and Richards [109] (C:S = 175 ± 50; N:S = 60 ± 20;), and instead, aligned with wt%S reported in modern bone collagen from marine (0.24–0.49%, [110,111]) and freshwater species (0.31–0.38%, [112]) from tropical and subtropical regions. Comparable C:S (209 - 461) and N:S (67–149) molar ratios were reported in additional studies by [110,111]. Notably, various studies highlight differences in C:N ratios between cold- and warm-water bony fish species [86,113,114]; however, a closer look at the available data also points to differences in wt%S, and C:S and N:S ratios. For example, Szpak's collated data [115] for modern skin (n = 91) and bone (n = 12) across marine and freshwater species from subtropical and tropical regions (warm-water fish) show a wider range of methionine and thus wt%S values (0.09–1.02%) compared to those from polar and temperate zones (0.25–

0.61%, cold-water fish) (Figure 6.3). Even though the observed differences were not statistically significant (Kruskal-Wallis test, $p < 0.05$, for skin only), this also leads to higher average C:S (343 ± 198) and N:S (109 ± 61) ratios in warm-water fish than in cold-water species (CS = 297 ± 69, NS = 95 ± 22), which are consistent with our results. Elemental composition of modern fish bone collagen presented here suggests that the existing sulphur quality benchmarks [109] do not encompass the full spectrum of wt%S found in modern fish collagen, especially those originating from warmer habitats, thus inviting further investigation.

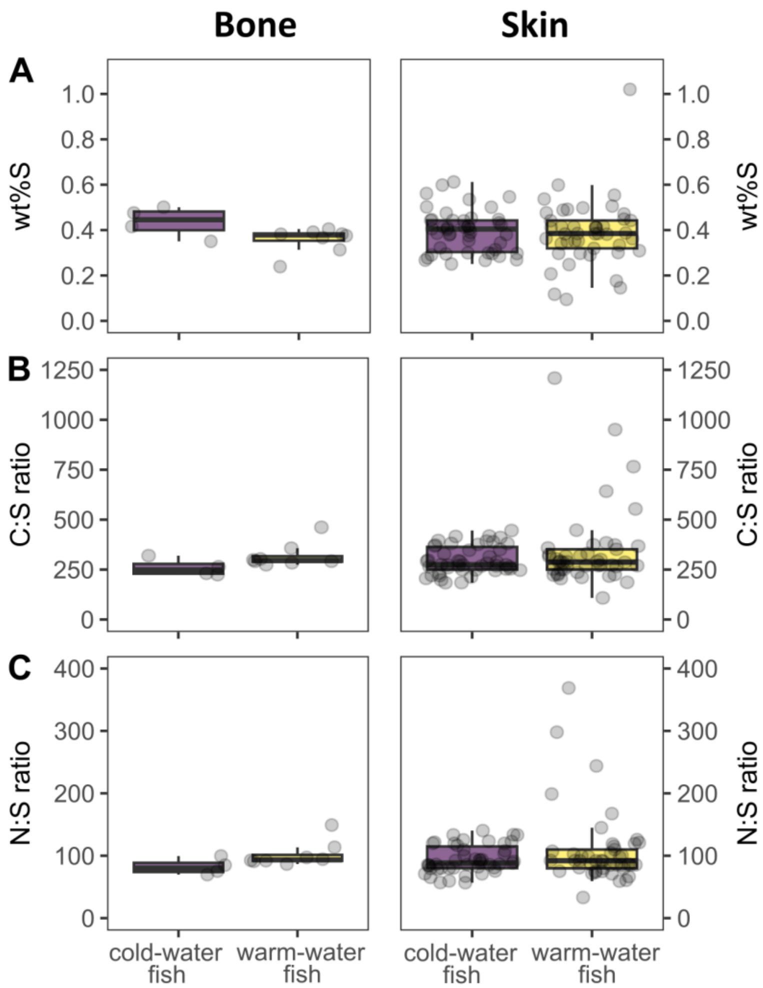

Figure 6.3. *Collagen wt%S, C:S and N:S molar ratios for cold-water and warm-water bony fish species observed in bone and skin from amino acid compositions (90). While the differences in wt%S (p = 0.67), C:S (p = 0.73), and N:S (p = 0.77) between cold-water and warm-water fish (considering only skin) were not statistically significant (Kruskal-Wallis test after rejecting normal distribution with Shapiro-Wilk normality test, p < 0.05), it is still evident that several warm-water fish tend to exhibit lower wt%S values when compared to cold-water species.*

6.3.2. Stable isotope values in modern fish

Median $\delta^{13}C$ values ranged from -10.98‰ (barred grunt) to -9.72‰ (white sea catfish), reflecting assimilated carbon from benthic microalgae and marine phytoplankton [116]. Fat snook exhibited a wider range of $\delta^{13}C$ values (-15.49‰ to -8.99‰), indicating that individuals with ^{13}C-depleted collagen assimilated organic matter in habitats with a higher input of continental waters [116,117]. Median $\delta^{15}N$ values of modern individuals ranged from +13.08‰ (whitemouth croaker) to +16.04‰ (white sea catfish), and distinguished piscivore (white sea catfish [118]) from invertivorous (fat snook, [119]) and omnivorous (barred grunt and whitemouth croaker) species feeding primarily on invertebrates and sporadically on fish [120]. Niche partitioning among species is evident through two CN ellipses groups: one featuring white sea catfish at a higher trophic level, with a slight overlap with fat snook, and the other encompassing barred grunt, whitemouth croaker, and fat snook, sharing food resources and habitats at a lower trophic position (Figure 6.4A). Median $\delta^{34}S$ values ranged from +12.03‰ (white sea catfish) to +17.69‰ (barred grunt), and further separated species based in distinct feeding grounds [46,51,56–58], as expressed by the CS ellipses (Figure 6.4B). Specifically, higher $\delta^{34}S$ values in barred grunt suggest the species feed predominantly on ^{34}S-enriched food webs located nearshore or in areas exposed to the open sea with a stronger influence of marine sulphates. In comparison, lower $\delta^{34}S$ values in white sea catfish, fat snook and whitemouth croaker are indicative of ^{34}S-depleted food webs in shallow and inner-estuarine waters [120]. The δ13C, δ15N and δ34S values were not significantly correlated with the measured BTL, which might be due to the fact that modern specimens were mostly large adult individuals (SM4). The only exception was a moderate negative correlation between $\delta^{13}C$ and BTL in white sea catfish ($r = -0.46$, $p = 0.039$, SM4), which could potentially be explained by the wide range of environments occupied by this species, forming brackish (spawning in estuarine waters and migrating to freshwater, marine waters or both) and freshwater residents [121,122].

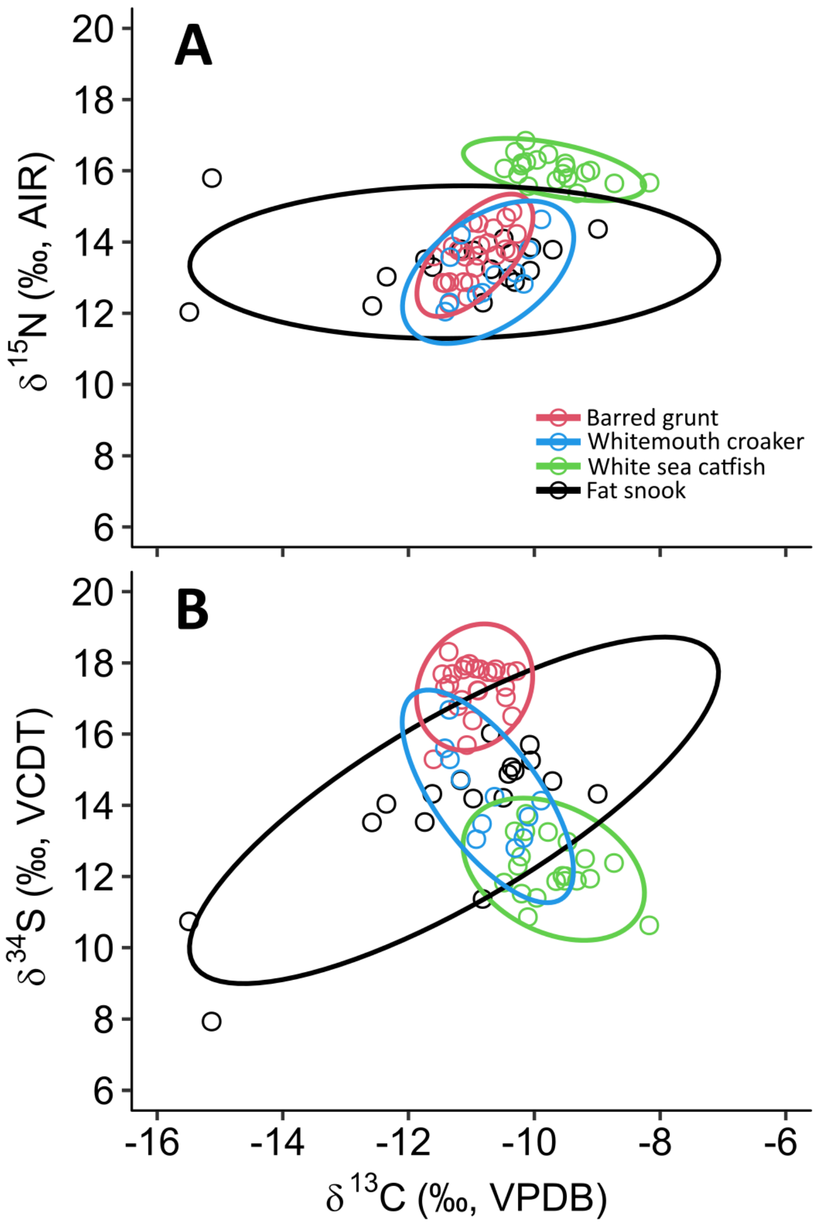

Figure 6.4. *Ellipse-derived isotopic niches according to (A) carbon and nitrogen and (B) carbon and sulphur isotope compositions.*

6.3.3. Collagen stable isotopes of archaeological fish remains

Collagen was successfully extracted from 140 out of 203 archaeological fish samples. Of these, 122 samples had C:N molar ratios (3.09 to 3.60) typical of well-preserved archaeological bone collagen [82,106,123]. 107 samples had enough collagen for δ34S analyses, exhibiting wt%S ranging from 0.24% to 0.59%. Of these, 72 samples had wt%S values consistent with values observed in modern individuals (0.34% to 0.59%). 35 samples had lower wt%S values than modern counterparts

(0.24% to 0.33%) but yielded comparable $\delta^{34}S$ results to those within acceptable wt%S values, thus their $\delta^{34}S$ values were deemed reliable (Figure 6.4A-B).

Median $\delta^{13}C$ values ranged from -13.60‰ (white sea catfish) to -11.04‰ (fat snook), with the wider range of values observed in pre-colonial fat snook (-21.40‰ to -9.20‰) from MO and BPII, and white sea catfish (-17.40‰ to -9.30‰) from MO. Median $\delta^{15}N$ values ranged from +9.40‰ (white sea catfish) to +13.93‰ (whitemouth croaker), whereas the median $\delta^{34}S$ values ranged from +7.45‰ (fat snook) to +14.27‰ (barred grunt) (Figure 6.5). Pre-colonial white sea catfish from MO had $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ values significantly lower than their modern counterparts, which is evident by the lack of overlap in the CN, CS and NS ellipses (SM4). Fat snook from MO and BPII exhibited $\delta^{15}N$ and $\delta^{34}S$ values significantly lower than modern specimens, but indistinguishable $\delta^{13}C$ values, with some overlap in the CN, CS and NS ellipses. Similarly, the $\delta^{13}C$ values of pre-colonial whitemouth croaker from MO were indistinguishable from modern specimens, with significant differences only between $\delta^{15}N$ values. By contrast, barred grunt from BPII show comparable $\delta^{13}C$ and $\delta^{15}N$ values with modern specimens, with the exception of δ34S values. Finally, barred grunt and whitemouth croaker from PG-U21 had $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ values significantly lower than modern specimens, with the exception of the comparable $\delta^{15}N$ values between modern and historical whitemouth croaker.

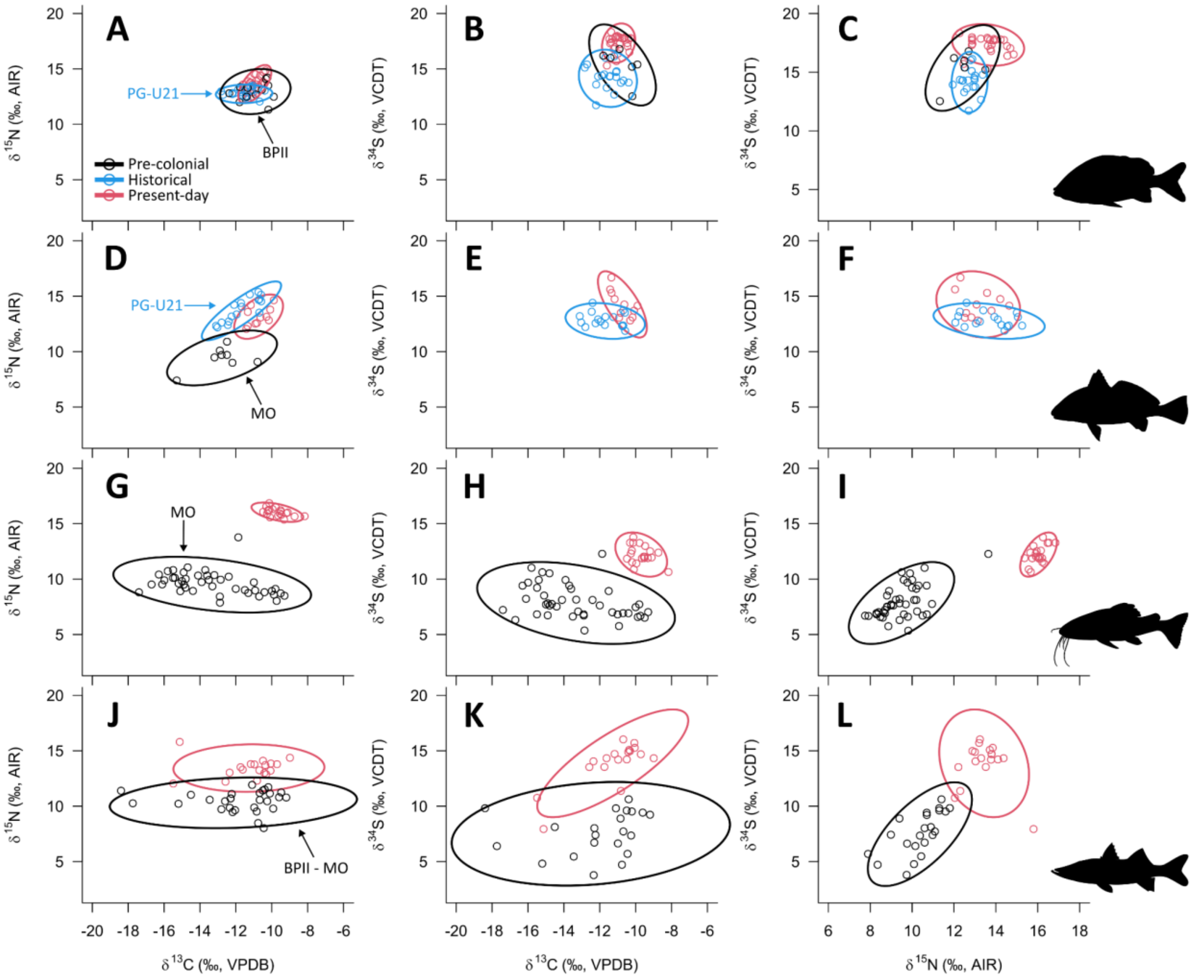

Figure 6.5. *Stable isotope values for (A–C) barred grunt, (D–F) whitemouth croaker, (G–I) white sea catfish, (J–L) fat snook. Pre-colonial whitemouth croaker (n = 8) individuals from Morro do Ouro (MO) previously analysed for $\delta^{13}C$ and $\delta^{15}N$ values (34) were also included in our study.*

6.3.4. Estimated body size

Archaeological barred grunt had median BTL of 21.58 cm (10.67 to 28.56 cm, n = 11, BPII), 22.88 cm (4.80 to 30.89 cm, n = 177, PG-U21) and 23.64 cm (17.97 to 28.80 cm, n = 37, RM) (SM5), and were statistically indistinguishable between sites (SM6). By contrast, modern specimens had a median BTL of 22.00 cm (2.8 to 35.4 cm, n = 410), which was significantly smaller than specimens captured in RM at 650–500 and 550–250 cal BP and in PG-U21 in the late 19th–early 20th centuries AD (Figure 6.6A). As barred grunt reach sexual maturity at a BTL of ~14 cm [17,18], the majority of the archaeological specimens, regardless of their chronology, can be largely assigned to adult and sexually mature individuals. However, it is worth noting that sexual maturity may differ according to seawater temperatures. The reference used herein is from warmer waters of northern Brazil, which may differ from the colder waters of southern Brazil.

The estimated BTL of archaeological whitemouth croaker exhibited medians of 30.92 cm (16.36 to 49.24 cm, n = 37, CBI), 35.39 cm (15.98 to 62.70 cm, RM) and 43.80 cm (21.08 to 74.36 cm, n = 129, PG-U21) (Figure 6.6B). The results revealed a significantly higher BTL in historical (PG-U21) compared to pre-colonial (CBI, RM) specimens (SM6). Moreover, the median BTL of pre-colonial (CBI, RM) and historical (PG-U21) specimens were also significantly higher than modern counterparts, which had a median value of 29.00 cm (17.60 to 63.00 cm, n = 357, SM6). A few individuals from the late 19th–early 20th centuries AD also exceeded the maximum BTL of modern specimens in the region and elsewhere [124]. In southeastern Brazil, whitemouth croakers typically attain sexual maturity at a BTL of approximately 27 cm [76,125,126], therefore the archaeological specimens from pre-colonial and historical periods can be predominantly assigned to sexually mature, adult individuals.

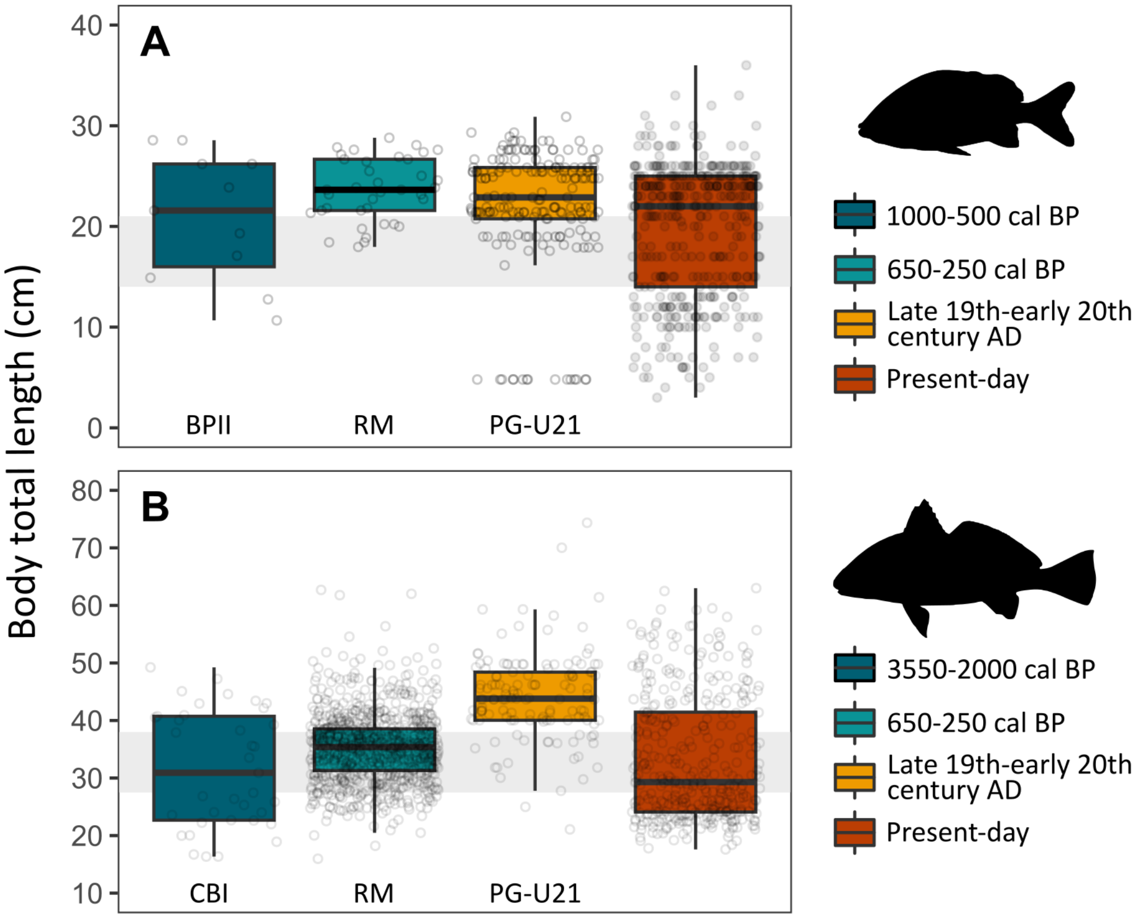

Figure 6.6. *Body total length of (A) barred grunt and (B) whitemouth croaker across time periods. The size interval of first sexual maturity is represented by the grey bar for each species (barred grunt, (17, 18), whitemouth croaker (76, 101)). The horizontal lines correspond to the medians and the hinges to the 25th (Q1) and 75th (Q3) percentiles. The whiskers extend from the hinge to the smallest or largest observation greater than or equal to − 1.5 * IQR (interquartile range) or less than or equal to + 1.5 * IQR, respectively. The individual observations are represented by circles.*

6.4. Discussion

6.4.1. Pre-colonial fisheries

Stable isotope analyses have been extensively employed to uncover feeding, residential and mobility patterns among marine organisms, and also to reconstruct the ecology of past fishing practices [45,47,60,61]. In this study, we have expanded this approach to investigate pre-colonial and historical fisheries operating in Babitonga Bay for at least 4500 years. Overall, the results suggest that pre-colonial groups exploited a range of mangrove habitats. Specifically, groups residing at MO (4800–4550 and 4500–4100 cal BP) and CBI (3550–3100 and 2350–2000 cal BP), located in the inner sector of the bay, primarily targeted white sea catfish, fat snook, and whitemouth croaker within a gradient of fresh/brackishwater to full marine habitats. The wide range of $\delta^{13}C$ and $\delta^{34}S$ values observed in these species reflect dietary heterogeneity, thus suggesting the capture of transient animals. Pre-colonial groups inhabiting BPII (1000–750 and 650–500 cal BP), an open coastal site, exploited fat snook with a broader range of $\delta^{13}C$ and $\delta^{34}S$ values, indicating a wider home range. However, they also targeted barred grunt from less diverse isotopic niches, which we attribute to stocks residing mostly in open coastal areas [18,98].

