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Facing Change through Diversity: Resilience and Diversification of Plant Management Strategies during the Mid to Late Holocene Transition at the Monte Castelo Shellmound, SW Amazonia

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Abstract: Recent advances in the archaeology of lowland South America are furthering our understanding of the Holocene development of plant cultivation and domestication, cultural niche construction, and relationships between environmental changes and cultural strategies of food production. This article offers new data on plant and landscape management and mobility in Southwestern Amazonia during a period of environmental change at the Middle to Late Holocene transition, based on archaeobotanical analysis of the Monte Castelo shellmound, occupied between 6000 and 650 yr BP and located in a modern, seasonally flooded savanna–forest mosaic. Through diachronic comparisons of carbonized plant remains, phytoliths, and starch grains, we construct an ecology of resource use and explore its implications for the long-term history of landscape formation, resource management practices, and mobility. We show how, despite important changes visible in the archaeological record of the shellmound during this period, there persisted an ancient, local, and resilient pattern of plant management which implies a degree of stability in both subsistence and settlement patterns over the last 6000 years. This pattern is characterized by management practices that relied on increasingly diversified, rather than intensive, food production systems. Our findings have important implications in debates regarding the history of settlement permanence, population growth, and carrying capacity in the Amazon basin.

Keywords: Amazonian archaeology; shellmounds; archaeobotany; agriculture; cultural niche; paleoenvironment; mobility patterns; resilience; carrying capacity

1. Introduction

1.1. Theoretical Background

The origins of agriculture and its relations to patterns of mobility and settlement permanence are key issues that remain to be completely understood in Amazonian archaeology. As our knowledge of early human occupations, dating back to ~13,000 yr BP [1–4], expands, archaeological and archaeobotanical records contradict the dominant notion that ancient human groups were nomadic hunter-gatherers that gradually became horticulturalists—and then agriculturalists—through the intensification of food production. A growing body of data suggests that plant cultivation in Amazonia is as old as human occupation itself [5–7], and a brief glance at the plants identified from the retrospective sites suggests progressive diversification (rather than intensification) of utilized species throughout the Holocene [8–11]. Furthermore, even the most ancient sites were frequented as part of established territories, becoming significant places to be reoccupied over millennia [12,13]. Such a pattern is likened to people "walking in their own footsteps" [4], although how the mobility of these groups occurred in a more restricted time scale is still unknown.

Issues of mobility and cultivation in Amazonia have recently received indirect attention in studies related to environmental carrying capacity [14,15] and the degree to which pre-Columbian cultures were resilient in the face of climatic changes and resource stress [14,16]. A recent study mapped the chronological distribution of different late pre-Columbian archaeological cultures in Amazonia and proposed that societies that were politically less stratified and had broader spectrum food production systems based on polyculture agroforestry [8] were better equipped to face abrupt climatic changes than societies that cultivated one or two staple crops and had more stratified political structures [14]. This hypothesis is based on the assumption that local changes in material culture phases or site types represent cultural substitutions (i.e., the substitution of one society with another, and of intensive agriculture by polyculture agroforestry). While this provides an interesting contrast to models that emphasize the progressive development of more stable economies based on the intensification and specialization of food production (and a transition to domesticated staple foods, cf. [17]), the emphasis upon transformations as episodes of collapse and replacement simplifies what were likely complex local trajectories of cultural interactions, network formation, and resilience. Non-evolutionary archaeological models with long-term historical approaches point to nonlinear oscillations between village fusion (demographic concentrations) and fission (demographic dispersal) to explain diachronic variation [18–20], which are widespread processes in indigenous Amazonia nowadays [21–25]. Rather than comprehending variation as a result of environmental or subsistence crises, they stress the role of cultural choices and social network formation in creating alternating cycles of centripetal (politically decentralizing) and centrifugal (centralizing and more hierarchical) social forces that are not related to societal collapse [19,23,26–29].

Amazonian resource abundance seems to have guaranteed an expanding population in the past, inhibiting food production stresses that would lead to the necessity of intensification [18,27]. Furthermore, indigenous populations in the Amazon increased environmental carrying capacity through engaging in cultural niche construction [30–32], and a recent study suggests that this allowed exponential population growth in the region throughout much of the Late Holocene [15]. If this is true, the necessity of groups to migrate or dissolve in order to resolve hypothetical environmental and resource stresses would have been low. This perspective complements the suggestion that food abundance during the Holocene played an essential role in the trajectory of agricultural development [33,34].

To complement and contrast with these studies that tackle issues of carrying capacity and resilience versus change, which are largely based on big data analysis, this paper seeks to address these debates through the lens of one particular site, the Monte Castelo shellmound (dated to between 6000 and 700 cal. BP), and construct a "history of a place" [13] in order to get closer to the local processes of cultural transformations, entangled traditions, and innovations [35,36]. Aside from its location in Southwestern Amazonia, a region recognized as an ancient hub of plant cultivation, domestication, and cultural niche construction since >10,000 yr BP [5,7,37–39], the Monte Castelo site has played a key role in debates surrounding the origins of agriculture since the 1980s [2,40,41].

1.2. Regional Context

The Middle Holocene (8200 to 4200 BP) is a crucial period for the discussion of plant cultivation and sedentism. In several areas of the Amazon basin, a hiatus of archaeological remains (frequently interpreted as a hiatus of occupations) between circa 7000 and 3000 BP [42,43] is thought to reflect a population downturn during a period of prolonged drought conditions that affected human populations of the entire continent [16]. According to some authors (e.g., [44]), it was only after the restoration of humid climatic conditions, especially in forest transition areas, that Neotropical cultivation would emerge, concomitantly with Amazonian Dark Earths (ADEs) and expressive ceramic production.