Inter-specific isotopic variability in pre-colonial times was much higher than seen today. The wider range of $\delta^{13}C$ values in pre-colonial white sea catfish and fat snook, and their significantly lower $\delta^{15}N$ and $\delta^{34}S$ values compared to modern counterparts, suggest that small and juvenile individuals were the primary targets of pre-colonial groups. The lower $\delta^{15}N$ and $\delta^{34}S$ values of pre-colonial specimens also indicate diets based on benthic foods under a higher influence of sedimentary sulphides [60], again suggesting these were juvenile populations residing predominantly inside the bay. Direct comparison between archaeological and modern specimens, however, is hampered by the influence of anthropogenic activities on the $\delta^{15}N$ and $\delta^{34}S$ of modern aquatic food webs [127–129]. The high $\delta^{15}N$ values of the modern specimens may reflect inputs from untreated sewage, agricultural fertilisers, and industrial products, which have significantly increased in Babitonga Bay in recent decades [130]. The presence of smelting, galvanic, and textile industries in the region since the late 19th century [131,132] may also account for the substantial shifts in fish $\delta^{34}S$ values over time [127], however the isotopic directions derived from these processes are unknown in the area.

Nevertheless, the BTL data from whitemouth croaker support the view that small individuals were commonly exploited in pre-colonial times. Instead, for barred grunt, large adults and sexually mature individuals were consistently exploited, as shown by derived BTLs from BPII and RM (650–500 and 550–250 cal BP). Even though BTL data from otoliths are susceptible to issues of preservation and recovery techniques [102,103], these factors are unlikely to have significantly affected our size reconstructions. First, the mesh size used at RM (2 mm) is regarded as suitable for retrieving small archaeological fish remains [133]. Second, some of the smaller individuals, including both barred grunt and whitemouth croaker, were recovered from pre-colonial sites using larger mesh sizes (BPII and CBI). Finally, Fossile et al. have recently assessed the impact of recovery techniques on archaeological fish remains in southern Brazil and found no direct correlations between mesh size and species richness [9]. Together, these lines of evidence suggest that archaeological otoliths accurately reflect the original catch composition processed at the sites.

We found no evidence that pre-colonial Indigenous groups overexploited mangrove fish species, even though our results suggest their preference for juvenile individuals, as demonstrated in other regions [31]. Regrettably, the temporal resolution of our study is low and the number of sites is limited for conclusive interpretations to be drawn. The size distribution of juvenile whitemouth croaker, fat snook, and white sea catfish possibly indicate that these species were pursued in shallow, protected coastal habitats using a wider array of mass harvesting fishing devices, including nets, traps and weirs, which are documented in the Brazilian archaeological record [134–136]. Adult barred grunt could have been caught in deeper waters off the continental shelf using selective fishing gear such as baited fishing hooks [34,134]. Interestingly, groups occupying MO ~4500 years ago would have been exposed to more marine conditions due to the higher sea level (+ 2.6m) compared to present day [137]. However, the $\delta^{13}C$ and $\delta^{34}S$ values of fat snook, whitemouth croaker, and white sea catfish from this site reveal the capture of estuarine populations. Thus, despite coastal environmental changes linked to sea level fluctuations over the last 4500 years, our stable isotope and BTL results indicate a preference for shallow and sheltered estuarine waters by pre-colonial fisheries, where individuals of varying ages, strengths, and skills could have contributed to the collective nature of Indigenous fisheries.

6.4.2. Historical fisheries

Caches of whitemouth croaker and barred grunt in the late 19th and early 20th centuries AD were likely driven by both subsistence and the development of commercial fisheries to meet increased demands from local and regional markets

[40,81]. BTL data from barred grunt and whitemouth croaker indicate that most of the specimens in PG-U21 were adults and even larger than modern individuals from Babitonga Bay and southern Brazil. Given the historic and current economic importance of whitemouth croaker [126,138], the high frequency of larger individuals could be the outcome of some early market forces, such as the effect of higher unit prices for larger individuals [101,139]. Nowadays, barred grunt has limited market demand and is mainly pursued for household consumption [13,16,97], but large individuals may have had a higher market value in the past. The presence of a few juvenile individuals may be linked to bycatch (taxa accidentally caught), which has been documented in the region since at least the early 20th century [39].

Significantly, the observation that some archaeological specimens were larger than those reported for modern populations suggests past stocks were less affected by overfishing compared to modern populations, which is corroborated by previous studies in the region [9]. It is possible that the life history traits of these species, such as the high fecundity and multiple spawning events of whitemouth croaker, likely contributed to their resilience in the context of low-impact fishing communities. Nevertheless, long-term removal of large individuals is known to produce deleterious effects on fish populations, notably through the decline of offspring and spatial disruption in recruitments [140]. For example, fecundity and reproduction is higher in some species at a more advanced age and larger size, while the time and location of reproduction may also change depending on these same factors [141]. Studies have also shown that egg quality and larval performance traits are influenced by the size of female phenotypes, and that recruitment can be affected by size-dependent maternal effects on early survival, and their capacity to recover from overexploitation [141–143]. While further studies are needed, our results suggest that some key demersal stocks have experienced size truncation for at least 150 years. This implies that the anthropogenic impacts documented from the mid-20th century [41,42] actually affected stocks that had already undergone decades or even centuries of selective fishing practices. Our study advocates for the integration of historical data in fisheries assessment and management to set more informed reference baselines in Brazilian mangrove systems.

The overlap of CN ellipses between historical and modern barred grunt and whitemouth croaker confirm that specimens in PG-U21 were primarily targeted in fully marine habitats, which concentrate large and adult individuals [120]. These were possibly caught using gillnets, which have been documented in Santa Catarina since the 1870's [40] and are currently some of the most common fishing gear used to capture demersal species in southern Brazil [144]. Subtle differences in the median $\delta^{15}N$ values, however, highlight the complexity of the nitrogen cycle in regional marine food webs. For example, while archaeological barred grunt had a lower median $\delta^{15}N$ value (-0.90‰) compared to modern specimens, the opposite offset was observed for whitemouth croaker (+0.85‰). For barred grunt the offset could be linked to ontogenetic differences in feeding behaviour, as suggested by the observed positive correlation between $\delta^{15}N$ and $\delta^{34}S$ values. Conversely, differences in whitemouth croaker are not easily explained in terms of size-related habitat segregation, even though the BTL of these individuals could not be estimated. These could instead be attributed to temporal differences (e.g. seasonal, inter-annual) in feeding ecology [120] that cannot be addressed with bulk collagen isotope data.

6.5. Conclusion

Mangrove systems have supported human societies since prehistoric times, but the benefits they provide have become increasingly threatened by overexploitation, habitat degradation, pollution, and climate change in recent times. Understanding the origin and evolving nature of these anthropogenic stressors is essential for identifying historical turning points and anticipating future drivers of change. Interestingly, no body size decline has been observed between pre-colonial and historical fisheries, suggesting that Indigenous and late colonial groups had minimal detrimental impacts on mangrove fish stocks in Babitonga Bay. However, the preference for targeting large and adult individuals by subsistence-commercial fisheries 150 years ago reveal that some drivers of fish decline and contemporary market forces shaping the fishing industry, such as fish species price and size considerations, have a long history in southern Brazil.

6.6. Supplementary material

SM1. Radiocarbon date of archaeological sites

To improve new chronological attributions of the BPII, bones of terrestrial mammals (n = 2) were selected for radiocarbon dating (AMS) at CEDAD, Università di Salento (Italy). Conventional radiocarbon dates were calibrated using OxCal v. 4.4 (1). Samples were calibrated using the 100% atmospheric calibration curve for the southern hemisphere, SHCal20 (2). Calibrated dates with 68% probability were rounded to 50 years.

Table 1. Radiocarbon chronology and contextual information of archaeological bone samples from pre-colonial sites. Dates using only one calibration curve (atmospheric, marine) are unmodelled BP. Dates using two calibration curves (human samples) are modelled BP.

Site	Lab code	Material	^{14}C yr. BP	^{14}C yr. cal BP (2σ)	Median cal BP	Reference
Bupeva II	Kia22262	Marine mammal	2325 ± 25	2100 – 1700	1900	(*3*)
Bupeva II	LTL22554	Terrestrial mammal	586 ± 40	650 – 500	550	This study
Bupeva II	LTL22555	*Tayassu* sp.	1002 ± 40	1000 – 750	850	This study
Sambaqui Morro do Ouro	AA104767	Human teeth	4425 ± 39	4800 – 4550	4700	(*4*)
Sambaqui Morro do Ouro	AA104770	Human bone	3938 ± 55	4500 – 4100	4300	(*4*)
Sambaqui Morro do Ouro	Beta444034	Human bone	4200 ± 30	4550 – 4250	4400	(*4*)

Sambaqui Morro do Ouro	AA104768	Human bone	4086 ± 42	4500 – 4250	4400	(*4*)
Sambaqui Cubatão I	Beta-259823	Shell	2560 ± 40	2350 – 2000	2200	(*5*)
Sambaqui Cubatão I	Beta-268518	Human bone	2430 ± 40	2350 – 2100	2250	(*5*)
Sambaqui Cubatão I	Beta-268526	Charcoal	2250 ± 40	2350 – 2100	2250	(*5*)
Sambaqui Cubatão I	Beta-268523	Human bone	2460 ± 40	2350 – 2200	2300	(*5*)
Sambaqui Cubatão I	Beta-268525	Human bone	2460 ± 40	2400 – 2200	2300	(*5*)
Sambaqui Cubatão I	Ly- 4524	Human bone	2460 ± 30	2350 – 2150	2250	(*5*)
Sambaqui Cubatão I	Ly-4527	Human bone	2495 ± 30	2350 – 2200	2300	(*5*)
Sambaqui Cubatão I	Beta 268524	Human bone	2510 ± 40	2350 – 2200	2300	(*5*)
Sambaqui Cubatão I	Beta-259519	Human bone	2520 ± 40	2400 – 2200	2350	(*5*)
Sambaqui Cubatão I	Ly-4528	Human bone	2520 ± 40	2400 – 2250	2350	(*5*)

Sambaqui Cubatão I	Beta-259824	Shell	2660 ± 40	2550 – 2100	2350	(*5*)
Sambaqui Cubatão I	Ly-4526	Human bone	2620 ± 30	2400 – 2150	2300	(*5*)
Sambaqui Cubatão I	Beta-259821	Human bone	2630 ± 40	2450 – 2300	2350	(*5*)
Sambaqui Cubatão I	Beta-259820	Human bone	2670 ± 40	2450 – 2300	2350	(*5*)
Sambaqui Cubatão I	Beta-259827	Charcoal	2890 ± 70	3200 – 2750	2950	(*5*)
Sambaqui Cubatão I	Beta-259825	Charcoal	2970 ± 60	3350 – 2850	3100	(*5*)
Sambaqui Cubatão I	Ly-4525	Charcoal	2975 ± 30	3250 – 2950	3100	(*5*)
Sambaqui Cubatão I	Beta-259829	Charcoal	3040 ± 60	3400 – 2950	3200	(*5*)
Sambaqui Cubatão I	Beta-259826	Charcoal	3110 ± 70	3450 – 3050	3250	(*5*)
Sambaqui Cubatão I	Beta-259828	Shell	3480 ± 60	3550 – 3100	3350	(*5*)

Rio do Meio (FLN-57)	Beta-451660	Charcoal	600 ± 30	650 – 500	550	(*6*)
Rio do Meio (FLN-57)	Beta-451661	Charcoal	620 ± 30	650 – 500	600	(*6*)
Rio do Meio (FLN-57)	Beta-178077	Marine shell	780 ± 60	550 – 250	400	(7)
Rio do Meio (FLN-57)	Beta-451662	Otolith	870 ± 30	600 – 300	450	(*6*)

Table 2. Radiocarbon chronology and contextual information of archaeological bone samples from historical sites, Praia Grande Unidade 21 (PG-U21).

Site	Lab code	Material	^{14}C yr. BP	^{14}C yr. cal BP (2σ)	Median cal AD	Reference
PG-U21	LTL-22550	Bovidae	281 ± 45	1510 – 1800	1660	(*8*)
PG-U21	LTL-22551	Dasypodidae	139 ± 40	1690 - 1950	1850	(*8*)

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SM2. Samples treatment for Morro do Ouro

Table 1. Sample treatment for Morro do Ouro.

ID	NaOH	wt%C	wt%N	wt%S	CN	CS	NS	$\delta^{13}C$	$\delta^{15}N$	$\delta^{34}S$
TRD_777	Y	38.35	13.80	0.34	3.25	310.00	96.00	-10.50	11.20	9.00
TRD_777	N	35.00	12.80	0.28	3.20	337.52	105.58	-10.50	11.30	9.50
TRD_778	Y	29.10	9.90	0.32	3.40	246.00	72.00	-10.70	11.40	7.30
TRD_778	N	34.80	12.30	0.30	3.31	307.34	92.88	-10.20	11.60	9.40
TRD_779	Y	38.70	13.90	0.33	3.20	316.00	98.00	-9.40	10.70	8.80
TRD_779	N	34.80	12.50	0.32	3.24	288.81	89.14	-9.60	10.70	9.30

Table 2. Paired analysis of weight percent carbon (wt%C) in treated and untreated NaOH samples from Morro do Ouro.

Paired analysis for wt%C	
wt%C (treated NaOH)	wt%C (untreated NaOH)
N: 3	
Mean: 35.383	Mean: 34.867
Median: 38.35	Median: 34.8
t test	
Mean difference: 0.51667	95% conf.: (-12.875 13.908)
t : 0.166	p (same mean): 0.88342
Exact:	p (same mean): 1
Sign test	
r : 2	p (same median): 1

Wilcoxon test (normal approximation inaccurate) :	
W : 3	
Normal appr. z : 0	p (same median): 1
Monte Carlo (n=99999):	p (same median): 1
Exact:	p (same median): 1

Table 3. Paired analysis of weight percent nitrogen (wt%N) in treated and untreated NaOH samples from Morro do Ouro.

Paired analysis for wt%N	
wt%N (treated NaOH)	wt%N (untreated NaOH)
N: 3	
Mean: 12.533	Mean: 12.533
Median: 13.8	Median: 12.5
t test	
Mean difference: 0	95% conf.: (-5.187 5.187)
t : 0	p (same mean): 1
Exact:	p (same mean): 1
Sign test	
r : 2	p (same median): 1
Wilcoxon test (normal approximation inaccurate) :	
W : 3	
Normal appr. z : 0	p (same median): 1
Monte Carlo (n=99999):	p (same median): 1
Exact:	p (same median): 1

Table 4. Paired analysis for weight percent sulphur (wt%S) in treated and untreated NaOH samples from Morro do Ouro.

Paired analysis for wt%S	
wt%S (treated NaOH)	wt%S (untreated NaOH)
N: 3	

Mean: 0.33	Mean: 0.3
Mean: 0.33	Mean: 0.3
t test	
Mean difference: 0.03	95% conf.: (-0.035724 0.095724)
t : 1.964	p (same mean): 0.1885
Exact:	p (same mean): 0.25
Sign test	
r : 3	p (same median): 0.25
Wilcoxon test (normal approximation inaccurate) :	
W : 6	
Normal appr. z : 1.6036	p (same median): 0.10881
Monte Carlo (n=99999):	p (same median): 0.2495
Exact:	p (same median): 0.25

Table 5. Paired analysis of CN ratio in treated and untreated NaOH samples from Morro do Ouro.

Paired analysis for CN ratio	
CN ratio (treated NaOH)	CN ratio (untreated NaOH)
N: 3	
Mean: 3.2833	Mean: 3.25
Median: 3.25	Median: 3.24
t test	
Mean difference: 0.033333	95% conf.: (-0.13207 0.19874)
t : 0.86711	p (same mean): 0.47729
Exact:	p (same mean): 0.5
Sign test	

r : 2	p (same median): 1
Wilcoxon test (normal approximation inaccurate) :	
W : 5	
Normal appr. z : 1.069	p (same median): 0.28505
Monte Carlo (n=99999):	p (same median): 0.49977
Exact:	p (same median): 0.5

Table 6. Paired analysis of CS ratio in treated and untreated NaOH samples from Morro do Ouro.

Paired analysis for CS ratio	
CS ratio (treated NaOH)	CS ratio (untreated NaOH)
N: 3	
Mean: 290.67	Mean: 311.22
Median: 310	Median: 307.34
t test	
Mean difference: 20.557	95% conf.: (-90.419 131.53)
t : -0.797	p (same mean): 0.50903
Exact:	p (same mean): 0.5
Sign test	
r : 2	p (same median): 1
Wilcoxon test (normal approximation inaccurate) :	
W : 5	
Normal appr. z : 1.069	p (same median): 0.28505
Monte Carlo (n=99999):	p (same median): 0.4992
Exact:	p (same median): 0.5

Table 7. Paired analysis of NS ratio in treated and untreated NaOH samples from Morro do Ouro.

Paired analysis for NS ratio	
NS ratio (treated NaOH)	NS ratio (untreated NaOH)
N: 3	
Mean: 88.667	Mean: 95.867
Median: 96	Median: 92.88
t test	
Mean difference: 7.2	95% conf.: (-30.092 44.492)
t : -0.83071	p (same mean): 0.49351
Exact:	p (same mean): 0.5
Sign test	
r : 2	p (same median): 1
Wilcoxon test (normal approximation inaccurate) :	
W : 5	
Normal appr. z : 1.069	p (same median): 0.28505
Monte Carlo (n=99999):	p (same median): 0.50003
Exact:	p (same median): 0.5

Table 8. Paired analysis of $\delta^{13}C$ in treated and untreated NaOH samples from Morro do Ouro.

Paired analysis for $\delta^{13}C$	
$\delta^{13}C$ (treated NaOH)	$\delta^{13}C$ (untreated NaOH)
N: 3	
Mean: -10.2	Mean: -10.1
Median: -10.5	Median: -10.2
t test	
Mean difference: 0.1	95% conf.: (-0.79567 0.99567)
t : -0.48038	p (same mean): 0.67837
Exact:	p (same mean): 1

Sign test	
r : 1	p (same median): 0.5
Wilcoxon test (normal approximation inaccurate) :	
W : 2	
Normal appr. z : 0.44721	p (same median): 0.65472
Monte Carlo (n=99999):	p (same median): 1
Exact:	p (same median): 1

Table 9. Paired analysis of $\delta^{15}N$ in treated and untreated NaOH samples from Morro do Ouro.

Paired analysis for $\delta^{15}N$	
$\delta^{15}N$ (treated NaOH)	$\delta^{15}N$ (untreated NaOH)
N: 3	
Mean: 11.1	Mean: 11.2
Median: 11.2	Median: 11.3
t test	
Mean difference: 0.1	95% conf.: (-0.14841 0.34841)
t : -1.7321	p (same mean): 0.2254
Exact:	p (same mean): 0.5
Sign test	
r : 2	p (same median): 0.5
Wilcoxon test (normal approximation inaccurate) :	
W : 3	
Normal appr. z : 1.3416	p (same median): 0.17971
Monte Carlo (n=99999):	p (same median): 0.49912
Exact:	p (same median): 0.5

Table 10. Paired analysis of $\delta^{34}S$ in treated and untreated NaOH samples from Morro do Ouro.

Paired analysis for $\delta^{34}S$	
$\delta^{34}S$ (treated NaOH)	$\delta^{34}S$ (untreated NaOH)
N: 3	
Mean: 8.3667	Mean: 9.4
Median: 8.8	Median: 9.4
t test	
Mean difference: 1.0333	95% conf.: (-1.2614 3.3281)
t : -1.9375	p (same mean): 0.19228
Exact:	p (same mean): 0.25
Sign test	
r : 3	p (same median): 0.25
Wilcoxon test (normal approximation inaccurate) :	
W : 6	
Normal appr. z : 1.633	p (same median): 0.10247
Monte Carlo (n=99999):	p (same median): 0.24951
Exact:	p (same median): 0.25

SM3. Stable isotope data

ID	Scientific name	Common name	Site	Type	wt%C	wt%N	wt%S	C:N	C:S	N:S	$\delta^{13}C$	$\delta^{15}N$	$\delta^{34}S$	Lab	Reference
TRD_1038	*Micropogonias furnieri*	Whitemouth croaker	Praia Grande Unidade 21	Historical	40.16	14.64	0.45	3.20	238.31	74.52	-10.60	15.00	13.39	SUERC	This study
TRD_1039	*Micropogonias furnieri*	Whitemouth croaker	Praia Grande Unidade 21	Historical	41.28	14.59	0.39	3.30	283.71	86.01	-12.45	12.28	13.48	SUERC	This study
TRD_1040	*Micropogonias furnieri*	Whitemouth croaker	Praia Grande Unidade 21	Historical	41.94	15.40	0.44	3.18	256.15	80.69	-10.73	14.54	12.17	SUERC	This study
TRD_1041	*Micropogonias furnieri*	Whitemouth croaker	Praia Grande Unidade 21	Historical	40.90	14.92	0.42	3.20	262.89	82.24	-10.75	15.26	12.23	SUERC	This study
TRD_1042	*Micropogonias furnieri*	Whitemouth croaker	Praia Grande Unidade 21	Historical	40.55	15.08	0.44	3.13	245.58	78.34	-10.69	14.62	12.23	SUERC	This study
TRD_1043	*Micropogonias furnieri*	Whitemouth croaker	Praia Grande Unidade 21	Historical	40.56	14.12	0.39	3.35	274.28	81.86	-11.72	14.27	12.30	SUERC	This study
TRD_1044	*Micropogonias furnieri*	Whitemouth croaker	Praia Grande Unidade 21	Historical	40.69	14.66	0.43	3.24	251.50	77.70	-11.23	15.05	13.00	SUERC	This study
TRD_1045	*Micropogonias furnieri*	Whitemouth croaker	Praia Grande Unidade 21	Historical	41.20	15.04	0.41	3.19	266.82	83.52	-10.59	14.42	11.77	SUERC	This study
TRD_1046	*Micropogonias furnieri*	Whitemouth croaker	Praia Grande Unidade 21	Historical	39.88	14.49	0.40	3.21	266.94	83.17	-11.96	13.24	12.59	SUERC	This study
TRD_1047	*Micropogonias furnieri*	Whitemouth croaker	Praia Grande Unidade 21	Historical	41.30	14.50	0.53	3.30	208.00	63.00	-10.70	13.40	13.60	SUERC	This study
TRD_1048	*Micropogonias furnieri*	Whitemouth croaker	Praia Grande Unidade 21	Historical	39.00	13.10	0.49	3.50	212.00	61.00	-12.10	14.10	12.80	SUERC	This study
TRD_1049	*Micropogonias furnieri*	Whitemouth croaker	Praia Grande Unidade 21	Historical	42.40	15.20	0.58	3.30	195.00	60.00	-12.40	12.60	14.30	SUERC	This study
TRD_1051	*Micropogonias furnieri*	Whitemouth croaker	Praia Grande Unidade 21	Historical	39.00	14.40	0.36	3.20	291.00	92.00	-12.80	12.50	12.10	SUERC	This study
TRD_1052	*Micropogonias furnieri*	Whitemouth croaker	Praia Grande Unidade 21	Historical	39.13	14.09	0.39	3.24	265.38	81.94	-12.24	13.05	12.45	SUERC	This study
TRD_1054	*Micropogonias furnieri*	Whitemouth croaker	Praia Grande Unidade 21	Historical	40.33	14.64	0.44	3.21	245.32	76.38	-13.11	12.20	13.07	SUERC	This study
TRD_1056	*Micropogonias furnieri*	Whitemouth croaker	Praia Grande Unidade 21	Historical	40.20	14.36	0.40	3.26	270.60	82.89	-11.68	13.93	13.02	SUERC	This study
TRD_1057	*Micropogonias furnieri*	Whitemouth croaker	Praia Grande Unidade 21	Historical	40.02	14.39	0.41	3.24	259.29	79.96	-13.03	12.07	12.51	SUERC	This study

TRD_1018	*Conodon nobilis*	Barred grunt	Praia Grande Unidade 21	Historical	39.50	14.60	0.35	3.20	305.00	96.00	-12.20	12.70	11.60	SUERC	This study
TRD_1019	*Conodon nobilis*	Barred grunt	Praia Grande Unidade 21	Historical	36.58	13.74	0.44	3.11	224.26	72.18	-11.09	12.40	14.15	SUERC	This study
TRD_1020	*Conodon nobilis*	Barred grunt	Praia Grande Unidade 21	Historical	35.82	12.33	0.43	3.39	221.29	65.30	-11.69	12.80	15.91	SUERC	This study
TRD_1021	*Conodon nobilis*	Barred grunt	Praia Grande Unidade 21	Historical	38.69	13.95	0.54	3.23	190.93	59.04	-12.71	12.54	15.28	SUERC	This study
TRD_1022	*Conodon nobilis*	Barred grunt	Praia Grande Unidade 21	Historical	41.61	14.77	0.50	3.29	220.92	67.24	-11.19	12.87	16.01	SUERC	This study
TRD_1023	*Conodon nobilis*	Barred grunt	Praia Grande Unidade 21	Historical	40.19	14.33	0.50	3.27	212.70	65.05	-11.06	13.37	14.67	SUERC	This study
TRD_1024	*Conodon nobilis*	Barred grunt	Praia Grande Unidade 21	Historical	41.81	13.63		3.58			-11.49	12.87		ICTA	This study
TRD_1025	*Conodon nobilis*	Barred grunt	Praia Grande Unidade 21	Historical	38.84	13.94	0.51	3.25	203.18	62.54	-12.20	12.61	13.48	SUERC	This study
TRD_1026	*Conodon nobilis*	Barred grunt	Praia Grande Unidade 21	Historical	42.17	15.10	0.50	3.26	224.32	68.87	-10.39	12.92	13.65	SUERC	This study
TRD_1027	*Conodon nobilis*	Barred grunt	Praia Grande Unidade 21	Historical	40.36	14.04	0.59	3.35	181.62	54.17	-11.19	13.29	12.56	SUERC	This study
TRD_1028	*Conodon nobilis*	Barred grunt	Praia Grande Unidade 21	Historical	41.51	14.56	0.53	3.32	209.61	63.04	-11.88	12.99	14.27	SUERC	This study
TRD_1029	*Conodon nobilis*	Barred grunt	Praia Grande Unidade 21	Historical	41.08	14.70	0.47	3.26	236.60	72.71	-11.09	13.00	14.59	SUERC	This study
TRD_1030	*Conodon nobilis*	Barred grunt	Praia Grande Unidade 21	Historical	41.23	14.64	0.47	3.28	235.46	71.69	-11.75	12.97	14.39	SUERC	This study
TRD_1031	*Conodon nobilis*	Barred grunt	Praia Grande Unidade 21	Historical	40.47	14.76	0.52	3.20	208.83	65.32	-11.43	12.28	14.24	SUERC	This study
TRD_1032	*Conodon nobilis*	Barred grunt	Praia Grande Unidade 21	Historical	41.76	14.30	0.48	3.41	232.90	68.37	-12.83	12.85	14.99	SUERC	This study
TRD_1033	*Conodon nobilis*	Barred grunt	Praia Grande Unidade 21	Historical	36.51	13.62	0.41	3.13	237.00	75.84	-11.45	12.42	14.19	SUERC	This study
TRD_1034	*Conodon nobilis*	Barred grunt	Praia Grande Unidade 21	Historical	39.93	15.06	0.43	3.09	247.82	80.16	-10.82	13.02	13.63	SUERC	This study
TRD_1035	*Conodon nobilis*	Barred grunt	Praia Grande Unidade 21	Historical	41.19	14.53	0.50	3.31	222.10	67.19	-10.68	11.94	13.83	SUERC	This study
TRD_1036	*Conodon nobilis*	Barred grunt	Praia Grande Unidade 21	Historical	41.30	14.79	0.50	3.26	222.55	68.34	-12.09	12.67	14.19	SUERC	This study
TRD_1037	*Conodon nobilis*	Barred grunt	Praia Grande Unidade 21	Historical	38.32	14.09	0.44	3.17	230.09	72.52	-11.61	12.49	13.18	SUERC	This study

TRD_1107	*Conodon nobilis*	Barred grunt	Bupeva II	Pre-colonial	40.40	14.40	0.42	3.30	255.00	78.00	-9.90	12.50	15.40	SUERC	This study
TRD_1108	*Conodon nobilis*	Barred grunt	Bupeva II	Pre-colonial	39.93	13.10		3.56			-11.78	13.37		ICTA	This study
TRD_1110	*Conodon nobilis*	Barred grunt	Bupeva II	Pre-colonial	36.41	12.27		3.47			-12.37	12.80		ICTA	This study
TRD_1111	*Conodon nobilis*	Barred grunt	Bupeva II	Pre-colonial	41.90	14.50	0.43	3.40	260.00	77.00	-10.20	13.50	15.20	SUERC	This study
TRD_1112	*Conodon nobilis*	Barred grunt	Bupeva II	Pre-colonial	42.90	15.00	0.43	3.30	268.00	80.00	-11.40	12.50	16.00	SUERC	This study
TRD_1113	*Conodon nobilis*	Barred grunt	Bupeva II	Pre-colonial	36.52	12.10		3.53			-10.33	14.11		ICTA	This study
TRD_1117	*Conodon nobilis*	Barred grunt	Bupeva II	Pre-colonial	42.00	14.90	0.49	3.30	230.00	70.00	-11.80	12.00	16.20	SUERC	This study
TRD_1118	*Conodon nobilis*	Barred grunt	Bupeva II	Pre-colonial	42.27	14.42		3.42			-10.55	13.12		ICTA	This study
TRD_1119	*Conodon nobilis*	Barred grunt	Bupeva II	Pre-colonial	41.96	14.68	0.46	3.33	245.47	73.66	-10.19	11.32	12.54	SUERC	This study
TRD_1120	*Conodon nobilis*	Barred grunt	Bupeva II	Pre-colonial	41.47	13.78		3.51			-11.34	13.29		ICTA	This study
TRD_1124	*Conodon nobilis*	Barred grunt	Bupeva II	Pre-colonial	41.87	14.38		3.40			-10.24	14.22		ICTA	This study
TRD_1125	*Conodon nobilis*	Barred grunt	Bupeva II	Pre-colonial	43.00	14.80	0.38	3.40	305.00	90.00	-10.90	12.70	16.80	SUERC	This study
TRD_1126	*Centropomus* sp	Snook	Bupeva II	Pre-colonial	41.15	13.41		3.59			-9.48	11.12		ICTA	This study
TRD_1128	*Centropomus* sp	Snook	Bupeva II	Pre-colonial	41.90	14.00	0.38	3.50	294.00	84.00	-12.30	10.60	7.90	SUERC	This study
TRD_1129	*Centropomus* sp	Snook	Bupeva II	Pre-colonial	41.40	14.30	0.42	3.40	265.00	78.00	-12.30	10.60	6.60	SUERC	This study
TRD_1130	*Centropomus* sp	Snook	Bupeva II	Pre-colonial	42.02	14.07		3.49			-12.18	9.37		ICTA	This study
TRD_1131	*Centropomus* sp	Snook	Bupeva II	Pre-colonial	41.10	13.71		3.50			-12.05	9.52		ICTA	This study
TRD_1132	*Centropomus* sp	Snook	Bupeva II	Pre-colonial	40.60	14.60	0.40	3.30	273.00	84.00	-11.10	11.80	9.70	SUERC	This study
TRD_1133	*Centropomus* sp	Snook	Bupeva II	Pre-colonial	41.70	14.90	0.32	3.30	352.00	108.00	-10.40	11.40	10.50	SUERC	This study
TRD_1134	*Centropomus* sp	Snook	Bupeva II	Pre-colonial	42.00	13.80		3.55			-12.60	10.35		ICTA	This study
TRD_1135	*Centropomus* sp	Snook	Bupeva II	Pre-colonial	41.49	13.91		3.48			-12.81	9.60		ICTA	This study

TRD_1136	*Centropomus* sp	Snook	Bupeva II	Pre-colonial	38.33	13.23		3.38			-10.67	10.46		ICTA	This study
TRD_1137	*Centropomus* sp	Snook	Bupeva II	Pre-colonial	41.80	14.40	0.34	3.40	326.00	96.00	-14.50	10.90	8.00	SUERC	This study
TRD_1138	*Centropomus* sp	Snook	Bupeva II	Pre-colonial	41.10	14.80	0.29	3.20	380.00	118.00	-9.20	10.70	9.10	SUERC	This study
TRD_1139	*Centropomus* sp	Snook	Bupeva II	Pre-colonial	40.90	14.50	0.31	3.30	352.00	107.00	-21.40	9.00	7.30	SUERC	This study
TRD_1140	*Centropomus* sp	Snook	Bupeva II	Pre-colonial	40.96	14.82	0.28	3.22	394.94	122.54	-12.23	10.98	7.28	SUERC	This study
TRD_1141	*Centropomus* sp	Snook	Bupeva II	Pre-colonial	39.30	14.70	0.33	3.10	318.00	102.00	-15.20	10.10	4.70	SUERC	This study
TRD_1142	*Centropomus* sp	Snook	Bupeva II	Pre-colonial	40.10	14.70	0.37	3.20	290.00	91.00	-18.40	11.30	9.70	SUERC	This study
TRD_1143	*Centropomus* sp	Snook	Bupeva II	Pre-colonial	35.32	11.76		3.51			-10.11	11.05		ICTA	This study
TRD_1144	*Centropomus* sp	Snook	Bupeva II	Pre-colonial	41.00	14.90	0.31	3.21	357.23	111.36	-12.34	9.74	3.67	SUERC	This study
TRD_758	*Centropomus* sp	Snook	Morro do Ouro	Pre-colonial	42.21	14.27	0.39	3.45	285.89	82.90	-10.68	11.09	7.60	SUERC	This study
TRD_759	*Centropomus* sp	Snook	Morro do Ouro	Pre-colonial	43.21	14.19		3.55			-9.92	9.67		ICTA	This study
TRD_760	*Centropomus* sp	Snook	Morro do Ouro	Pre-colonial	42.18	13.95	0.48	3.52	232.17	65.86	-10.84	9.40	8.77	SUERC	This study
TRD_764	*Centropomus* sp	Snook	Morro do Ouro	Pre-colonial	37.26	12.60	0.40	3.45	249.54	72.35	-10.25	10.37	7.23	SUERC	This study
TRD_765	*Centropomus* sp	Snook	Morro do Ouro	Pre-colonial	37.75	12.60	0.38	3.49	265.89	76.12	-10.76	8.36	4.60	SUERC	This study
TRD_767	*Centropomus* sp	Snook	Morro do Ouro	Pre-colonial	30.66	10.35	0.43	3.45	188.65	54.63	-17.73	10.15	6.28	SUERC	This study
TRD_770	*Centropomus* sp	Snook	Morro do Ouro	Pre-colonial	36.18	12.07	0.43	3.49	224.40	64.21	-10.98	9.76	6.51	SUERC	This study
TRD_773	*Centropomus* sp	Snook	Morro do Ouro	Pre-colonial	37.21	13.03	0.36	3.33	277.42	83.28	-13.45	10.45	5.34	SUERC	This study
TRD_777	*Centropomus* sp	Snook	Morro do Ouro	Pre-colonial	35.00	12.80	0.28	3.20	337.52	105.58	-10.50	11.30	9.50	SUERC	This study
TRD_778	*Centropomus* sp	Snook	Morro do Ouro	Pre-colonial	34.80	12.30	0.30	3.31	307.34	92.88	-10.20	11.60	9.40	SUERC	This study
TRD_779	*Centropomus* sp	Snook	Morro do Ouro	Pre-colonial	34.80	12.50	0.32	3.24	288.81	89.14	-9.60	10.70	9.30	SUERC	This study
TRD_782	*Centropomus* sp	Snook	Morro do Ouro	Pre-colonial	24.70	8.67	0.30	3.32	218.07	65.68	-10.45	7.90	5.58	SUERC	This study
TRD_785	Ariidae	Catfish	Morro do Ouro	Pre-colonial	24.18	8.62	0.29	3.27	219.17	67.02	-9.73	7.91	6.57	SUERC	This study
TRD_786	Ariidae	Catfish	Morro do Ouro	Pre-colonial	30.97	11.03	0.31	3.27	267.59	81.73	-9.88	8.48	6.46	SUERC	This study
TRD_788	Ariidae	Catfish	Morro do Ouro	Pre-colonial	40.21	14.01	0.41	3.35	264.75	79.10	-11.30	8.64	6.89	SUERC	This study
TRD_792	Ariidae	Catfish	Morro do Ouro	Pre-colonial	23.58	8.72	0.36	3.15	173.15	54.94	-12.89	7.75	6.59	SUERC	This study
TRD_794	Ariidae	Catfish	Morro do Ouro	Pre-colonial	31.47	10.71	0.27	3.43	309.02	90.14	-15.99	9.78	9.57	SUERC	This study
TRD_795	Ariidae	Catfish	Morro do Ouro	Pre-colonial	36.50	12.84	0.34	3.32	286.10	86.29	-10.93	8.87	5.64	SUERC	This study

TRD_806	Ariidae	Catfish	Morro do Ouro	Pre-colonial	34.30	11.89	0.31	3.36	299.16	88.91	-14.68	10.95	7.65	SUERC	This study
TRD_808	Ariidae	Catfish	Morro do Ouro	Pre-colonial	30.06	10.52	0.29	3.33	276.72	83.02	-13.31	9.23	8.02	SUERC	This study
TRD_811	Ariidae	Catfish	Morro do Ouro	Pre-colonial	30.23	10.47	0.35	3.37	233.38	69.30	-12.85	9.81	5.24	SUERC	This study
TRD_812	Ariidae	Catfish	Morro do Ouro	Pre-colonial	19.10	6.30	0.24	3.55	213.36	60.03	-12.40	10.10	8.00	SUERC	This study
TRD_813	Ariidae	Catfish	Morro do Ouro	Pre-colonial	25.70	9.00	0.26	3.30	269.00	81.00	-11.00	9.60	6.70	SUERC	This study
TRD_814	Ariidae	Catfish	Morro do Ouro	Pre-colonial	35.20	12.40	0.32	3.30	298.51	90.35	-9.50	8.60	6.40	SUERC	This study
TRD_816	Ariidae	Catfish	Morro do Ouro	Pre-colonial	34.60	11.80	0.37	3.43	253.19	73.85	-15.50	10.00	9.10	SUERC	This study
TRD_818	Ariidae	Catfish	Morro do Ouro	Pre-colonial	41.43	14.90	0.34	3.24	321.90	99.27	-11.86	13.64	12.15	SUERC	This study
TRD_820	Ariidae	Catfish	Morro do Ouro	Pre-colonial	29.30	9.80	0.29	3.50	271.00	78.00	-15.00	9.70	7.60	SUERC	This study
TRD_823	Ariidae	Catfish	Morro do Ouro	Pre-colonial	24.50	8.20	0.51	3.50	128.00	37.00	-12.90	8.30	6.70	SUERC	This study
TRD_824	Ariidae	Catfish	Morro do Ouro	Pre-colonial	32.65	11.55	0.34	3.30	257.39	77.99	-15.40	10.00	9.80	SUERC	This study
TRD_825	Ariidae	Catfish	Morro do Ouro	Pre-colonial	29.40	10.50	0.36	3.30	221.00	68.00	-12.00	9.00	7.50	SUERC	This study
TRD_827	Ariidae	Catfish	Morro do Ouro	Pre-colonial	33.05	11.70	0.37	3.28	237.56	72.39	-9.80	9.00	7.60	SUERC	This study
TRD_828	Ariidae	Catfish	Morro do Ouro	Pre-colonial	33.99	12.49	0.31	3.17	292.51	92.13	-13.20	10.24	6.95	SUERC	This study
TRD_829	Ariidae	Catfish	Morro do Ouro	Pre-colonial	29.40	10.50	0.32	3.30	248.00	76.00	-9.30	8.40	6.90	SUERC	This study
TRD_830	Ariidae	Catfish	Morro do Ouro	Pre-colonial	34.55	12.15	0.40	3.31	229.68	69.45	-10.00	8.80	7.35	SUERC	This study
TRD_831	Ariidae	Catfish	Morro do Ouro	Pre-colonial	33.80	11.70	0.32	3.40	285.00	85.00	-15.20	9.50	10.50	SUERC	This study
TRD_832	Ariidae	Catfish	Morro do Ouro	Pre-colonial	25.70	8.90	0.31	3.40	221.00	65.00	-14.80	9.10	7.50	SUERC	This study
TRD_833	Ariidae	Catfish	Morro do Ouro	Pre-colonial	32.70	11.30	0.31	3.40	282.00	83.00	-14.90	9.40	7.70	SUERC	This study
TRD_835	Ariidae	Catfish	Morro do Ouro	Pre-colonial	29.80	9.70	0.38	3.60	211.00	59.00	-15.50	10.70	6.70	SUERC	This study
TRD_837	Ariidae	Catfish	Morro do Ouro	Pre-colonial	29.85	10.75	0.30	3.24	269.20	83.19	-14.80	9.90	10.40	SUERC	This study
TRD_838	Ariidae	Catfish	Morro do Ouro	Pre-colonial	33.90	11.40	0.39	3.50	232.00	67.00	-14.40	8.80	7.40	SUERC	This study
TRD_839	Ariidae	Catfish	Morro do Ouro	Pre-colonial	28.80	10.30	0.40	3.30	195.00	60.00	-10.70	8.30	6.80	SUERC	This study
TRD_840	Ariidae	Catfish	Morro do Ouro	Pre-colonial	17.40	6.60	0.30	3.10	157.00	51.00	-13.50	9.80	6.50	SUERC	This study
TRD_852	Ariidae	Catfish	Morro do Ouro	Pre-colonial	34.30	11.70	0.33	3.41	278.94	81.90	-13.60	10.20	9.00	SUERC	This study
TRD_853	Ariidae	Catfish	Morro do Ouro	Pre-colonial	35.60	11.80	0.33	3.52	285.81	81.26	-16.30	10.30	9.30	SUERC	This study
TRD_857	Ariidae	Catfish	Morro do Ouro	Pre-colonial	30.40	10.50	0.39	3.40	208.00	61.00	-16.70	9.40	6.20	SUERC	This study

TRD_859	Ariidae	Catfish	Morro do Ouro	Pre-colonial	36.40	12.80	0.29	3.32	329.83	99.47	-13.90	9.60	9.80	SUERC	This study
TRD_860	Ariidae	Catfish	Morro do Ouro	Pre-colonial	38.40	13.40	0.29	3.34	357.95	107.27	-15.80	10.60	10.90	SUERC	This study
TRD_862	Ariidae	Catfish	Morro do Ouro	Pre-colonial	26.90	9.20	0.28	3.43	260.49	75.88	-16.10	9.40	8.10	SUERC	This study
TRD_864	Ariidae	Catfish	Morro do Ouro	Pre-colonial	19.50	6.30	0.34	3.60	153.03	42.53	-17.40	8.70	7.10	SUERC	This study
TRD_866	Ariidae	Catfish	Morro do Ouro	Pre-colonial	32.15	11.20	0.27	3.36	323.67	96.37	-13.70	10.70	9.30	SUERC	This study
TRD_867	Ariidae	Catfish	Morro do Ouro	Pre-colonial	41.30	13.50	0.39	3.58	285.50	79.83	-10.40	8.70	6.80	SUERC	This study
TRD_870	Ariidae	Catfish	Morro do Ouro	Pre-colonial	30.40	10.00	0.31	3.50	261.00	74.00	-11.50	8.90	8.80	SUERC	This study
TRD_873	Ariidae	Catfish	Morro do Ouro	Pre-colonial	27.90	9.60	0.28	3.39	267.24	78.73	-15.10	8.80	8.40	SUERC	This study
TRD_877	Ariidae	Catfish	Morro do Ouro	Pre-colonial	22.60	8.00	0.35	3.30	171.00	52.00	-14.90	10.50	6.60	SUERC	This study
TRD_879	Ariidae	Catfish	Morro do Ouro	Pre-colonial	23.50	7.60	0.28	3.60	224.17	62.26	-14.10	10.20	8.00	SUERC	This study
MO 012	*Micropogonias furnieri*	Whitemouth croaker	Morro do Ouro	Pre-colonial	42.10	14.60		3.36			-13.20	9.50		YORK	(1)
MO 013	*Micropogonias furnieri*	Whitemouth croaker	Morro do Ouro	Pre-colonial	42.90	15.20		3.29			-12.80	9.70		YORK	(1)
MO 015	*Micropogonias furnieri*	Whitemouth croaker	Morro do Ouro	Pre-colonial	21.50	8.00		3.15			-12.20	9.00		YORK	(1)
MO 016	*Micropogonias furnieri*	Whitemouth croaker	Morro do Ouro	Pre-colonial	23.40	8.60		3.17			-15.30	7.40		YORK	(1)
MO 017	*Micropogonias furnieri*	Whitemouth croaker	Morro do Ouro	Pre-colonial	36.40	12.60		3.36			-12.50	9.70		YORK	(1)
MO 018	*Micropogonias furnieri*	Whitemouth croaker	Morro do Ouro	Pre-colonial	32.50	11.40		3.33			-12.90	10.10		YORK	(1)
MO 019	*Micropogonias furnieri*	Whitemouth croaker	Morro do Ouro	Pre-colonial	39.70	14.40		3.21			-10.80	9.10		YORK	(1)
MO 020	*Micropogonias furnieri*	Whitemouth croaker	Morro do Ouro	Pre-colonial	40.70	14.70		3.23			-12.50	10.90		YORK	(1)

Reference

1. Toso et al. 2021. Fishing Intensification as Response to Late Holocene Socio-Ecological Instability in Southeastern South America. Scientific Reports 11 (1): 23506.

SM4. Statistical analysis of isotope data

Figure 1. Pearson correlation C:N ratio and carbon ($\delta^{13}C$) for modern fish

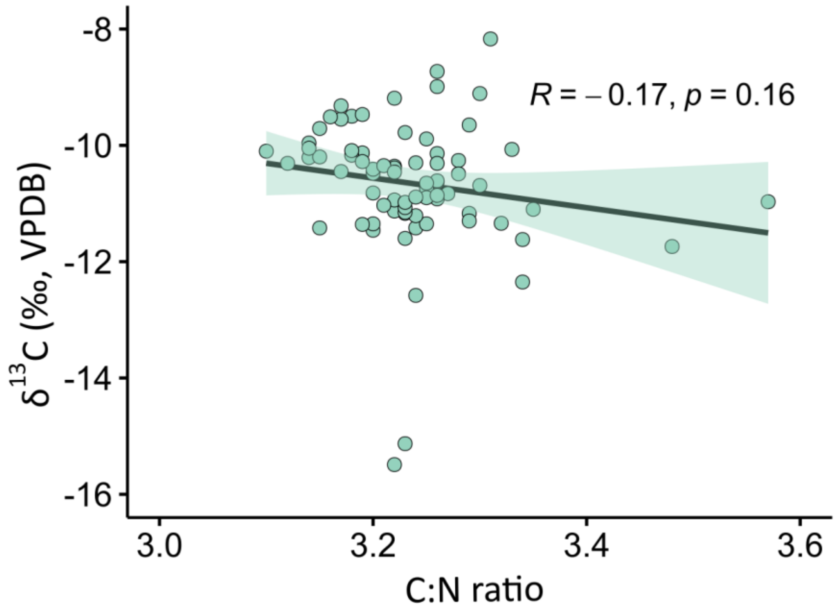

Table 1. Body Total Length (BTL) and stable isotope values of $\delta^{13}C$, $\delta^{15}N$, $\delta^{34}S$ for modern barred grunt (*Conodon nobilis*), whitemouth croaker (*Micropogonias furnieri*), white sea catfish (*Genidens barbus*) and fat snook (*Centropomus parallelus*).

ID	Scientific name	BTL (cm)	$\delta^{13}C$	$\delta^{15}N$	$\delta^{34}S$
TRD_1574	*Conodon nobilis*	25	-11.5	12.9	17.7
TRD_1575	*Conodon nobilis*	24	-11.3	13.9	17.7
TRD_1576	*Conodon nobilis*	22	-11.4	12.9	17.4
TRD_1577	*Conodon nobilis*	28	-10.3	14.2	17.8
TRD_1578	*Conodon nobilis*	20.5	-10.7	14.0	17.8
TRD_1579	*Conodon nobilis*	25.5	-10.4	13.7	17.7
TRD_1580	*Conodon nobilis*	25	-11.4	12.9	17.3
TRD_1581	*Conodon nobilis*	20	-10.9	13.6	17.2
TRD_1582	*Conodon nobilis*	27	-11.4	12.3	18.3
TRD_1583	*Conodon nobilis*	25	-11.1	12.9	17.8
TRD_1584	*Conodon nobilis*	26	-10.9	13.3	17.9
TRD_1585	*Conodon nobilis*	20.5	-10.6	13.6	17.8
TRD_1586	*Conodon nobilis*	17	-11.2	13.8	16.8
TRD_1587	*Conodon nobilis*	23	-11.2	13.7	17.0
TRD_1588	*Conodon nobilis*	22	-11.1	12.5	15.7
TRD_1589	*Conodon nobilis*	26	-11.6	13.6	15.3
TRD_1590	*Conodon nobilis*	26	-11.0	12.9	18.0
TRD_1591	*Conodon nobilis*	23	-10.4	14.9	16.5

TRD_1592	*Conodon nobilis*	25	-10.5	14.7	17.0
TRD_1593	*Conodon nobilis*	20	-11.0	14.6	16.4
TRD_1594	*Conodon nobilis*	22	-10.5	13.8	17.3
TRD_1595	*Conodon nobilis*	22	-10.9	14.5	17.2
TRD_1596	*Conodon nobilis*	22	-10.9	13.9	17.8
TRD_1597	*Conodon nobilis*	21	-11.1	13.6	17.9
TRD_1598	*Conodon nobilis*	24	-10.7	14.4	17.7
TRD_1563	*Micropogonias furnieri*	35	-11.3	13.6	15.3
TRD_1564	*Micropogonias furnieri*	41	-10.8	12.6	13.5
TRD_1565	*Micropogonias furnieri*	44	-11.4	12.1	15.6
TRD_1566	*Micropogonias furnieri*	38	-10.2	12.8	13.1
TRD_1567	*Micropogonias furnieri*	36	-10.9	12.5	13.1
TRD_1568	*Micropogonias furnieri*	43	-10.1	13.8	13.7
TRD_1569	*Micropogonias furnieri*	58	-9.9	14.6	14.1
TRD_1570	*Micropogonias furnieri*	48	-11.4	12.3	16.7
TRD_1571	*Micropogonias furnieri*	38	-10.6	13.1	14.3
TRD_1572	*Micropogonias furnieri*	45	-10.3	13.1	12.8
TRD_1573	*Micropogonias furnieri*		-11.2	14.2	14.7
TRD_1524	*Genidens barbus*	42	-9.5	16.1	12.0
TRD_1525	*Genidens barbus*	50	-10.2	16.2	12.6
TRD_1526	*Genidens barbus*	43	-10.0	16.3	11.4
TRD_1527	*Genidens barbus*	45	-9.6	15.9	12.0
TRD_1528	*Genidens barbus*	50	-10.3	16.5	13.3
TRD_1529	*Genidens barbus*	46	-10.1	15.6	10.9
TRD_1530	*Genidens barbus*	45	-9.5	15.8	13.0
TRD_1531	*Genidens barbus*	44	-8.7	15.7	12.4
TRD_1532	*Genidens barbus*	47	-9.5	16.2	11.9
TRD_1533	*Genidens barbus*	41	-10.1	16.3	13.8
TRD_1534	*Genidens barbus*	50	-10.2	16.2	11.5
TRD_1535	*Genidens barbus*	45	-9.8	16.5	13.3
TRD_1536	*Genidens barbus*	43	-9.3	15.4	11.9
TRD_1537	*Genidens barbus*	45	-9.2	16.0	12.5
TRD_1538	*Genidens barbus*	43	-10.1	16.9	13.3
TRD_1539	*Genidens barbus*	44	-9.1	16.0	12.0
TRD_1540	*Genidens barbus*	44	-8.2	15.7	10.6
TRD_1541	*Genidens barbus*	44	-9.7	15.7	11.9
TRD_1542	*Genidens barbus*	51	-10.5	16.1	11.8
TRD_1543	*Genidens barbus*	46	-10.3	15.9	12.3
TRD_1544	*Centropomus parallelus*	38	-11.0	13.8	14.2
TRD_1545	*Centropomus parallelus*	41	-10.1	13.2	15.7
TRD_1546	*Centropomus parallelus*	35	-10.3	12.9	15.0
TRD_1548	*Centropomus parallelus*	37	-15.5	12.0	10.8
TRD_1549	*Centropomus parallelus*	39	-10.1	13.9	15.3

TRD_1550	*Centropomus parallelus*	38	-11.7	13.5	13.5
TRD_1551	*Centropomus parallelus*	38	-10.4	13.7	15.1
TRD_1552	*Centropomus parallelus*	34	-12.4	13.0	14.1
TRD_1553	*Centropomus parallelus*	34	-15.1	15.8	7.9
TRD_1554	*Centropomus parallelus*	37	-11.2	13.8	14.7
TRD_1555	*Centropomus parallelus*	35	-10.5	14.1	14.2
TRD_1556	*Centropomus parallelus*	37	-9.0	14.4	14.3
TRD_1557	*Centropomus parallelus*	38	-9.7	13.8	14.7
TRD_1558	*Centropomus parallelus*	36	-10.7	13.2	16.0
TRD_1559	*Centropomus parallelus*	33	-10.4	13.0	14.9
TRD_1560	*Centropomus parallelus*	40	-11.6	13.3	14.3
TRD_1561	*Centropomus parallelus*	37	-10.8	12.3	11.4
TRD_1562	*Centropomus parallelus*	35	-12.6	12.2	13.5

Figure 2. Pearson correlation between body total length (BTL) and stable isotope values of δ^{13}C, δ^{15}N, δ^{34}S for modern barred grunt (*Conodon nobilis*), whitemouth croaker (*Micropogonias furnieri*), white sea catfish (*Genidens barbus*) and fat snook (*Centropomus parallelus*).

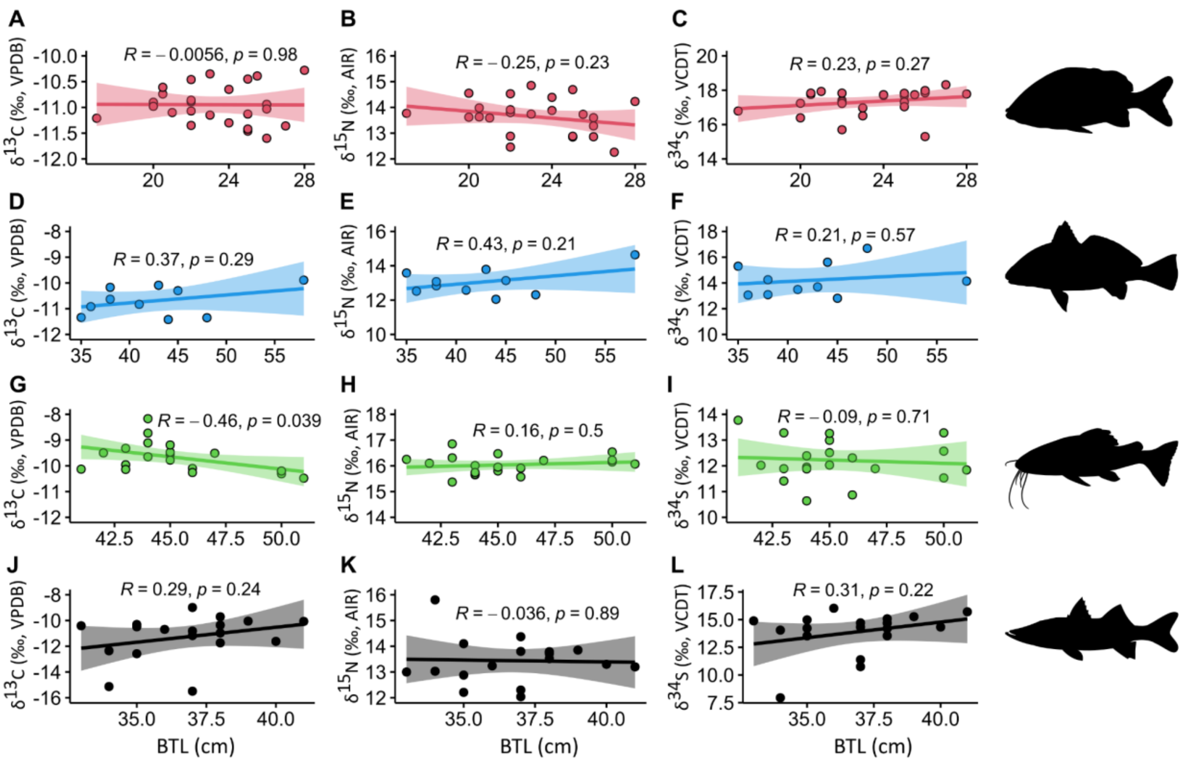

Table 2. Statistical analysis on $\delta^{13}C$ of barred grunt over time.

Kruskal-Wallis rank sum test		
Kruskal-Wallis chi-squared = 10.818, df = 2, p-value = 0.004476 Pairwise comparisons using Wilcoxon rank sum test with continuity correction		
	Historical	**Present-day**
Present-day	0.0035	-
Pre-colonial	0.1117	1.0000
P value adjustment method: Bonferroni		

Table 3. Statistical analysis on $\delta^{15}N$ of barred grunt over time

Kruskal-Wallis rank sum test		
Kruskal-Wallis chi-squared = 16.389, df = 2, p-value = 0.0002762 Pairwise comparisons using Wilcoxon rank sum test with continuity correction		
	Historical	**Present-day**
Present-day	0.00028	-
Pre-colonial	1.00000	0.05592
P value adjustment method: Bonferroni		

Table 4. Statistical analysis on $\delta^{34}S$ of barred grunt over time

Kruskal-Wallis rank sum test		
Kruskal-Wallis chi-squared = 35.171, df = 2, p-value = 2.305e-08 Pairwise comparisons using Wilcoxon rank sum test with continuity correction		
	Historical	**Present-day**
Present-day	1e-07	-
Pre-colonial	0.1158	0.0038
P value adjustment method: Bonferroni		

Table 5. Statistical analysis on $\delta^{13}C$ of whitemouth croaker over time

Kruskal-Wallis rank sum test
Kruskal-Wallis chi-squared = 13.727, df = 2, p-value = 0.001045 Pairwise comparisons using Wilcoxon rank sum test with continuity correction

	Historical	Present-day
Present-day	0.0378	-
Pre-colonial	0.0592	0.0058
P value adjustment method: Bonferroni		

Table 6. Statistical analysis on $\delta^{15}N$ of whitemouth croaker over time

Kruskal-Wallis rank sum test		
Kruskal-Wallis chi-squared = 19.042, df = 2, p-value = 7.331e-05 Pairwise comparisons using Wilcoxon rank sum test with continuity correction		
	Historical	Present-day
Present-day	0.73243	-
Pre-colonial	0.00025	0.00098
P value adjustment method: Bonferroni		

Table 7. Statistical analysis on $\delta^{34}S$ of whitemouth croaker over time

Kruskal-Wallis rank sum test		
Kruskal-Wallis chi-squared = 11.634, df = 1, p-value = 0.0006475 Pairwise comparisons using Wilcoxon rank sum test with continuity correction		
	Historical	**Present-day**
Present-day	0.00071	-
P value adjustment method: Bonferroni		

Table 8. Statistical analysis on $\delta^{13}C$ of white sea catfish over time

Kruskal-Wallis rank sum test	
Kruskal-Wallis chi-squared = 28.811, df = 1, p-value = 7.981e-08 Pairwise comparisons using Wilcoxon rank sum test with continuity correction	
	Present-day
Pre-colonial	8.3e-08
P value adjustment method: Bonferroni	

Table 9. Statistical analysis on $\delta^{15}N$ of white sea catfish over time

Kruskal-Wallis rank sum test	
Kruskal-Wallis chi-squared = 40.327, df = 1, p-value = 2.148e-10 Pairwise comparisons using Wilcoxon rank sum test with continuity correction	
	Present-day
Pre-colonial	2.3e-10
P value adjustment method: Bonferroni	

Table 10. Statistical analysis on $\delta^{34}S$ of white sea catfish over time

Kruskal-Wallis rank sum test	
Kruskal-Wallis chi-squared = 37.923, df = 1, p-value = 7.36e-10 Pairwise comparisons using Wilcoxon rank sum test with continuity correction	
	Present-day
Pre-colonial	7.7e-10
P value adjustment method: Bonferroni	

Table 11. Statistical analysis on $\delta^{13}C$ of fat snook over time

Kruskal-Wallis rank sum test		
Kruskal-Wallis chi-squared = 0.87805, df = 1, p-value = 0.3487 Pairwise comparisons using Wilcoxon rank sum test with continuity correction		
	Present-day	
Pre-colonial	0.35	
P value adjustment method: Bonferroni		

Table 12. Statistical analysis on $\delta^{15}N$ of fat snook over time

Kruskal-Wallis rank sum test		
Kruskal-Wallis chi-squared = 33.067, df = 1, p-value = 8.906e-09 Pairwise comparisons using Wilcoxon rank sum test with continuity correction		
	Present-day	
Pre-colonial	9.5e-09	

P value adjustment method: Bonferroni

Table 13. Statistical analysis on $\delta^{34}S$ of fat snook over time

Kruskal-Wallis rank sum test		
Kruskal-Wallis chi-squared = 26.406, df = 1, p-value = 2.766e-07 Pairwise comparisons using Wilcoxon rank sum test with continuity correction		
	Present-day	
Pre-colonial	3e-07	
P value adjustment method: Bonferroni		

Table 14. Statistical analysis on $\delta^{13}C$ of fat snook between Bupeva II (BPII) and Morro do Ouro (MO)

Mann-Whitney test for "equal medians"	
BPII	MO
N: 18	N: 12
Mean rank: 7.9667	Mean rank: 7.5333
Mann-Whitn U : 68	
z : 1.6724	p (same med.): 0.094454
Monte Carlo permutation:	p (same med.): 0.0895

Table 15. Statistical analysis on $\delta^{15}N$ of fat snook between Bupeva II (BPII) and Morro do Ouro (MO)

Mann-Whitney test for "equal medians"	
BPII	MO
N: 18	N: 12
Mean rank: 9.9667	Mean rank: 5.5333
Mann-Whitn U : 88	
z : 0.82578	p (same med.): 0.40893
Monte Carlo permutation:	p (same med.): 0.408

Table 16. Statistical analysis on $\delta^{34}S$ of fat snook between Bupeva II (BPII) and Morro do Ouro (MO)

Mann-Whitney test for "equal medians"	
BPII	MO
N: 11	N: 11
Mean rank: 6.3182	Mean rank: 5.1818
Mann-Whitn U : 48	
z : 0.7882	p (same med.): 0.43058
Monte Carlo permutation:	p (same med.): 0.4311
Exact permutation:	p (same med.): 0.42798

SM5. Body total length (BTL) of *Conodon nobilis* (barred grunt) and *Micropogonias furnieri* (whitemouth croaker)

Period	Age	Taxon	Archaeological site	Estimated body total length (mm)	Estimated body total length (cm)	Estimating equation reference	Otolith length (OL)	Reference
Pre-colonial	1000-500 cal BP	*Conodon nobilis*	Bupeva II (BPII)	262.02	26.20	(1)	13.0	This study
Pre-colonial	1000-500 cal BP	*Conodon nobilis*	Bupeva II (BPII)	262.02	26.20	(1)	13.0	This study
Pre-colonial	1000-500 cal BP	*Conodon nobilis*	Bupeva II (BPII)	215.77	21.58	(1)	11.0	This study
Pre-colonial	1000-500 cal BP	*Conodon nobilis*	Bupeva II (BPII)	170.89	17.09	(1)	9.0	This study
Pre-colonial	1000-500 cal BP	*Conodon nobilis*	Bupeva II (BPII)	193.15	19.31	(1)	10.0	This study
Pre-colonial	1000-500 cal BP	*Conodon nobilis*	Bupeva II (BPII)	149.02	14.90	(1)	8.0	This study
Pre-colonial	1000-500 cal BP	*Conodon nobilis*	Bupeva II (BPII)	127.60	12.76	(1)	7.0	This study
Pre-colonial	1000-500 cal BP	*Conodon nobilis*	Bupeva II (BPII)	106.67	10.67	(1)	6.0	This study
Pre-colonial	1000-500 cal BP	*Conodon nobilis*	Bupeva II (BPII)	285.58	28.56	(1)	14.0	This study
Pre-colonial	1000-500 cal BP	*Conodon nobilis*	Bupeva II (BPII)	238.74	23.87	(1)	12.0	This study
Pre-colonial	1000-500 cal BP	*Conodon nobilis*	Bupeva II (BPII)	285.58	28.56	(1)	14.0	This study
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	231.82	23.18	(1)	11.7	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	276.12	27.61	(1)	13.6	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	231.82	23.18	(1)	11.7	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	255.00	25.50	(1)	12.7	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	280.85	28.08	(1)	13.8	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	188.67	18.87	(1)	9.8	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	243.37	24.34	(1)	12.2	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	273.76	27.38	(1)	13.5	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	287.96	28.80	(1)	14.1	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	215.77	21.58	(1)	11.0	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	218.06	21.81	(1)	11.1	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	250.34	25.03	(1)	12.5	(3)

Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	197.65	19.76	(1)	10.2	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	202.16	20.22	(1)	10.4	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	218.06	21.81	(1)	11.1	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	179.75	17.97	(1)	9.4	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	264.36	26.44	(1)	13.1	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	245.69	24.57	(1)	12.3	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	227.22	22.72	(1)	11.5	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	184.20	18.42	(1)	9.6	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	234.12	23.41	(1)	11.8	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	184.20	18.42	(1)	9.6	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	236.43	23.64	(1)	11.9	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	227.22	22.72	(1)	11.5	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	236.43	23.64	(1)	11.9	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	276.12	27.61	(1)	13.6	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	269.06	26.91	(1)	13.3	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	199.90	19.99	(1)	10.3	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	266.71	26.67	(1)	13.2	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	238.74	23.87	(1)	12.0	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	215.77	21.58	(1)	11.0	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	266.71	26.67	(1)	13.2	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	202.16	20.22	(1)	10.4	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	238.74	23.87	(1)	12.0	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	271.41	27.14	(1)	13.4	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	213.50	21.35	(1)	10.9	(3)
Pre-colonial	650-250 cal BP	*Conodon nobilis*	Rio do Meio (RM)	278.48	27.85	(1)	13.7	(3)
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	230.43	23.04	(1)	11.6	This study

Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	207.36	20.74	(1)	10.6	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	233.89	23.39	(1)	11.8	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	226.53	22.65	(1)	11.5	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	193.60	19.36	(1)	10.0	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	254.30	25.43	(1)	12.7	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	254.30	25.43	(1)	12.7	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	254.30	25.43	(1)	12.7	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	254.30	25.43	(1)	12.7	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	254.30	25.43	(1)	12.7	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	254.30	25.43	(1)	12.7	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	254.30	25.43	(1)	12.7	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	254.30	25.43	(1)	12.7	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	254.30	25.43	(1)	12.7	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	254.30	25.43	(1)	12.7	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	213.95	21.40	(1)	10.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	213.95	21.40	(1)	10.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	213.95	21.40	(1)	10.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	213.95	21.40	(1)	10.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	213.95	21.40	(1)	10.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	213.95	21.40	(1)	10.9	This study

Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	213.95	21.40	(1)	10.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	179.08	17.91	(1)	9.4	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	179.08	17.91	(1)	9.4	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	179.08	17.91	(1)	9.4	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	179.08	17.91	(1)	9.4	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	213.50	21.35	(1)	10.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	284.87	28.49	(1)	14.0	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	284.87	28.49	(1)	14.0	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	284.87	28.49	(1)	14.0	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	284.87	28.49	(1)	14.0	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	284.87	28.49	(1)	14.0	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	284.87	28.49	(1)	14.0	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	48.03	4.80	(1)	3.0	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	48.03	4.80	(1)	3.0	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	48.03	4.80	(1)	3.0	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	48.03	4.80	(1)	3.0	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	48.03	4.80	(1)	3.0	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	48.03	4.80	(1)	3.0	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	48.03	4.80	(1)	3.0	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	48.03	4.80	(1)	3.0	This study

Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	48.03	4.80	(1)	3.0	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	48.03	4.80	(1)	3.0	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	48.03	4.80	(1)	3.0	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	48.03	4.80	(1)	3.0	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	48.03	4.80	(1)	3.0	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	48.03	4.80	(1)	3.0	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	48.03	4.80	(1)	3.0	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	207.59	20.76	(1)	10.6	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	207.59	20.76	(1)	10.6	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	207.59	20.76	(1)	10.6	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	181.75	18.17	(1)	9.5	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	181.75	18.17	(1)	9.5	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	181.75	18.17	(1)	9.5	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	161.43	16.14	(1)	8.6	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	258.50	25.85	(1)	12.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	258.50	25.85	(1)	12.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	258.50	25.85	(1)	12.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	258.50	25.85	(1)	12.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	207.59	20.76	(1)	10.6	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	293.19	29.32	(1)	14.3	This study

Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	293.19	29.32	(1)	14.3	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	276.12	27.61	(1)	13.6	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	276.12	27.61	(1)	13.6	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	276.12	27.61	(1)	13.6	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	276.12	27.61	(1)	13.6	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	276.12	27.61	(1)	13.6	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	276.12	27.61	(1)	13.6	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	276.12	27.61	(1)	13.6	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	276.12	27.61	(1)	13.6	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	276.12	27.61	(1)	13.6	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	276.12	27.61	(1)	13.6	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	276.12	27.61	(1)	13.6	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	258.27	25.83	(1)	12.8	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	258.27	25.83	(1)	12.8	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	258.27	25.83	(1)	12.8	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	258.27	25.83	(1)	12.8	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	258.27	25.83	(1)	12.8	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	214.41	21.44	(1)	10.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	214.41	21.44	(1)	10.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	214.41	21.44	(1)	10.9	This study

Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	214.41	21.44	(1)	10.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	214.41	21.44	(1)	10.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	214.41	21.44	(1)	10.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	214.41	21.44	(1)	10.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	214.41	21.44	(1)	10.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	214.41	21.44	(1)	10.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	214.41	21.44	(1)	10.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	214.41	21.44	(1)	10.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	214.41	21.44	(1)	10.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	214.41	21.44	(1)	10.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	189.78	18.98	(1)	9.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	189.78	18.98	(1)	9.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	189.78	18.98	(1)	9.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	189.78	18.98	(1)	9.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	189.78	18.98	(1)	9.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	189.78	18.98	(1)	9.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	189.78	18.98	(1)	9.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	189.78	18.98	(1)	9.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	189.78	18.98	(1)	9.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	189.78	18.98	(1)	9.9	This study

Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	189.78	18.98	(1)	9.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	189.78	18.98	(1)	9.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	189.78	18.98	(1)	9.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	175.75	17.58	(1)	9.2	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	175.75	17.58	(1)	9.2	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	218.06	21.81	(1)	11.1	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	261.08	26.11	(1)	13.0	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	280.61	28.06	(1)	13.8	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	182.19	18.22	(1)	9.5	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	249.18	24.92	(1)	12.5	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	216.23	21.62	(1)	11.0	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	226.30	22.63	(1)	11.5	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	209.63	20.96	(1)	10.7	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	209.63	20.96	(1)	10.7	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	196.52	19.65	(1)	10.2	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	238.05	23.80	(1)	12.0	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	308.95	30.89	(1)	15.0	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	275.65	27.57	(1)	13.6	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	275.65	27.57	(1)	13.6	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	275.65	27.57	(1)	13.6	This study

Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	275.65	27.57	(1)	13.6	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	254.07	25.41	(1)	12.7	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	254.07	25.41	(1)	12.7	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	254.07	25.41	(1)	12.7	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	254.07	25.41	(1)	12.7	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	254.07	25.41	(1)	12.7	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	254.07	25.41	(1)	12.7	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	254.07	25.41	(1)	12.7	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	218.97	21.90	(1)	11.1	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	218.97	21.90	(1)	11.1	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	218.97	21.90	(1)	11.1	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	218.97	21.90	(1)	11.1	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	218.97	21.90	(1)	11.1	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	218.97	21.90	(1)	11.1	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	218.97	21.90	(1)	11.1	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	218.97	21.90	(1)	11.1	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	218.97	21.90	(1)	11.1	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	218.97	21.90	(1)	11.1	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	218.97	21.90	(1)	11.1	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	191.80	19.18	(1)	9.9	This study

Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	289.14	28.91	(1)	14.2	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	228.82	22.88	(1)	11.6	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	228.82	22.88	(1)	11.6	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	228.82	22.88	(1)	11.6	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	228.82	22.88	(1)	11.6	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	228.82	22.88	(1)	11.6	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	228.82	22.88	(1)	11.6	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	258.50	25.85	(1)	12.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	258.50	25.85	(1)	12.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	258.50	25.85	(1)	12.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	258.50	25.85	(1)	12.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	258.50	25.85	(1)	12.9	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	209.40	20.94	(1)	10.7	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	209.40	20.94	(1)	10.7	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	209.40	20.94	(1)	10.7	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	247.78	24.78	(1)	12.4	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	247.78	24.78	(1)	12.4	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	247.78	24.78	(1)	12.4	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	247.78	24.78	(1)	12.4	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	247.78	24.78	(1)	12.4	This study

Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	247.78	24.78	(1)	12.4	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	247.78	24.78	(1)	12.4	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	247.78	24.78	(1)	12.4	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	247.78	24.78	(1)	12.4	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	247.78	24.78	(1)	12.4	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	247.78	24.78	(1)	12.4	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	247.78	24.78	(1)	12.4	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	266.47	26.65	(1)	13.2	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	266.47	26.65	(1)	13.2	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	266.47	26.65	(1)	13.2	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	266.47	26.65	(1)	13.2	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	266.47	26.65	(1)	13.2	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	266.47	26.65	(1)	13.2	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	266.47	26.65	(1)	13.2	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	266.47	26.65	(1)	13.2	This study
Historical	19th-early 20th century AD	*Conodon nobilis*	Praia Grande Unidade 21 (PG-U21)	266.47	26.65	(1)	13.2	This study
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	258.62	25.86	(2)	10.4	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	379.14	37.91	(2)	15.7	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	335.35	33.54	(2)	13.8	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	309.17	30.92	(2)	12.6	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	450.91	45.09	(2)	18.9	(4)

Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	472.35	47.24	(2)	19.9	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	382.75	38.28	(2)	15.9	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	222.50	22.25	(2)	8.8	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	274.42	27.44	(2)	11.1	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	163.60	16.36	(2)	6.2	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	163.60	16.36	(2)	6.2	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	405.10	40.51	(2)	16.9	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	220.02	22.00	(2)	8.7	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	434.21	43.42	(2)	18.2	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	235.82	23.58	(2)	9.4	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	409.16	40.92	(2)	17.1	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	429.92	42.99	(2)	18.0	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	263.81	26.38	(2)	10.6	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	421.57	42.16	(2)	17.6	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	268.55	26.85	(2)	10.8	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	200.39	20.04	(2)	7.8	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	167.21	16.72	(2)	6.3	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	354.76	35.48	(2)	14.6	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	226.34	22.63	(2)	9.0	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	199.93	19.99	(2)	7.8	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	492.44	49.24	(2)	20.7	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	253.20	25.32	(2)	10.1	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	226.79	22.68	(2)	9.0	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	392.68	39.27	(2)	16.3	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	240.11	24.01	(2)	9.6	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	400.58	40.06	(2)	16.7	(4)

Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	356.12	35.61	(2)	14.7	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	189.33	18.93	(2)	7.3	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	429.47	42.95	(2)	18.0	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	445.95	44.59	(2)	18.7	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	407.35	40.74	(2)	17.0	(4)
Pre-colonial	3550-2000 cal BP	*Micropogonias furnieri*	Cubatão I (CBI)	240.56	24.06	(2)	9.6	(4)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	265.84	26.58	(2)	10.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	480.25	48.03	(2)	20.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	369.66	36.97	(2)	15.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	331.29	33.13	(2)	13.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	376.43	37.64	(2)	15.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	412.54	41.25	(2)	17.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	335.81	33.58	(2)	13.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	414.80	41.48	(2)	17.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	342.58	34.26	(2)	14.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	283.90	28.39	(2)	11.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	414.80	41.48	(2)	17.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	448.66	44.87	(2)	18.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	396.75	39.67	(2)	16.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	331.29	33.13	(2)	13.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	243.27	24.33	(2)	9.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	261.33	26.13	(2)	10.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	297.44	29.74	(2)	12.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	317.75	31.78	(2)	13.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	295.18	29.52	(2)	12.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	272.61	27.26	(2)	11.0	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	288.41	28.84	(2)	11.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	374.18	37.42	(2)	15.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	351.61	35.16	(2)	14.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	306.47	30.65	(2)	12.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	252.30	25.23	(2)	10.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	356.12	35.61	(2)	14.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	277.12	27.71	(2)	11.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	292.92	29.29	(2)	11.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	236.50	23.65	(2)	9.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	317.75	31.78	(2)	13.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	419.32	41.93	(2)	17.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	320.01	32.00	(2)	13.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	502.82	50.28	(2)	21.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	387.72	38.77	(2)	16.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	356.12	35.61	(2)	14.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	468.97	46.90	(2)	19.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	288.41	28.84	(2)	11.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	405.77	40.58	(2)	16.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	394.49	39.45	(2)	16.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	331.29	33.13	(2)	13.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	369.66	36.97	(2)	15.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	383.20	38.32	(2)	15.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	360.63	36.06	(2)	14.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	464.46	46.45	(2)	19.5	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	290.67	29.07	(2)	11.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	304.21	30.42	(2)	12.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	329.04	32.90	(2)	13.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	353.86	35.39	(2)	14.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	342.58	34.26	(2)	14.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	365.15	36.51	(2)	15.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	392.23	39.22	(2)	16.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	417.06	41.71	(2)	17.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	491.54	49.15	(2)	20.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	374.18	37.42	(2)	15.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	380.95	38.09	(2)	15.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	376.43	37.64	(2)	15.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	353.86	35.39	(2)	14.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	353.86	35.39	(2)	14.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	417.06	41.71	(2)	17.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	353.86	35.39	(2)	14.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	308.72	30.87	(2)	12.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	290.67	29.07	(2)	11.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	220.70	22.07	(2)	8.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	374.18	37.42	(2)	15.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	403.52	40.35	(2)	16.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	310.98	31.10	(2)	12.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	313.24	31.32	(2)	12.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	344.83	34.48	(2)	14.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	331.29	33.13	(2)	13.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	392.23	39.22	(2)	16.3	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	412.54	41.25	(2)	17.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	268.10	26.81	(2)	10.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	272.61	27.26	(2)	11.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	389.97	39.00	(2)	16.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	340.32	34.03	(2)	14.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	340.32	34.03	(2)	14.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	340.32	34.03	(2)	14.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	295.18	29.52	(2)	12.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	326.78	32.68	(2)	13.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	385.46	38.55	(2)	16.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	340.32	34.03	(2)	14.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	292.92	29.29	(2)	11.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	329.04	32.90	(2)	13.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	403.52	40.35	(2)	16.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	342.58	34.26	(2)	14.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	353.86	35.39	(2)	14.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	342.58	34.26	(2)	14.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	351.61	35.16	(2)	14.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	342.58	34.26	(2)	14.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	466.71	46.67	(2)	19.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	392.23	39.22	(2)	16.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	335.81	33.58	(2)	13.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	374.18	37.42	(2)	15.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	340.32	34.03	(2)	14.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	367.40	36.74	(2)	15.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	380.95	38.09	(2)	15.8	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	408.03	40.80	(2)	17.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	331.29	33.13	(2)	13.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	473.48	47.35	(2)	19.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	347.09	34.71	(2)	14.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	344.83	34.48	(2)	14.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	437.37	43.74	(2)	18.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	225.21	22.52	(2)	8.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	333.55	33.35	(2)	13.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	380.95	38.09	(2)	15.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	250.04	25.00	(2)	10.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	475.74	47.57	(2)	20.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	464.46	46.45	(2)	19.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	367.40	36.74	(2)	15.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	410.29	41.03	(2)	17.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	378.69	37.87	(2)	15.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	333.55	33.35	(2)	13.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	304.21	30.42	(2)	12.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	290.67	29.07	(2)	11.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	518.62	51.86	(2)	21.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	471.23	47.12	(2)	19.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	394.49	39.45	(2)	16.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	342.58	34.26	(2)	14.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	297.44	29.74	(2)	12.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	360.63	36.06	(2)	14.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	358.38	35.84	(2)	14.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	317.75	31.78	(2)	13.0	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	261.33	26.13	(2)	10.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	496.05	49.61	(2)	20.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	270.35	27.04	(2)	10.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	414.80	41.48	(2)	17.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	380.95	38.09	(2)	15.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	356.12	35.61	(2)	14.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	401.26	40.13	(2)	16.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	342.58	34.26	(2)	14.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	351.61	35.16	(2)	14.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	344.83	34.48	(2)	14.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	383.20	38.32	(2)	15.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	356.12	35.61	(2)	14.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	326.78	32.68	(2)	13.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	238.76	23.88	(2)	9.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	216.19	21.62	(2)	8.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	313.24	31.32	(2)	12.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	283.90	28.39	(2)	11.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	360.63	36.06	(2)	14.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	380.95	38.09	(2)	15.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	473.48	47.35	(2)	19.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	320.01	32.00	(2)	13.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	306.47	30.65	(2)	12.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	385.46	38.55	(2)	16.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	295.18	29.52	(2)	12.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	250.04	25.00	(2)	10.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	340.32	34.03	(2)	14.0	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	351.61	35.16	(2)	14.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	295.18	29.52	(2)	12.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	317.75	31.78	(2)	13.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	374.18	37.42	(2)	15.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	385.46	38.55	(2)	16.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	340.32	34.03	(2)	14.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	340.32	34.03	(2)	14.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	385.46	38.55	(2)	16.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	250.04	25.00	(2)	10.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	408.03	40.80	(2)	17.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	374.18	37.42	(2)	15.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	453.17	45.32	(2)	19.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	317.75	31.78	(2)	13.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	498.31	49.83	(2)	21.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	340.32	34.03	(2)	14.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	227.47	22.75	(2)	9.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	295.18	29.52	(2)	12.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	453.17	45.32	(2)	19.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	453.17	45.32	(2)	19.0	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	453.17	45.32	(2)	19.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	408.03	40.80	(2)	17.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	351.61	35.16	(2)	14.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	408.03	40.80	(2)	17.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	295.18	29.52	(2)	12.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	317.75	31.78	(2)	13.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	306.47	30.65	(2)	12.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	317.75	31.78	(2)	13.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	340.32	34.03	(2)	14.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	250.04	25.00	(2)	10.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	453.17	45.32	(2)	19.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	340.32	34.03	(2)	14.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	317.75	31.78	(2)	13.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	435.11	43.51	(2)	18.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	333.55	33.35	(2)	13.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	360.63	36.06	(2)	14.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	371.92	37.19	(2)	15.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	371.92	37.19	(2)	15.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	333.55	33.35	(2)	13.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	308.72	30.87	(2)	12.6	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	374.18	37.42	(2)	15.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	324.52	32.45	(2)	13.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	338.06	33.81	(2)	13.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	374.18	37.42	(2)	15.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	301.95	30.20	(2)	12.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	365.15	36.51	(2)	15.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	344.83	34.48	(2)	14.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	320.01	32.00	(2)	13.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	288.41	28.84	(2)	11.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	234.24	23.42	(2)	9.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	347.09	34.71	(2)	14.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	259.07	25.91	(2)	10.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	279.38	27.94	(2)	11.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	281.64	28.16	(2)	11.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	304.21	30.42	(2)	12.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	315.49	31.55	(2)	12.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	385.46	38.55	(2)	16.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	333.55	33.35	(2)	13.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	374.18	37.42	(2)	15.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	292.92	29.29	(2)	11.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	292.92	29.29	(2)	11.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	315.49	31.55	(2)	12.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	335.81	33.58	(2)	13.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	279.38	27.94	(2)	11.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	367.40	36.74	(2)	15.2	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	279.38	27.94	(2)	11.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	401.26	40.13	(2)	16.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	322.26	32.23	(2)	13.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	270.35	27.04	(2)	10.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	347.09	34.71	(2)	14.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	344.83	34.48	(2)	14.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	356.12	35.61	(2)	14.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	417.06	41.71	(2)	17.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	367.40	36.74	(2)	15.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	468.97	46.90	(2)	19.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	263.58	26.36	(2)	10.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	396.75	39.67	(2)	16.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	340.32	34.03	(2)	14.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	374.18	37.42	(2)	15.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	367.40	36.74	(2)	15.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	455.43	45.54	(2)	19.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	360.63	36.06	(2)	14.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	322.26	32.23	(2)	13.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	304.21	30.42	(2)	12.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	387.72	38.77	(2)	16.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	471.23	47.12	(2)	19.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	387.72	38.77	(2)	16.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	320.01	32.00	(2)	13.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	342.58	34.26	(2)	14.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	389.97	39.00	(2)	16.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	396.75	39.67	(2)	16.5	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	335.81	33.58	(2)	13.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	387.72	38.77	(2)	16.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	509.60	50.96	(2)	21.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	245.53	24.55	(2)	9.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	299.69	29.97	(2)	12.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	446.40	44.64	(2)	18.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	412.54	41.25	(2)	17.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	380.95	38.09	(2)	15.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	297.44	29.74	(2)	12.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	338.06	33.81	(2)	13.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	324.52	32.45	(2)	13.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	396.75	39.67	(2)	16.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	333.55	33.35	(2)	13.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	277.12	27.71	(2)	11.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	353.86	35.39	(2)	14.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	324.52	32.45	(2)	13.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	365.15	36.51	(2)	15.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	387.72	38.77	(2)	16.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	313.24	31.32	(2)	12.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	353.86	35.39	(2)	14.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	335.81	33.58	(2)	13.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	358.38	35.84	(2)	14.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	385.46	38.55	(2)	16.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	308.72	30.87	(2)	12.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	374.18	37.42	(2)	15.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	430.60	43.06	(2)	18.0	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	283.90	28.39	(2)	11.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	347.09	34.71	(2)	14.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	290.67	29.07	(2)	11.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	331.29	33.13	(2)	13.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	500.57	50.06	(2)	21.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	335.81	33.58	(2)	13.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	347.09	34.71	(2)	14.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	329.04	32.90	(2)	13.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	247.78	24.78	(2)	9.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	408.03	40.80	(2)	17.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	349.35	34.93	(2)	14.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	353.86	35.39	(2)	14.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	356.12	35.61	(2)	14.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	380.95	38.09	(2)	15.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	394.49	39.45	(2)	16.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	340.32	34.03	(2)	14.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	383.20	38.32	(2)	15.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	344.83	34.48	(2)	14.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	380.95	38.09	(2)	15.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	326.78	32.68	(2)	13.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	428.34	42.83	(2)	17.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	315.49	31.55	(2)	12.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	304.21	30.42	(2)	12.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	304.21	30.42	(2)	12.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	380.95	38.09	(2)	15.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	353.86	35.39	(2)	14.6	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	356.12	35.61	(2)	14.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	283.90	28.39	(2)	11.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	369.66	36.97	(2)	15.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	426.09	42.61	(2)	17.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	387.72	38.77	(2)	16.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	369.66	36.97	(2)	15.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	365.15	36.51	(2)	15.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	399.00	39.90	(2)	16.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	351.61	35.16	(2)	14.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	333.55	33.35	(2)	13.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	299.69	29.97	(2)	12.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	358.38	35.84	(2)	14.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	304.21	30.42	(2)	12.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	277.12	27.71	(2)	11.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	403.52	40.35	(2)	16.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	360.63	36.06	(2)	14.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	439.63	43.96	(2)	18.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	306.47	30.65	(2)	12.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	256.81	25.68	(2)	10.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	247.78	24.78	(2)	9.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	308.72	30.87	(2)	12.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	277.12	27.71	(2)	11.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	353.86	35.39	(2)	14.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	301.95	30.20	(2)	12.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	356.12	35.61	(2)	14.7	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	371.92	37.19	(2)	15.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	360.63	36.06	(2)	14.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	317.75	31.78	(2)	13.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	338.06	33.81	(2)	13.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	446.40	44.64	(2)	18.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	374.18	37.42	(2)	15.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	421.57	42.16	(2)	17.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	349.35	34.93	(2)	14.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	329.04	32.90	(2)	13.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	360.63	36.06	(2)	14.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	297.44	29.74	(2)	12.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	347.09	34.71	(2)	14.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	378.69	37.87	(2)	15.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	360.63	36.06	(2)	14.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	322.26	32.23	(2)	13.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	333.55	33.35	(2)	13.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	426.09	42.61	(2)	17.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	369.66	36.97	(2)	15.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	272.61	27.26	(2)	11.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	387.72	38.77	(2)	16.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	511.85	51.19	(2)	21.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	277.12	27.71	(2)	11.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	250.04	25.00	(2)	10.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	414.80	41.48	(2)	17.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	351.61	35.16	(2)	14.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	475.74	47.57	(2)	20.0	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	376.43	37.64	(2)	15.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	385.46	38.55	(2)	16.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	428.34	42.83	(2)	17.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	308.72	30.87	(2)	12.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	315.49	31.55	(2)	12.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	394.49	39.45	(2)	16.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	385.46	38.55	(2)	16.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	450.91	45.09	(2)	18.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	329.04	32.90	(2)	13.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	279.38	27.94	(2)	11.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	403.52	40.35	(2)	16.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	405.77	40.58	(2)	16.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	401.26	40.13	(2)	16.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	315.49	31.55	(2)	12.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	322.26	32.23	(2)	13.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	369.66	36.97	(2)	15.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	360.63	36.06	(2)	14.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	376.43	37.64	(2)	15.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	351.61	35.16	(2)	14.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	304.21	30.42	(2)	12.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	322.26	32.23	(2)	13.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	394.49	39.45	(2)	16.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	331.29	33.13	(2)	13.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	335.81	33.58	(2)	13.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	545.71	54.57	(2)	23.1	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	419.32	41.93	(2)	17.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	502.82	50.28	(2)	21.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	247.78	24.78	(2)	9.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	329.04	32.90	(2)	13.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	290.67	29.07	(2)	11.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	333.55	33.35	(2)	13.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	333.55	33.35	(2)	13.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	426.09	42.61	(2)	17.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	371.92	37.19	(2)	15.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	412.54	41.25	(2)	17.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	369.66	36.97	(2)	15.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	367.40	36.74	(2)	15.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	378.69	37.87	(2)	15.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	380.95	38.09	(2)	15.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	333.55	33.35	(2)	13.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	331.29	33.13	(2)	13.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	401.26	40.13	(2)	16.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	317.75	31.78	(2)	13.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	329.04	32.90	(2)	13.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	353.86	35.39	(2)	14.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	333.55	33.35	(2)	13.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	342.58	34.26	(2)	14.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	351.61	35.16	(2)	14.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	394.49	39.45	(2)	16.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	563.76	56.38	(2)	23.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	482.51	48.25	(2)	20.3	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	385.46	38.55	(2)	16.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	376.43	37.64	(2)	15.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	365.15	36.51	(2)	15.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	274.87	27.49	(2)	11.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	410.29	41.03	(2)	17.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	385.46	38.55	(2)	16.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	313.24	31.32	(2)	12.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	369.66	36.97	(2)	15.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	351.61	35.16	(2)	14.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	389.97	39.00	(2)	16.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	369.66	36.97	(2)	15.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	358.38	35.84	(2)	14.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	417.06	41.71	(2)	17.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	338.06	33.81	(2)	13.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	324.52	32.45	(2)	13.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	378.69	37.87	(2)	15.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	274.87	27.49	(2)	11.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	283.90	28.39	(2)	11.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	385.46	38.55	(2)	16.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	360.63	36.06	(2)	14.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	317.75	31.78	(2)	13.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	367.40	36.74	(2)	15.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	297.44	29.74	(2)	12.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	419.32	41.93	(2)	17.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	338.06	33.81	(2)	13.9	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	367.40	36.74	(2)	15.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	340.32	34.03	(2)	14.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	371.92	37.19	(2)	15.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	320.01	32.00	(2)	13.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	367.40	36.74	(2)	15.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	329.04	32.90	(2)	13.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	304.21	30.42	(2)	12.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	317.75	31.78	(2)	13.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	374.18	37.42	(2)	15.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	376.43	37.64	(2)	15.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	374.18	37.42	(2)	15.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	394.49	39.45	(2)	16.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	360.63	36.06	(2)	14.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	369.66	36.97	(2)	15.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	365.15	36.51	(2)	15.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	338.06	33.81	(2)	13.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	399.00	39.90	(2)	16.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	351.61	35.16	(2)	14.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	369.66	36.97	(2)	15.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	353.86	35.39	(2)	14.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	353.86	35.39	(2)	14.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	389.97	39.00	(2)	16.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	371.92	37.19	(2)	15.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	292.92	29.29	(2)	11.9	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	288.41	28.84	(2)	11.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	200.39	20.04	(2)	7.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	159.76	15.98	(2)	6.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	374.18	37.42	(2)	15.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	358.38	35.84	(2)	14.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	304.21	30.42	(2)	12.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	358.38	35.84	(2)	14.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	356.12	35.61	(2)	14.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	376.43	37.64	(2)	15.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	344.83	34.48	(2)	14.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	333.55	33.35	(2)	13.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	455.43	45.54	(2)	19.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	380.95	38.09	(2)	15.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	313.24	31.32	(2)	12.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	349.35	34.93	(2)	14.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	245.53	24.55	(2)	9.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	281.64	28.16	(2)	11.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	274.87	27.49	(2)	11.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	250.04	25.00	(2)	10.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	317.75	31.78	(2)	13.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	270.35	27.04	(2)	10.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	301.95	30.20	(2)	12.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	304.21	30.42	(2)	12.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	301.95	30.20	(2)	12.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	369.66	36.97	(2)	15.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	268.10	26.81	(2)	10.8	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	243.27	24.33	(2)	9.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	272.61	27.26	(2)	11.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	272.61	27.26	(2)	11.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	254.55	25.46	(2)	10.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	281.64	28.16	(2)	11.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	254.55	25.46	(2)	10.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	234.24	23.42	(2)	9.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	265.84	26.58	(2)	10.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	295.18	29.52	(2)	12.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	329.04	32.90	(2)	13.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	322.26	32.23	(2)	13.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	283.90	28.39	(2)	11.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	423.83	42.38	(2)	17.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	468.97	46.90	(2)	19.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	430.60	43.06	(2)	18.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	261.33	26.13	(2)	10.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	263.58	26.36	(2)	10.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	410.29	41.03	(2)	17.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	374.18	37.42	(2)	15.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	356.12	35.61	(2)	14.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	342.58	34.26	(2)	14.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	317.75	31.78	(2)	13.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	288.41	28.84	(2)	11.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	353.86	35.39	(2)	14.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	313.24	31.32	(2)	12.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	466.71	46.67	(2)	19.6	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	439.63	43.96	(2)	18.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	378.69	37.87	(2)	15.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	333.55	33.35	(2)	13.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	340.32	34.03	(2)	14.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	342.58	34.26	(2)	14.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	342.58	34.26	(2)	14.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	351.61	35.16	(2)	14.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	310.98	31.10	(2)	12.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	335.81	33.58	(2)	13.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	374.18	37.42	(2)	15.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	369.66	36.97	(2)	15.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	387.72	38.77	(2)	16.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	405.77	40.58	(2)	16.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	414.80	41.48	(2)	17.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	378.69	37.87	(2)	15.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	299.69	29.97	(2)	12.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	277.12	27.71	(2)	11.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	333.55	33.35	(2)	13.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	399.00	39.90	(2)	16.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	333.55	33.35	(2)	13.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	399.00	39.90	(2)	16.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	326.78	32.68	(2)	13.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	387.72	38.77	(2)	16.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	304.21	30.42	(2)	12.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	286.15	28.62	(2)	11.6	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	360.63	36.06	(2)	14.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	304.21	30.42	(2)	12.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	333.55	33.35	(2)	13.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	358.38	35.84	(2)	14.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	389.97	39.00	(2)	16.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	401.26	40.13	(2)	16.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	349.35	34.93	(2)	14.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	468.97	46.90	(2)	19.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	496.05	49.61	(2)	20.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	320.01	32.00	(2)	13.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	326.78	32.68	(2)	13.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	338.06	33.81	(2)	13.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	265.84	26.58	(2)	10.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	365.15	36.51	(2)	15.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	387.72	38.77	(2)	16.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	353.86	35.39	(2)	14.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	317.75	31.78	(2)	13.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	389.97	39.00	(2)	16.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	446.40	44.64	(2)	18.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	403.52	40.35	(2)	16.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	401.26	40.13	(2)	16.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	333.55	33.35	(2)	13.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	380.95	38.09	(2)	15.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	333.55	33.35	(2)	13.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	308.72	30.87	(2)	12.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	356.12	35.61	(2)	14.7	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	389.97	39.00	(2)	16.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	374.18	37.42	(2)	15.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	371.92	37.19	(2)	15.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	338.06	33.81	(2)	13.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	412.54	41.25	(2)	17.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	475.74	47.57	(2)	20.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	453.17	45.32	(2)	19.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	324.52	32.45	(2)	13.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	453.17	45.32	(2)	19.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	403.52	40.35	(2)	16.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	313.24	31.32	(2)	12.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	414.80	41.48	(2)	17.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	356.12	35.61	(2)	14.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	389.97	39.00	(2)	16.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	430.60	43.06	(2)	18.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	383.20	38.32	(2)	15.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	335.81	33.58	(2)	13.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	351.61	35.16	(2)	14.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	471.23	47.12	(2)	19.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	410.29	41.03	(2)	17.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	371.92	37.19	(2)	15.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	279.38	27.94	(2)	11.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	374.18	37.42	(2)	15.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	408.03	40.80	(2)	17.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	374.18	37.42	(2)	15.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	367.40	36.74	(2)	15.2	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	304.21	30.42	(2)	12.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	335.81	33.58	(2)	13.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	374.18	37.42	(2)	15.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	304.21	30.42	(2)	12.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	369.66	36.97	(2)	15.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	358.38	35.84	(2)	14.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	351.61	35.16	(2)	14.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	256.81	25.68	(2)	10.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	383.20	38.32	(2)	15.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	331.29	33.13	(2)	13.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	320.01	32.00	(2)	13.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	331.29	33.13	(2)	13.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	464.46	46.45	(2)	19.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	333.55	33.35	(2)	13.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	333.55	33.35	(2)	13.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	247.78	24.78	(2)	9.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	385.46	38.55	(2)	16.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	457.68	45.77	(2)	19.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	412.54	41.25	(2)	17.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	417.06	41.71	(2)	17.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	347.09	34.71	(2)	14.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	268.10	26.81	(2)	10.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	617.93	61.79	(2)	26.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	446.40	44.64	(2)	18.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	292.92	29.29	(2)	11.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	412.54	41.25	(2)	17.2	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	304.21	30.42	(2)	12.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	182.33	18.23	(2)	7.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	347.09	34.71	(2)	14.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	414.80	41.48	(2)	17.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	272.61	27.26	(2)	11.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	286.15	28.62	(2)	11.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	301.95	30.20	(2)	12.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	507.34	50.73	(2)	21.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	356.12	35.61	(2)	14.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	342.58	34.26	(2)	14.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	310.98	31.10	(2)	12.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	353.86	35.39	(2)	14.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	403.52	40.35	(2)	16.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	272.61	27.26	(2)	11.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	349.35	34.93	(2)	14.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	329.04	32.90	(2)	13.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	412.54	41.25	(2)	17.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	335.81	33.58	(2)	13.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	351.61	35.16	(2)	14.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	392.23	39.22	(2)	16.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	290.67	29.07	(2)	11.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	283.90	28.39	(2)	11.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	268.10	26.81	(2)	10.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	274.87	27.49	(2)	11.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	437.37	43.74	(2)	18.3	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	356.12	35.61	(2)	14.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	295.18	29.52	(2)	12.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	331.29	33.13	(2)	13.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	234.24	23.42	(2)	9.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	399.00	39.90	(2)	16.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	401.26	40.13	(2)	16.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	353.86	35.39	(2)	14.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	351.61	35.16	(2)	14.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	268.10	26.81	(2)	10.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	385.46	38.55	(2)	16.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	331.29	33.13	(2)	13.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	385.46	38.55	(2)	16.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	299.69	29.97	(2)	12.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	385.46	38.55	(2)	16.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	444.14	44.41	(2)	18.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	396.75	39.67	(2)	16.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	288.41	28.84	(2)	11.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	306.47	30.65	(2)	12.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	308.72	30.87	(2)	12.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	324.52	32.45	(2)	13.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	389.97	39.00	(2)	16.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	295.18	29.52	(2)	12.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	308.72	30.87	(2)	12.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	315.49	31.55	(2)	12.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	399.00	39.90	(2)	16.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	335.81	33.58	(2)	13.8	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	441.89	44.19	(2)	18.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	288.41	28.84	(2)	11.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	281.64	28.16	(2)	11.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	263.58	26.36	(2)	10.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	446.40	44.64	(2)	18.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	335.81	33.58	(2)	13.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	403.52	40.35	(2)	16.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	329.04	32.90	(2)	13.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	270.35	27.04	(2)	10.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	306.47	30.65	(2)	12.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	304.21	30.42	(2)	12.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	250.04	25.00	(2)	10.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	254.55	25.46	(2)	10.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	290.67	29.07	(2)	11.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	333.55	33.35	(2)	13.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	259.07	25.91	(2)	10.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	259.07	25.91	(2)	10.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	369.66	36.97	(2)	15.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	317.75	31.78	(2)	13.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	399.00	39.90	(2)	16.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	392.23	39.22	(2)	16.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	335.81	33.58	(2)	13.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	430.60	43.06	(2)	18.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	421.57	42.16	(2)	17.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	326.78	32.68	(2)	13.4	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	301.95	30.20	(2)	12.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	281.64	28.16	(2)	11.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	405.77	40.58	(2)	16.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	387.72	38.77	(2)	16.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	466.71	46.67	(2)	19.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	340.32	34.03	(2)	14.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	353.86	35.39	(2)	14.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	462.20	46.22	(2)	19.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	326.78	32.68	(2)	13.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	304.21	30.42	(2)	12.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	374.18	37.42	(2)	15.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	286.15	28.62	(2)	11.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	340.32	34.03	(2)	14.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	279.38	27.94	(2)	11.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	308.72	30.87	(2)	12.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	292.92	29.29	(2)	11.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	261.33	26.13	(2)	10.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	356.12	35.61	(2)	14.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	389.97	39.00	(2)	16.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	308.72	30.87	(2)	12.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	283.90	28.39	(2)	11.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	408.03	40.80	(2)	17.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	365.15	36.51	(2)	15.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	338.06	33.81	(2)	13.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	394.49	39.45	(2)	16.4	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	444.14	44.41	(2)	18.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	412.54	41.25	(2)	17.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	399.00	39.90	(2)	16.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	344.83	34.48	(2)	14.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	277.12	27.71	(2)	11.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	369.66	36.97	(2)	15.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	414.80	41.48	(2)	17.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	371.92	37.19	(2)	15.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	414.80	41.48	(2)	17.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	243.27	24.33	(2)	9.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	274.87	27.49	(2)	11.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	351.61	35.16	(2)	14.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	308.72	30.87	(2)	12.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	417.06	41.71	(2)	17.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	520.88	52.09	(2)	22.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	399.00	39.90	(2)	16.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	426.09	42.61	(2)	17.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	340.32	34.03	(2)	14.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	295.18	29.52	(2)	12.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	410.29	41.03	(2)	17.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	387.72	38.77	(2)	16.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	356.12	35.61	(2)	14.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	347.09	34.71	(2)	14.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	344.83	34.48	(2)	14.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	342.58	34.26	(2)	14.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	292.92	29.29	(2)	11.9	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	399.00	39.90	(2)	16.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	356.12	35.61	(2)	14.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	353.86	35.39	(2)	14.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	356.12	35.61	(2)	14.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	374.18	37.42	(2)	15.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	367.40	36.74	(2)	15.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	383.20	38.32	(2)	15.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	365.15	36.51	(2)	15.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	297.44	29.74	(2)	12.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	295.18	29.52	(2)	12.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	374.18	37.42	(2)	15.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	356.12	35.61	(2)	14.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	435.11	43.51	(2)	18.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	414.80	41.48	(2)	17.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	408.03	40.80	(2)	17.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	482.51	48.25	(2)	20.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	340.32	34.03	(2)	14.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	322.26	32.23	(2)	13.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	358.38	35.84	(2)	14.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	430.60	43.06	(2)	18.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	367.40	36.74	(2)	15.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	268.10	26.81	(2)	10.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	392.23	39.22	(2)	16.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	399.00	39.90	(2)	16.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	401.26	40.13	(2)	16.7	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	378.69	37.87	(2)	15.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	320.01	32.00	(2)	13.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	369.66	36.97	(2)	15.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	324.52	32.45	(2)	13.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	369.66	36.97	(2)	15.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	351.61	35.16	(2)	14.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	396.75	39.67	(2)	16.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	365.15	36.51	(2)	15.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	283.90	28.39	(2)	11.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	333.55	33.35	(2)	13.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	259.07	25.91	(2)	10.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	340.32	34.03	(2)	14.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	209.41	20.94	(2)	8.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	326.78	32.68	(2)	13.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	408.03	40.80	(2)	17.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	403.52	40.35	(2)	16.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	374.18	37.42	(2)	15.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	444.14	44.41	(2)	18.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	385.46	38.55	(2)	16.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	417.06	41.71	(2)	17.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	371.92	37.19	(2)	15.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	250.04	25.00	(2)	10.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	374.18	37.42	(2)	15.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	437.37	43.74	(2)	18.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	329.04	32.90	(2)	13.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	385.46	38.55	(2)	16.0	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	385.46	38.55	(2)	16.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	308.72	30.87	(2)	12.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	333.55	33.35	(2)	13.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	331.29	33.13	(2)	13.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	204.90	20.49	(2)	8.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	313.24	31.32	(2)	12.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	322.26	32.23	(2)	13.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	347.09	34.71	(2)	14.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	626.96	62.70	(2)	26.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	403.52	40.35	(2)	16.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	292.92	29.29	(2)	11.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	324.52	32.45	(2)	13.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	351.61	35.16	(2)	14.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	419.32	41.93	(2)	17.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	353.86	35.39	(2)	14.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	389.97	39.00	(2)	16.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	295.18	29.52	(2)	12.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	279.38	27.94	(2)	11.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	380.95	38.09	(2)	15.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	304.21	30.42	(2)	12.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	620.19	62.02	(2)	26.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	261.33	26.13	(2)	10.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	320.01	32.00	(2)	13.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	448.66	44.87	(2)	18.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	340.32	34.03	(2)	14.0	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	272.61	27.26	(2)	11.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	412.54	41.25	(2)	17.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	439.63	43.96	(2)	18.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	353.86	35.39	(2)	14.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	335.81	33.58	(2)	13.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	385.46	38.55	(2)	16.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	263.58	26.36	(2)	10.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	401.26	40.13	(2)	16.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	396.75	39.67	(2)	16.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	335.81	33.58	(2)	13.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	274.87	27.49	(2)	11.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	268.10	26.81	(2)	10.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	329.04	32.90	(2)	13.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	396.75	39.67	(2)	16.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	417.06	41.71	(2)	17.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	279.38	27.94	(2)	11.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	367.40	36.74	(2)	15.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	358.38	35.84	(2)	14.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	392.23	39.22	(2)	16.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	295.18	29.52	(2)	12.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	272.61	27.26	(2)	11.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	401.26	40.13	(2)	16.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	487.03	48.70	(2)	20.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	356.12	35.61	(2)	14.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	378.69	37.87	(2)	15.7	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	286.15	28.62	(2)	11.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	367.40	36.74	(2)	15.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	315.49	31.55	(2)	12.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	290.67	29.07	(2)	11.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	308.72	30.87	(2)	12.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	306.47	30.65	(2)	12.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	369.66	36.97	(2)	15.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	308.72	30.87	(2)	12.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	297.44	29.74	(2)	12.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	277.12	27.71	(2)	11.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	304.21	30.42	(2)	12.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	259.07	25.91	(2)	10.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	283.90	28.39	(2)	11.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	279.38	27.94	(2)	11.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	265.84	26.58	(2)	10.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	295.18	29.52	(2)	12.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	250.04	25.00	(2)	10.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	446.40	44.64	(2)	18.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	387.72	38.77	(2)	16.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	378.69	37.87	(2)	15.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	299.69	29.97	(2)	12.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	245.53	24.55	(2)	9.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	256.81	25.68	(2)	10.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	421.57	42.16	(2)	17.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	365.15	36.51	(2)	15.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	410.29	41.03	(2)	17.1	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	396.75	39.67	(2)	16.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	365.15	36.51	(2)	15.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	414.80	41.48	(2)	17.3	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	423.83	42.38	(2)	17.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	340.32	34.03	(2)	14.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	326.78	32.68	(2)	13.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	383.20	38.32	(2)	15.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	313.24	31.32	(2)	12.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	360.63	36.06	(2)	14.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	329.04	32.90	(2)	13.5	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	254.55	25.46	(2)	10.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	245.53	24.55	(2)	9.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	444.14	44.41	(2)	18.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	371.92	37.19	(2)	15.4	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	365.15	36.51	(2)	15.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	478.00	47.80	(2)	20.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	401.26	40.13	(2)	16.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	525.39	52.54	(2)	22.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	362.89	36.29	(2)	15.0	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	360.63	36.06	(2)	14.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	356.12	35.61	(2)	14.7	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	365.15	36.51	(2)	15.1	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	376.43	37.64	(2)	15.6	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	365.15	36.51	(2)	15.1	(3)

Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	290.67	29.07	(2)	11.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	367.40	36.74	(2)	15.2	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	292.92	29.29	(2)	11.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	383.20	38.32	(2)	15.9	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	380.95	38.09	(2)	15.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	358.38	35.84	(2)	14.8	(3)
Pre-colonial	650-250 cal BP	*Micropogonias furnieri*	Rio do Meio (RM)	347.09	34.71	(2)	14.3	(3)
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	490.18	49.02	(2)	20.6	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	614.09	61.41	(2)	26.1	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	413.45	41.34	(2)	17.2	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	413.45	41.34	(2)	17.2	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	371.92	37.19	(2)	15.4	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	557.44	55.74	(2)	23.6	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	445.95	44.59	(2)	18.7	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	445.95	44.59	(2)	18.7	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	445.95	44.59	(2)	18.7	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	394.04	39.40	(2)	16.4	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	351.83	35.18	(2)	14.5	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	524.94	52.49	(2)	22.2	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	446.62	44.66	(2)	18.7	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	333.55	33.35	(2)	13.7	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	700.31	70.03	(2)	30.0	This study

Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	490.41	49.04	(2)	20.7	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	337.16	33.72	(2)	13.9	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	461.97	46.20	(2)	19.4	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	461.97	46.20	(2)	19.4	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	461.97	46.20	(2)	19.4	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	461.97	46.20	(2)	19.4	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	461.97	46.20	(2)	19.4	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	461.97	46.20	(2)	19.4	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	461.97	46.20	(2)	19.4	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	461.97	46.20	(2)	19.4	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	461.97	46.20	(2)	19.4	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	374.85	37.49	(2)	15.5	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	374.85	37.49	(2)	15.5	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	374.85	37.49	(2)	15.5	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	499.21	49.92	(2)	21.0	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	499.21	49.92	(2)	21.0	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	402.61	40.26	(2)	16.8	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	402.61	40.26	(2)	16.8	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	438.73	43.87	(2)	18.4	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	250.04	25.00	(2)	10.0	This study

Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	564.21	56.42	(2)	23.9	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	416.38	41.64	(2)	17.4	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	593.10	59.31	(2)	25.2	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	593.10	59.31	(2)	25.2	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	497.41	49.74	(2)	21.0	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	497.41	49.74	(2)	21.0	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	497.41	49.74	(2)	21.0	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	416.38	41.64	(2)	17.4	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	416.38	41.64	(2)	17.4	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	416.38	41.64	(2)	17.4	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	365.37	36.54	(2)	15.1	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	562.41	56.24	(2)	23.8	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	550.90	55.09	(2)	23.3	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	437.37	43.74	(2)	18.3	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	398.32	39.83	(2)	16.6	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	277.80	27.78	(2)	11.2	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	492.44	49.24	(2)	20.7	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	410.74	41.07	(2)	17.1	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	410.74	41.07	(2)	17.1	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	484.09	48.41	(2)	20.4	This study

Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	484.09	48.41	(2)	20.4	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	484.09	48.41	(2)	20.4	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	360.63	36.06	(2)	14.9	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	360.63	36.06	(2)	14.9	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	503.95	50.40	(2)	21.3	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	503.95	50.40	(2)	21.3	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	451.59	45.16	(2)	18.9	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	417.74	41.77	(2)	17.4	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	417.74	41.77	(2)	17.4	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	417.74	41.77	(2)	17.4	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	417.74	41.77	(2)	17.4	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	300.60	30.06	(2)	12.2	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	438.95	43.90	(2)	18.4	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	516.37	51.64	(2)	21.8	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	516.37	51.64	(2)	21.8	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	516.37	51.64	(2)	21.8	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	476.64	47.66	(2)	20.0	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	476.64	47.66	(2)	20.0	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	476.64	47.66	(2)	20.0	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	476.64	47.66	(2)	20.0	This study

Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	455.88	45.59	(2)	19.1	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	455.88	45.59	(2)	19.1	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	455.88	45.59	(2)	19.1	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	455.88	45.59	(2)	19.1	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	455.88	45.59	(2)	19.1	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	400.36	40.04	(2)	16.7	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	400.36	40.04	(2)	16.7	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	400.36	40.04	(2)	16.7	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	400.36	40.04	(2)	16.7	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	400.36	40.04	(2)	16.7	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	400.36	40.04	(2)	16.7	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	400.36	40.04	(2)	16.7	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	400.36	40.04	(2)	16.7	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	400.36	40.04	(2)	16.7	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	400.36	40.04	(2)	16.7	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	318.20	31.82	(2)	13.0	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	318.20	31.82	(2)	13.0	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	318.20	31.82	(2)	13.0	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	743.65	74.36	(2)	31.9	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	422.93	42.29	(2)	17.7	This study

Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	297.66	29.77	(2)	12.1	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	362.66	36.27	(2)	15.0	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	362.66	36.27	(2)	15.0	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	362.66	36.27	(2)	15.0	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	362.66	36.27	(2)	15.0	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	478.22	47.82	(2)	20.1	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	478.22	47.82	(2)	20.1	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	478.22	47.82	(2)	20.1	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	438.05	43.80	(2)	18.3	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	498.08	49.81	(2)	21.0	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	498.08	49.81	(2)	21.0	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	498.08	49.81	(2)	21.0	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	498.08	49.81	(2)	21.0	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	498.08	49.81	(2)	21.0	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	498.08	49.81	(2)	21.0	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	498.08	49.81	(2)	21.0	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	498.08	49.81	(2)	21.0	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	436.69	43.67	(2)	18.3	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	436.69	43.67	(2)	18.3	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	436.69	43.67	(2)	18.3	This study

Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	436.69	43.67	(2)	18.3	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	436.69	43.67	(2)	18.3	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	436.69	43.67	(2)	18.3	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	436.69	43.67	(2)	18.3	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	436.69	43.67	(2)	18.3	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	210.77	21.08	(2)	8.3	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	406.45	40.65	(2)	16.9	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	406.45	40.65	(2)	16.9	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	406.45	40.65	(2)	16.9	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	406.45	40.65	(2)	16.9	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	582.27	58.23	(2)	24.7	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	481.61	48.16	(2)	20.3	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	417.74	41.77	(2)	17.4	This study
Historical	19th-early 20th century AD	*Micropogonias furnieri*	Praia Grande Unidade 21 (PG-U21)	326.10	32.61	(2)	13.4	This study

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SM6. Statistical analysis of body total length (BTL)

Table 1. Statistical analysis of body total length (BTL) of barred grunt

Kruskal-Wallis test for equal medians			
Kruskal-Wallis chi-squared = 20.556, df = 3, p-value = 0.0001302 Pairwise comparisons using Wilcoxon rank sum test with continuity correction			
	Present-day	**Late 19th-early 20th century AD**	**650-250 cal BP**
Late 19th-early 20th century AD	0.001	-	-
650-250 cal BP	0.012	1.000	-
1000-500 cal BP	1.000	1.000	1.000
P value adjustment method: bonferroni			

Table 2. Statistical analysis of body total length (BTL) of whitemouth croaker

Kruskal-Wallis rank sum test			
Kruskal-Wallis chi-squared = 183.05, df = 3, p-value < 2.2e-16 Pairwise comparisons using Wilcoxon rank sum test with continuity correction			
	Present-day	**Late 19th-early 20th century AD**	**650-250 cal BP**
Late 19th-early 20th century AD	< 2e-16	-	-
650-250 cal BP	1.4e-10	< 2e-16	-
3550-2000 cal BP	1.00	7.8e-09	0.36
P value adjustment method: Bonferroni			

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CHAPTER 7

Zooarchaeology: an educational booklet

7.1. A proposal for science-society interaction using zooarchaeology

In addition to the previously presented chapters, an educational booklet was designed to introduce readers to the field of Zooarchaeology. This project was selected for the *Prêmio Elisabete Anderle de Apoio à Cultura - Edição* 2020 and *Edição* 2022, executed with resources from the *Governo do Estado de Santa Catarina*, through the *Fundação Catarinense de Cultura*. The booklet titled "*Zooarqueologia - Fauna em Sambaquis (para entender e jogar)*" was elaborated based on the compiled data from ZooarchBR database, presented in Chapter 2 and previous studies (Fossile et al. 2020) (Figure 7.1). The booklet is intended for all age groups, but particularly for students aged 10 to 14, who are being introduced to the topic of archaeology through the study of Regional History. This booklet is a proposal for science-society interaction stemming from studies conducted at archaeological sites and within the collection of the *Museu Arqueológico de Sambaqui de Joinville* (MASJ) concerning the pre-colonial culture present in Babitonga Bay, Santa Catarina. Furthermore, this booklet also contributes significantly to enhancing Ocean Literacy - an understanding of the ocean's influence on us and our influence on the ocean (UNESCO 2017).

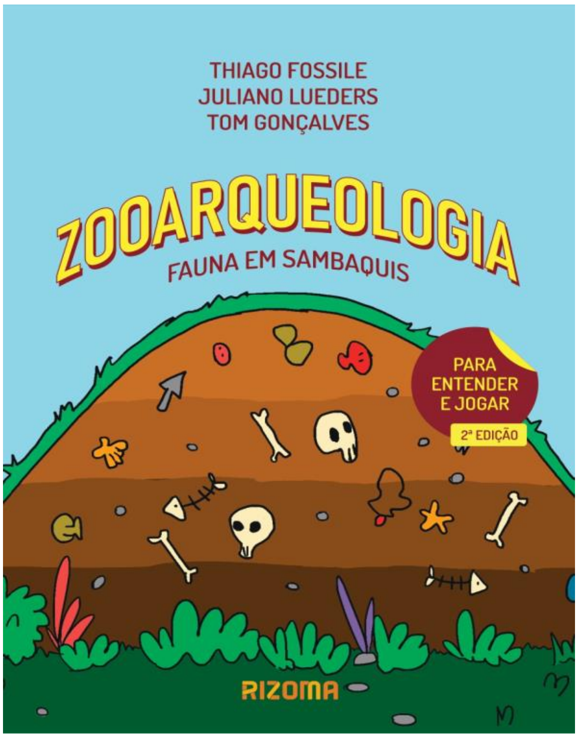

Figure 7.1. Cover of the booklet *Zooarqueologia - Fauna em Sambaquis (para entender e jogar).*

The booklet consists of seven chapters. The first chapter explains what archaeology is, emphasising its differences from the global and cinematic view while highlighting its various valuable findings. The second chapter aims to elucidate what archaeological sites of the "sambaqui" typology are, considering them as significant cultural and natural libraries in Brazil's coastal environments. The third chapter connects archaeological sites with the history and conservation of the Atlantic Forest (Figure 7.2). The fourth chapter introduces the environmental and archaeological context of Babitonga Bay, the last major estuary with the largest mangrove portion in southern Brazil. In the fifth chapter, zooarchaeology is defined, providing information on over 240 animal species found in sambaquis from Babitonga Bay. The sixth chapter draws readers' attention to the importance of preserving archaeological sites, not just as a part of history but also as tools contributing to discussions for Atlantic Forest conservation. The seventh, and final chapter, is the standout of the booklet, dedicated to a card game involving the archaeofauna from Babitonga Bay. The opportunity to read and transform the book into a card-game turns learning into a playful activity, fostering multiple opportunities for interaction among people.

A print run of thousand copies were distributed in schools and museums around Babitonga Bay (Figure 7.3, Figure 7.4), and the material can also be downloaded from https://linktr.ee/zooarqueologia. In addition to the distribution of copies, a social and educational action involving the local community was conducted to collect solid waste around the Sambaqui Morro do Ouro, situated in an urban area in Joinville/SC (Figure 7.5, Figure 7.6). Before the action, all participants received a brief introduction to the topics covered in the booklet (e.g. archaeology, zooarchaeology, and shell mounds), along with instructions on proper waste disposal. The initiative was coordinated by the project team with support from local institutions *Conexão Babitonga*, *Instituto Comar*, *Rotaract Joinville*, *Lixo Zero Joinville and Associação de Amigos do Museu Arqueológico de Sambaqui de Joinville (AAMASJ)*.

Figure 7.2. Third booklet chapter: “History and conservation of the Atlantic Forest involves shell mounds".

Figure 7.3. Distribution of booklets to the directors of EEB Titolívio Venâncio Rosa

Figure 7.4. Distribution of booklets to students of EEB Titolívio Venâncio Rosa

Figure 7.5. Social and educational action around the Sambaqui Morro do Ouro involving the Joinville community - solid waste collected during the action.

Figure 7.6. Social and educational action around the Sambaqui Morro do Ouro involving the Joinville community - distribution of booklet

7.2. References

Fossile, Thiago, Jessica Ferreira, Dione da Rocha Bandeira, Sérgio Dias-da-Silva, and André Carlo Colonese. 2020. “Integrating Zooarchaeology in the Conservation of Coastal-Marine Ecosystems in Brazil.” Quaternary International: The Journal of the International Union for Quaternary Research. https://doi.org/10.1016/j.quaint.2019.04.022.

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CHAPTER 8

Final considerations

8.1. Synthesis

The collection of research presented across Chapter 2 to Chapter 6 has shed light on the complex and dynamic relationship between humans and coastal ecosystems in the Southwestern Atlantic. Below is a synthesis of the five studies conducted within this thesis. In these studies a range of techniques were applied, including stable isotopes, bone taphonomy, metrics, and palaeoproteomics, with aim to explore the connections between fishing practices, climate change, technological advancements, and historical events concerning aquatic resources from pre-colonial through historical periods.

In **Chapter 2**, zooarchaeological data from Brazil were compiled and standardised to establish the Brazilian Zooarch Database (ZooarchBR), serving as the first collaborative and openly accessible zooarchaeological database in Brazil. This platform allows users to access existing data and contribute by inputting new information, thereby enhancing faunal records in the country's archaeological sites. Currently, the ZooarchBR repository integrates information from 71 publications spanning from 1975 to 2022. This extensive dataset encompasses 374 archaeological sites with varying cultural attributions along the southern coast of Brazil, identifying 366 distinct species across nine animal groups. Within this study, a total of 151 mollusk species, eight crustaceans, one echinoderm, 30 cartilaginous fish, 79 bony fish, one amphibian, 12 reptiles, 21 birds, and 63 mammals were mapped, illustrating the versatility of ZooarchBR for applications in Archaeology and Conservation Biology (Figure 8.1 to Figure 8.9).

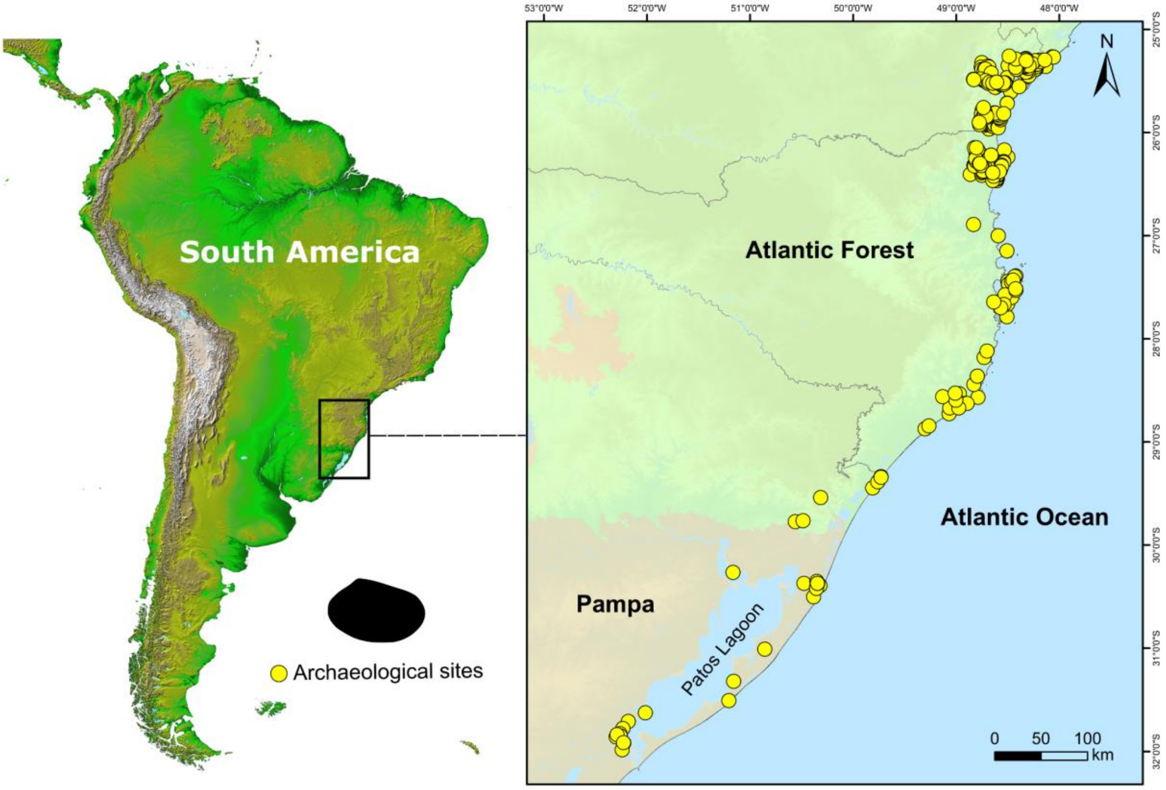

Figure 8.1. Distribution of archaeological sites on the Southern coast of Brazil with mollusks species.

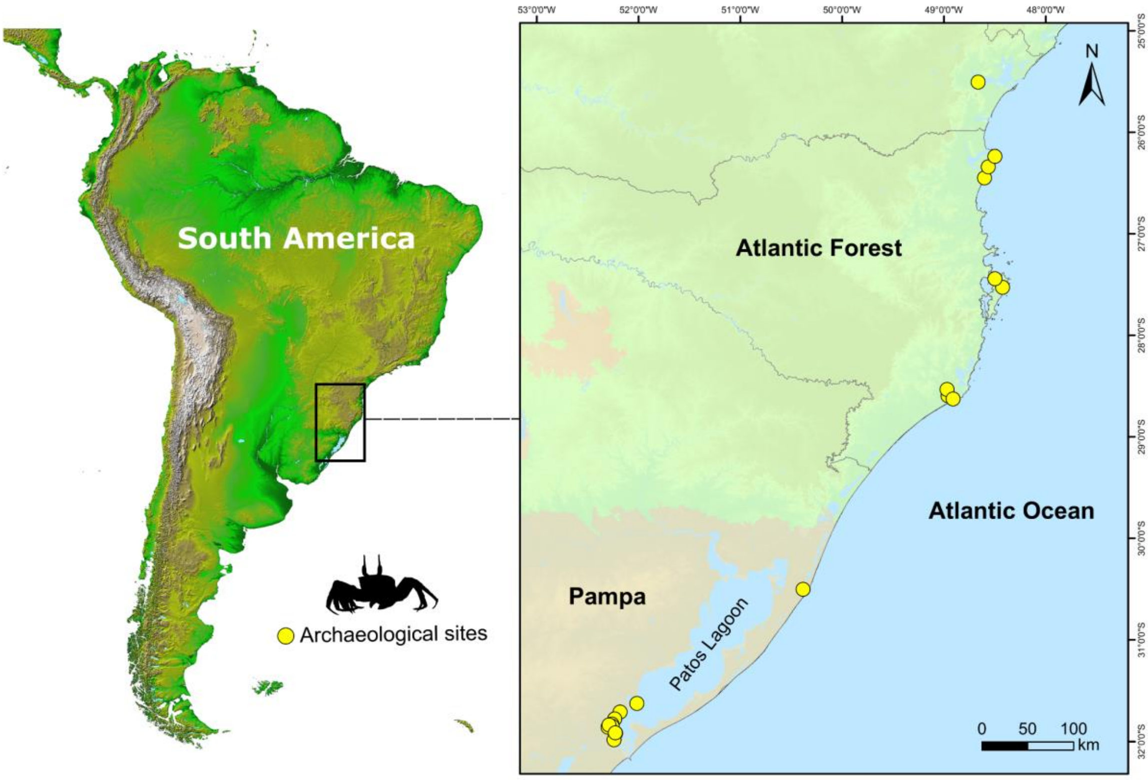

Figure 8.2. Distribution of archaeological sites on the Southern coast of Brazil with crustacean species.

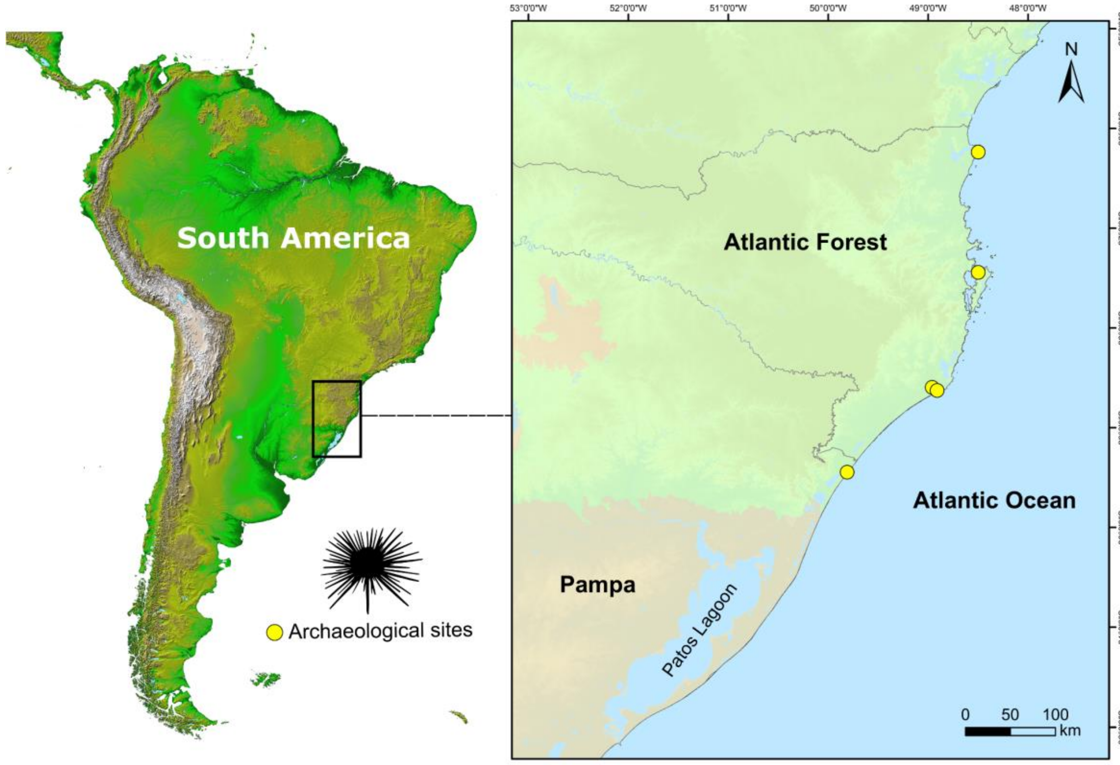

Figure 8.3. Distribution of archaeological sites on the Southern coast of Brazil with echinoderm species.

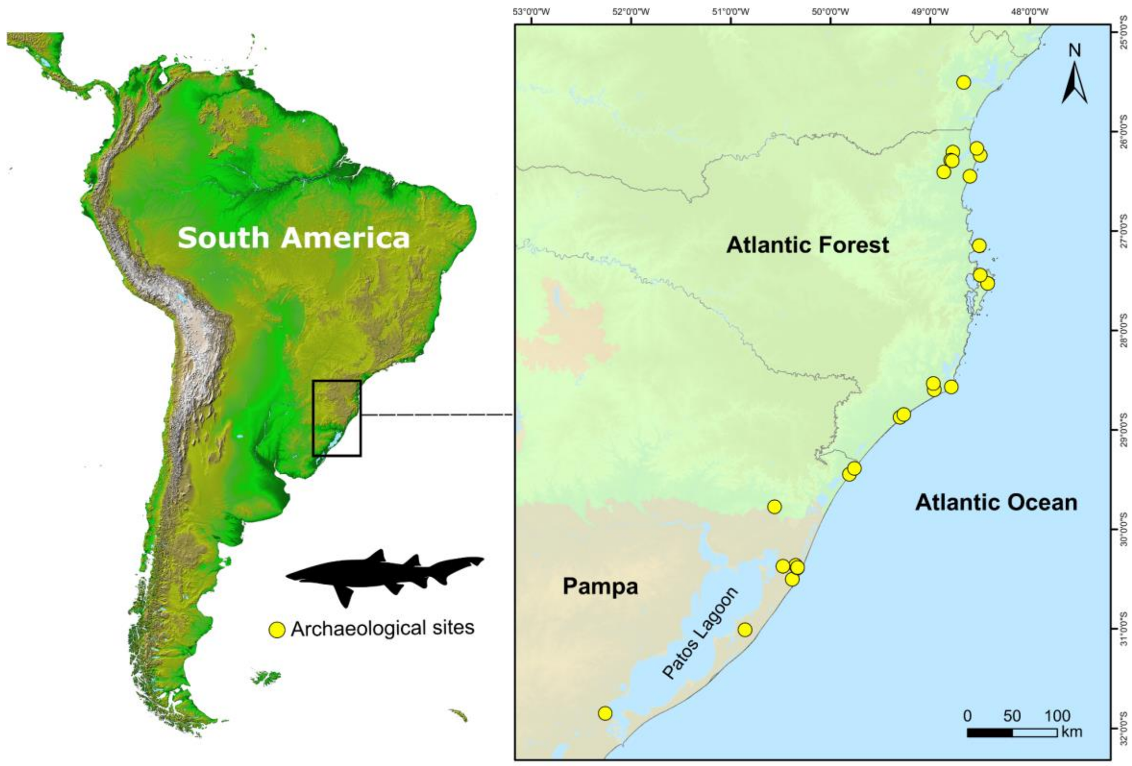

Figure 8.4. Distribution of archaeological sites on the Southern coast of Brazil with cartilaginous fish species.

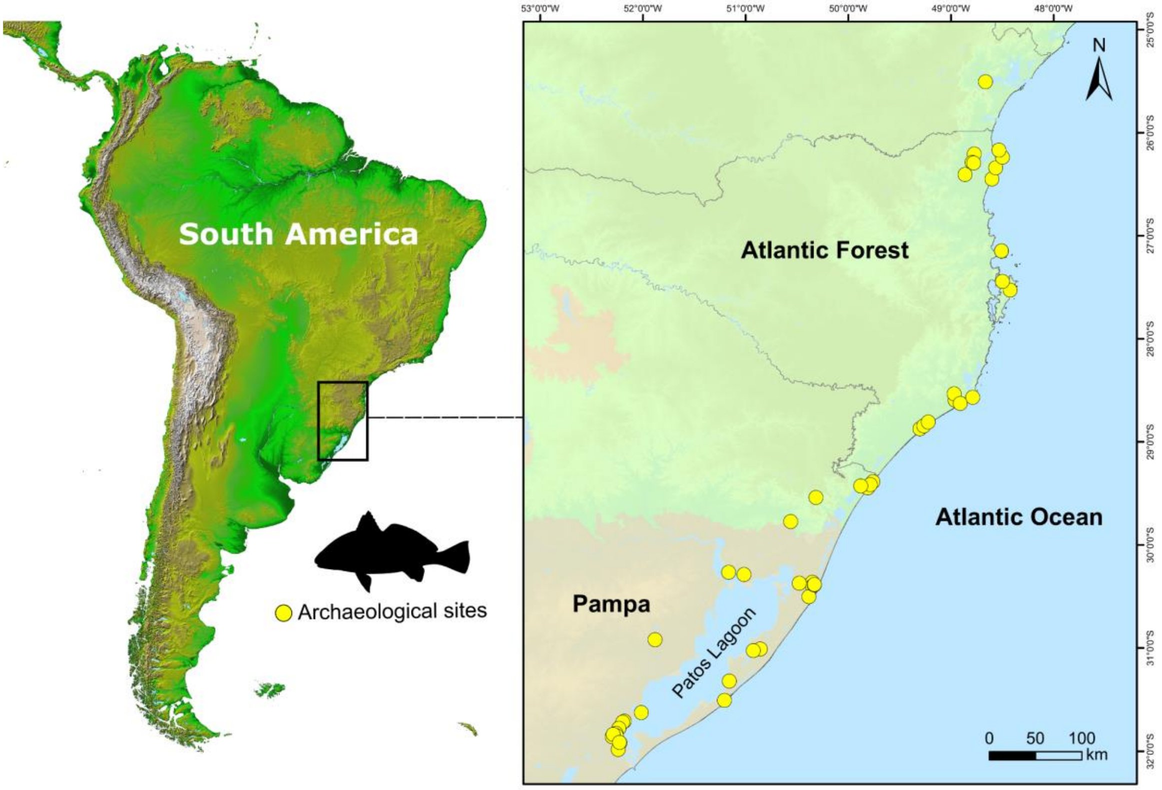

Figure 8.5. Distribution of archaeological sites on the Southern coast of Brazil with bony fish species.

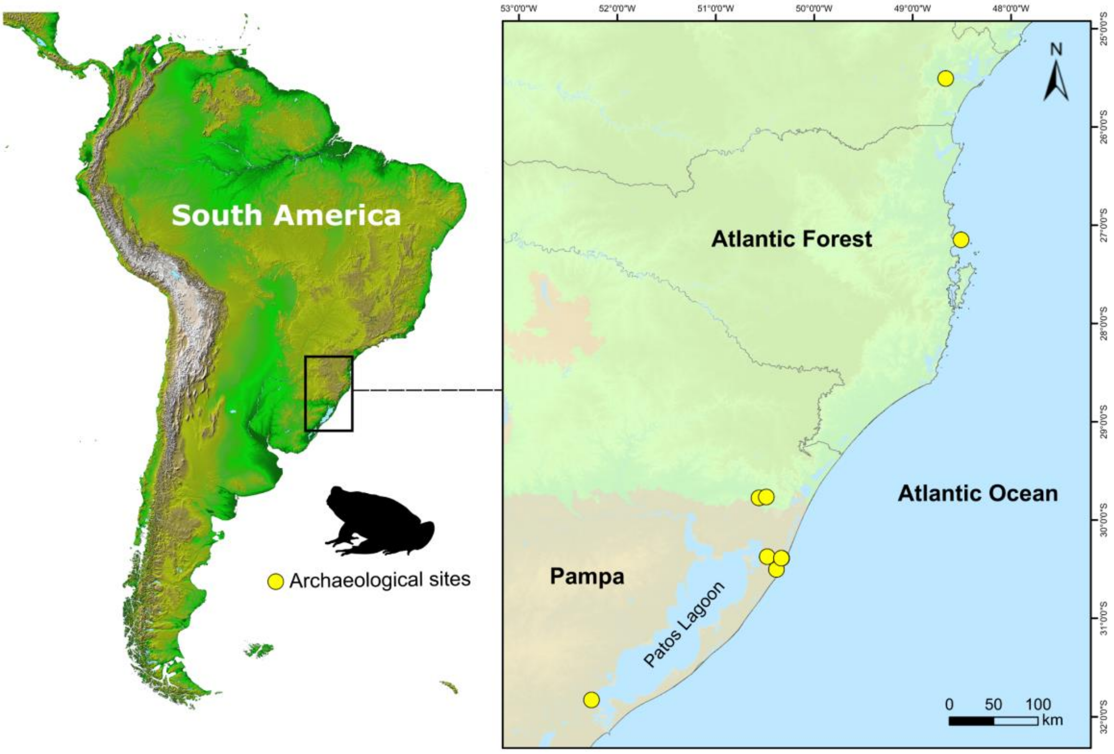

Figure 8.6. Distribution of archaeological sites on the Southern coast of Brazil with amphibian species.

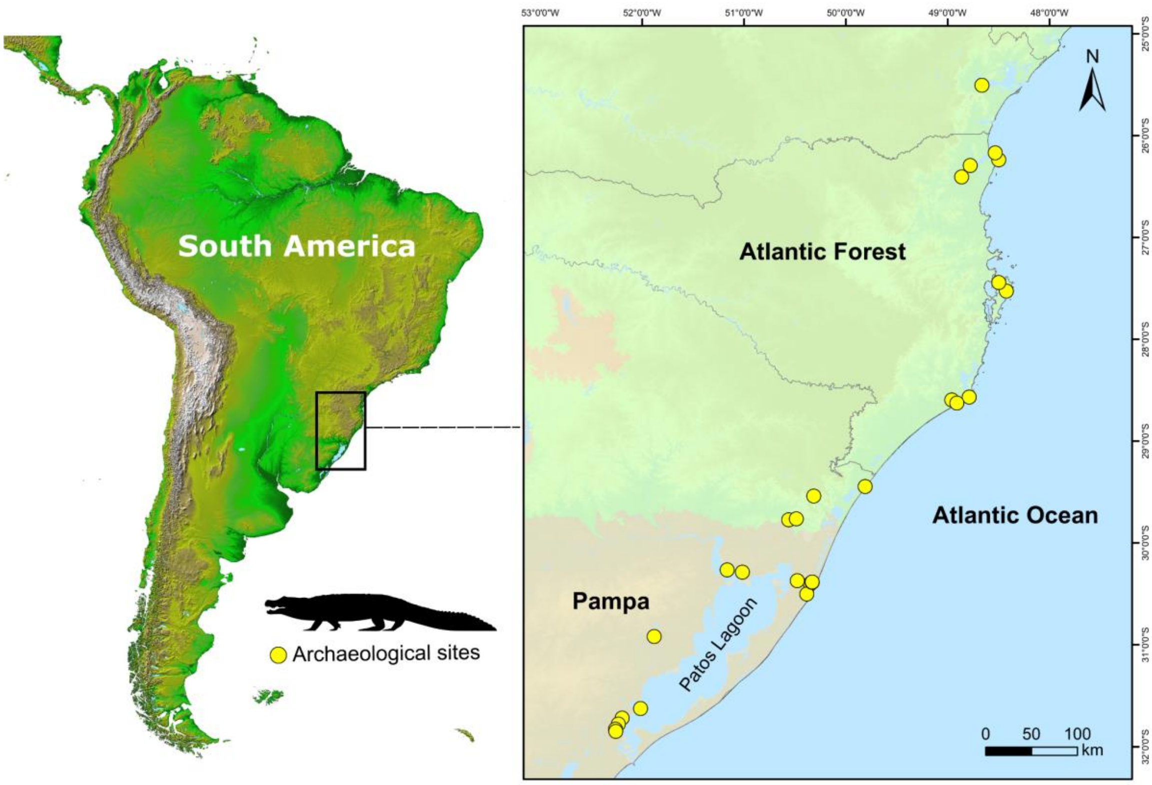

Figure 8.7. Distribution of reptile archaeological sites on the Southern coast of Brazil with reptile species.

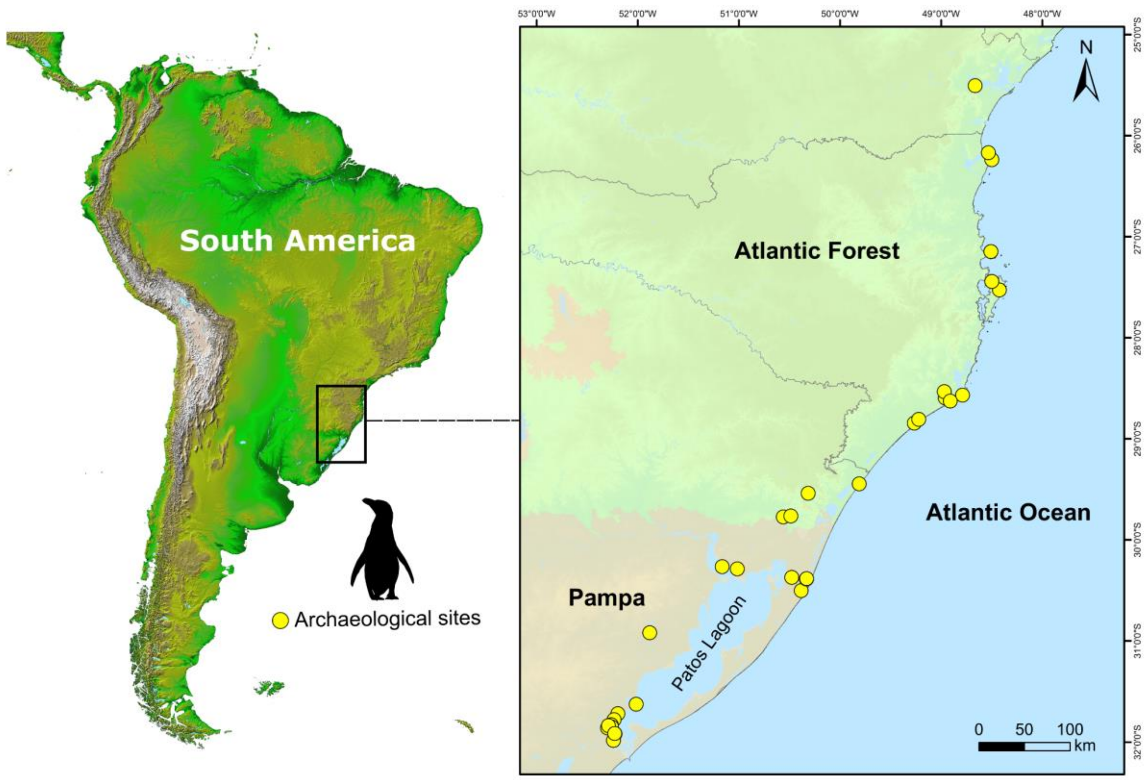

Figure 8.8. Distribution of archaeological sites on the Southern coast of Brazil with bird/Aves species.

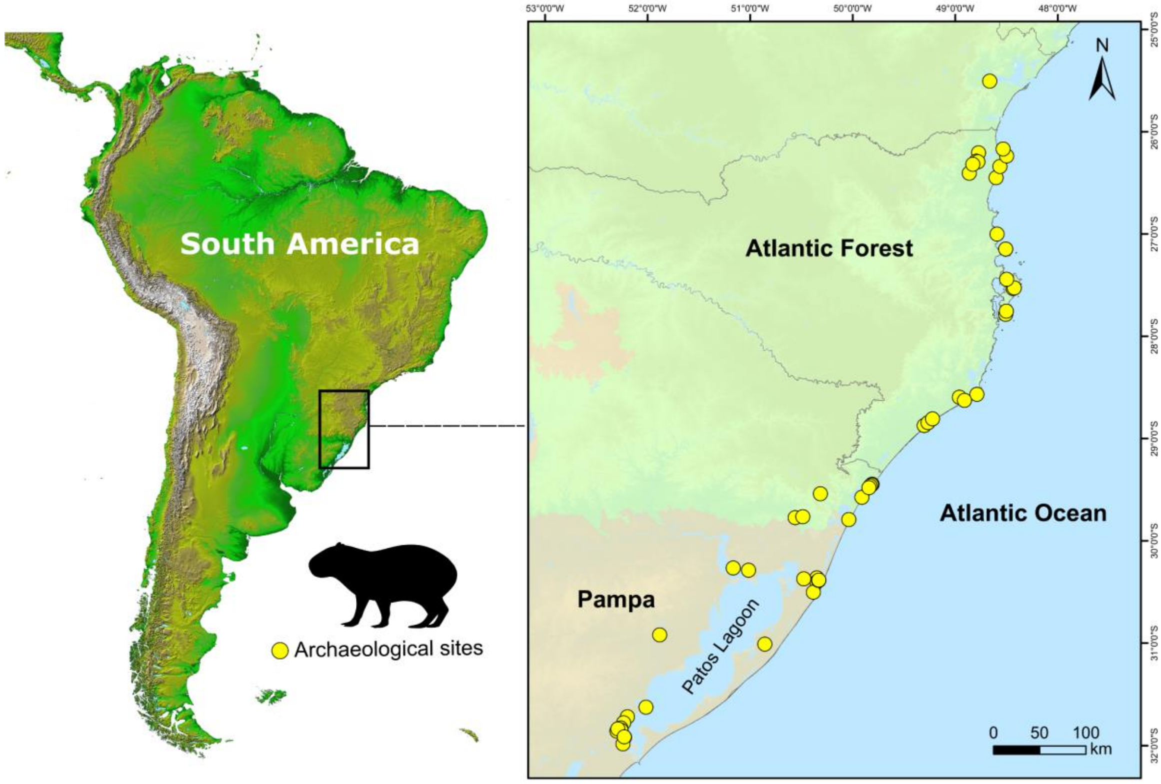

Figure 8.9. Distribution of archaeological sites on the Southern coast of Brazil with mammal species.

In **Chapter 3**, a comprehensive analysis was conducted to evaluate snapshots of species compositions and relative abundances over the past 9500 years. The study also involved modelling differences in species' functional traits between archaeological and modern fisheries. The findings revealed compelling evidence for both generalist and specialist fishing practices during pre-colonial eras, highlighting the regular capture of large body sizes and substantial body masses over extended periods. However, a comparative analysis with modern catches unveiled a significant decline in these fundamental functional traits. This decline is potentially linked to overfishing and escalating human impacts in recent times, signalling notable changes in fishing practices and their ecological consequences. This challenges our perception of the antiquity of the human footprint on ocean ecosystems in the region. Some of these species are currently threatened by overfishing and habitat degradation, while others face uncertainties regarding their modern distribution and abundance. The study's findings provide the most direct evidence of which species have been subjected to long-term fishing efforts and offer benchmarks of species' relative abundances and distributions before fish commoditization in the Southwestern Atlantic Ocean.

Chapter 4 focuses on the archaeological sites situated in Babitonga Bay, offering unique insights into pre-colonial Indigenous knowledge and the historical trends in marine species composition along the Atlantic Forest coast of Brazil. The review examines the fish catch composition prior to European colonisation, considering associated fishing artefacts found in archaeological sites in this region that span the last 6000 years. The study suggests that pre-colonial and historical communities engaged extensively in capturing pelagic and high trophic level species around 2000 years ago. This intensive activity was propelled by the adoption of advanced fishing and maritime technologies, coinciding with the emergence of single-piece baited fish hooks and evidence of human colonisation on oceanic islands. The findings strongly indicate an expansion of fishing practices into deep waters, challenging previous notions and prompting a reevaluation of the ancient impact of human presence on regional ocean ecosystems.

In **Chapter 5**, the research delves into understanding the historical impact of human activities on fish and terrestrial mammals in the Southwestern Atlantic. The study focuses on the analysis of faunal remains from two historical archaeological sites, Morro Grande 1 (MG1) and Praia Grande Unidade 21 (PG-U21), located in Babitonga Bay, Santa Catarina state, Brazil, dating between 1750 to 1950 AD. The study reveals a continuous pattern of selective hunting targeting medium- and large-bodied native terrestrial mammals for over 4500 years, challenging the conventional notion of heavy dependence on domestic animals during the period of European colonisation. It underscores the role of archaeology in unravelling the enduring anthropogenic pressures imposed on Neotropical mammals over the long term and raises awareness about potential threats faced by these species.

Chapter 6 advances our knowledge of marine and coastal ecosystems and the subsistence fishing practices targeting various species over time. This study employed otolith metrics and stable isotope analysis to examine alterations in body length and trophic ecology among several demersal species recovered from pre-colonial (prior to 1500 AD) and historical (late 19th to the early 20th century AD) sites in Babitonga Bay, southern Brazil. The findings indicate that pre-colonial and historical fisheries exploited diverse mangrove habitats, spanning freshwater to marine systems. While no evidence suggests size reduction in certain extensively exploited species across time, discernible recent anthropogenic impacts manifest in disparities in nitrogen ($\delta^{15}N$) and sulphur ($\delta^{34}S$) stable isotope values between modern and archaeological specimens. These discrepancies can be partially attributed to industrial, agricultural, and urban activities witnessed in the last few decades.

Lastly, **Chapter 7** serves as a proposal of relationship between science and society, using Zooarchaeology as a bridge due to the universal appeal of animals among children and the general public. This chapter introduces an educational approach through the creation of an engaging booklet and card-game designed for all age groups, particularly targeting students aged 10 to 14, who are being introduced to the topic of archaeology through the study of Regional History. The educational material features differentiated text and interactive elements, fostering an inclusive learning experience. Early indications showcase promising results, with positive feedback received from schools and museums. Notably, this initiative has garnered national recognition – *Prêmio Rodrigo Melo Franco de Andrade – Edição 2022*, exemplified by the esteemed inclusion of the booklet in its first edition. The successful reception underscores the potential and efficacy of employing creative educational tools within the Zooarchaeology to foster broader engagement and understanding within the community.

8.2. Research perspectives

8.2.1. Reference collections and identification guides

The first point to highlight relates to an initial aspect of zooarchaeological research, the taxonomic identification. There is an urgent need among researchers to develop comprehensive reference collections and identification guides for specimens (e.g., pre- and postcranial bones and teeth) of both fish and other species in the Neotropical fauna. This enhancement will aid zooarchaeologists in identifying specimens from the archaeofauna, thereby refining the quality of biodiversity data from the past. The lack of well-curated reference collections impedes the taxonomic detailing of archaeological specimens. Consequently, this deficiency affects the use of archaeological data in discussions related to conservation biology, as proposed here.

8.2.2. Standardised Practices in Zooarchaeological Sampling and Analysis

Although Zooarchaeology has been developed in Brazil since the 1970s (Garcia, 1969; Schorr, 1975), there is an urgent need for the standardisation, as extensively as possible, of sampling methods and analysis of faunal remains. In Brazil, sampling recommendations have been made for pre-colonial sites (Klokler, 2013), however, as demonstrated in Chapter 2 and Chapter 3, there are significant differences in sampling methods in Brazilian Archaeology. Standardisation should encompass, for instance, controlled sampling (m^3 or L) and the total quantification of faunal remains (Number of Specimens, NSP), rather than solely focusing on the identified remains (Number of Identified Specimens, NISP).

Additionally, establishing a comprehensive zooarchaeological research agenda is crucial to conduct studies that may seem basic but are key for advancing zooarchaeological research. These encompass, for instance, (I) allometric studies involving the primary species found at sites, i.e., measuring multiple specimens of individuals at various life stages (sizes) to create equations for estimating length and mass (Edwin Jackson, 1989; Reitz et al., 1987); and (II) taphonomic studies related to pre- and post-depositional processes (Zohar et al., 2001; Zohar & Belmaker, 2005; Zohar & Cooke, 1997).

Furthermore, it is necessary to establish and maintain a robust dialogue within the archaeology community, as there are rarely excavations dedicated to a zooarchaeological perspective. This approach will facilitate a comprehensive understanding of species distribution and abundance on a broad spatial and temporal scale, as elaborated in Chapter 3.

8.2.3. Advances in biomolecular analyses

Biomolecular analysis, encompassing stable isotope and paleoproteomic (ZooMS) studies, is crucial for advancing the Historical Ecology and other scientific areas within South America, particularly in the vast continental expanse of Brazil. Embracing and expanding these sophisticated analytical methods in the region promises to unlock a wealth of invaluable information concerning past environments, subsistence patterns, and cultural interactions. The use of stable isotopes offers a versatile approach to unravelling a myriad of ecological and biological aspects. These isotopic signatures provide valuable insights into diverse aspects of species' ecology, including their trophic levels and habitat preferences (Fry, 2006; Michener & Lajtha, 2008). Moreover, by analysing stable isotopes across various landscapes and temporal periods, researchers can decipher critical information about changes in ecosystems, such as alterations in food webs, responses to environmental shifts, and species adaptations over extended periods (Brugam et al., 2017; Guiry, 2019; Guiry et al., 2021; Pizzochero et al., 2017). This comprehensive understanding derived from stable isotopic analysis contributes significantly to ecological research, conservation efforts, and understanding the intricate interactions within ecosystems across different spatial and temporal scales.

Simultaneously, the field of paleoproteomics offers novel avenues for exploring ancient protein sequences, enabling the study to establish new molecular markers for taxonomic identification of key marine species using collagen peptide mass fingerprinting. Considering the constraints of taxonomic identifications of archaeological faunal remains through traditional methods, primarily due to extensive bone fragmentation — approximately 70% of bone remains at coastal sites in Brazil remaining unidentified (Fossile et al., 2019), the emergence of peptide mass-fingerprinting of Type I collagen through Mass Spectrometry — also known as Zooarchaeology by Mass Spectrometry, or ZooMS — has proven to be a rapid and cost-effective technique for discerning the taxonomy of bone fragments. This method capitalises on the variability in amino acid sequences among vertebrate taxa, utilising MALDI-ToF-MS to measure peptide masses (McGrath et al., 2019). As Brazil stands as a mosaic of ecosystems and cultural histories, an expansion of biomolecular analyses within this continental expanse holds immense potential to deepen our insights into the intricate tapestry of its prehistoric and historic narratives.

Furthermore, stable isotopes and proteomic analyses can be applied in forensic applications, particularly in combating the illegal trade of animals (Alexander et al., 2019; Andersson et al., 2021; Hopkins et al., 2022; Parker et al., 2021). These analytical methods enable the identification of geographical provenance, determination of the animal's diet and habitat, and taxonomic identification of species. Stable isotope analysis provides insights to differentiate between wild-caught and captive species of animals by discerning isotopic differences in the composition, as isotopic signatures vary according to the diet and environmental characteristics of different regions (Alexander et al., 2019; Andersson et al., 2021; Hopkins et al., 2022). On the other hand, proteomic analysis, by examining protein profiles, facilitates species identification even in heavily degraded or processed samples, thereby aiding in identifying illicitly traded animal parts and products (Parker et al., 2021). Together, these forensic applications of stable isotope and proteomic analyses play a pivotal role in law enforcement efforts, assisting in identifying and prosecuting illegal wildlife traffickers while aiding in wildlife conservation endeavours globally.

8.3. Final considerations

The five studies presented in this thesis offer insights into the fauna and coastal-marine environments of the Southwestern Atlantic. They underscore the potential of archaeological faunal remains for tracking long-term changes in marine environment and human perception of marine biodiversity in southern Brazil. They expand the historical contexts of pressing issues in the region, such as overfishing, defaunation, and other anthropogenic stressors on coastal species and habitats. The increasing demand for a multidisciplinary and temporal outlook in conservation discussions presents an opportunity for Neotropical Archaeology to engage actively and contribute to policy-driven measures, thereby amplifying the discipline's relevance to environmental issues at regional, national, and global scales.

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