The Southwest Amazon region represents a unique case study to explore the interactions among mobility, plant cultivation, and climatic changes, since it is one of the few regions that contain archaeological contexts of the Early and Middle Holocene periods, among them: the Llanos de Mojos forest islands, occupied between 10,600 and 4000 cal. BP [5,45,46]; the upper Madeira river sites dated to 9500 cal. BP, with ADEs since >6500–4000yr BP [47,48]; and our present case study, the Monte Castelo shellmound in the middle Guaporé river [49,50]. Archaeobotanical and genetic data show that cultural interventions in the landscape were such that the region became an independent center of domestication of native plants [51,52] such as manioc (*Manihotesculenta*, Crantz), peach palm (*Bactrisgasipaes* Kunth), cocoyam (*taioba*) (*Xanthosoma* spp. Schott), peanut (*Arachishypogaea* L.), chili pepper (*Capsicum* sp. L.), squash (*Cucurbita maxima* Duschesne ex. Lam), possibly annatto (*Bixaorellana* L.), and soursop (*biribá*) (*Annona mucosa* Jacq.), among others [5,7,38,52].

At the Llanos de Mojos forest islands such as Isla del Tesoro and Isla Manechi, phytolith analysis has evidenced the management and cultivation of squash (*Cucurbita* sp.) and herbaceous tuberous plants such as manioc and leren (*Calathea* sp. G. Mey.), and possibly other monocots such as *Phenakospermum guyannense* (Rich.) and *Heliconia* sp. (L.), since 10,200 cal. BP [5]. At the open air site of Teotônio, lerenhadalso been managed (and possibly cultivated) since ca. 9500 cal. BP in preceramic Girau strata alongside palms (Arecaceae) and arboreal species such as Brazil nut (*Bertholletiaexcelsa* Bonpl.), pequiá (*Caryocar* sp. L.), and guava (*Psidium* sp. L.)—a fire-favored species that suggests localized vegetation burning in the area [7]. In sequence, preceramic ADEs associated with the Massangana phase (6500 cal. BP) contain evidence of an increased investment in cultivated plants such as manioc, squash, and common bean (*Phaseolus* sp. L.);however, no substitution or specialization could be detected, and palms and other trees continued to be managed [7].

Added to this scenario, archaeobotanical data from the Middle Holocene also show the incorporation of maize (*Zea mays* L.) and wild rice (*Oryza* sp. L.) into food production systems during this time. The first wave of maize introduction in lowland Amazonia reached the Llanos de Mojos forest islands ca. 6850 cal. BP [5,53,54], and genetic data show that SW Amazonia was a critical secondary improvement center for this species [55]. Evidence for Mid Holocene wild rice management has currently only been detected at the Monte Castelo site, as well as its domestication in the Late Holocene [56], and the present paper adds to the interpretation of these findings.

The Monte Castelo shellmound presents an almost uninterrupted occupation sequence spanning the Middle and Late Holocene, and is currently used as a campsite by Tupi-speaking multiethnic indigenous groups, thus presenting a fine example of long-term indigenous history [23,57]. In this paper, we discuss the results of all archaeobotanical analysis (carbonized remains, phytoliths, and starch grains) conducted at the site to date to identify interactions among culture, climate and environmental change, and plant and landscape management during the Middle to Late Holocene transition. We then employ these results to identify patterns of human mobility and plant cultivation through considerations of resource ecology, harvesting and planting seasonality [58,59], possible bioindicators of environmental change [60], fire management [61,62], and site formation processes [63].

2. Southwestern Amazon Culture and Landscape Dynamics

2.1. The Monte Castelo Shellmound

The Monte Castelo shellmound is located within the Guaporé Wetlands, an ecological mosaic covering ca. 60,000 km^2 situated in the broad ecotonal region between Amazonian rainforest to the north, the Brazilian savanna (*cerrado*) biome and semideciduous dry forests to the south, and the seasonally flooded forest–savanna mosaics of the Llanos de Mojos to the west (Figure 1). The region currently experiences a strongly seasonal climate, with pluviosity regulated by the South American Monsoon System. Precipitation reaches up to 2200 mm/year, around 70% of which falls in the winter months (October to March), and the rest during the summer (April to September). It is the northernmost of the shellmounds in Southwestern Amazonia and is located in Brazil, while most other neighboring shellmounds are in the Bolivian Llanos de Mojos [46]. Monte Castelo, measuring 6.5 m high and 120 m in diameter, is situated atop an ancient levée of the Branco River (which, today, is located 300 m away and flows to meet the Guaporé River approximately 8 km south) and is one of the only areas of terra firme available for kilometers around during the wet season. It is formed of at least 21 archaeological strata consisting largely of a combination of gastropod (*Pomaceae)* shells and natural and anthropogenic soils (Figure 2) that attest to a largely uninterrupted occupation sequence between ca. 6000 and 700 BP. Shellmounds such as Monte Castelo date back to at least 6000 BP in other regions of Amazonia (e.g., Taperinha, Porto da Mina, and Bacanga, see Figure 1), and are associated with the earliest instances of ceramic production in lowland South America [17,49,64].

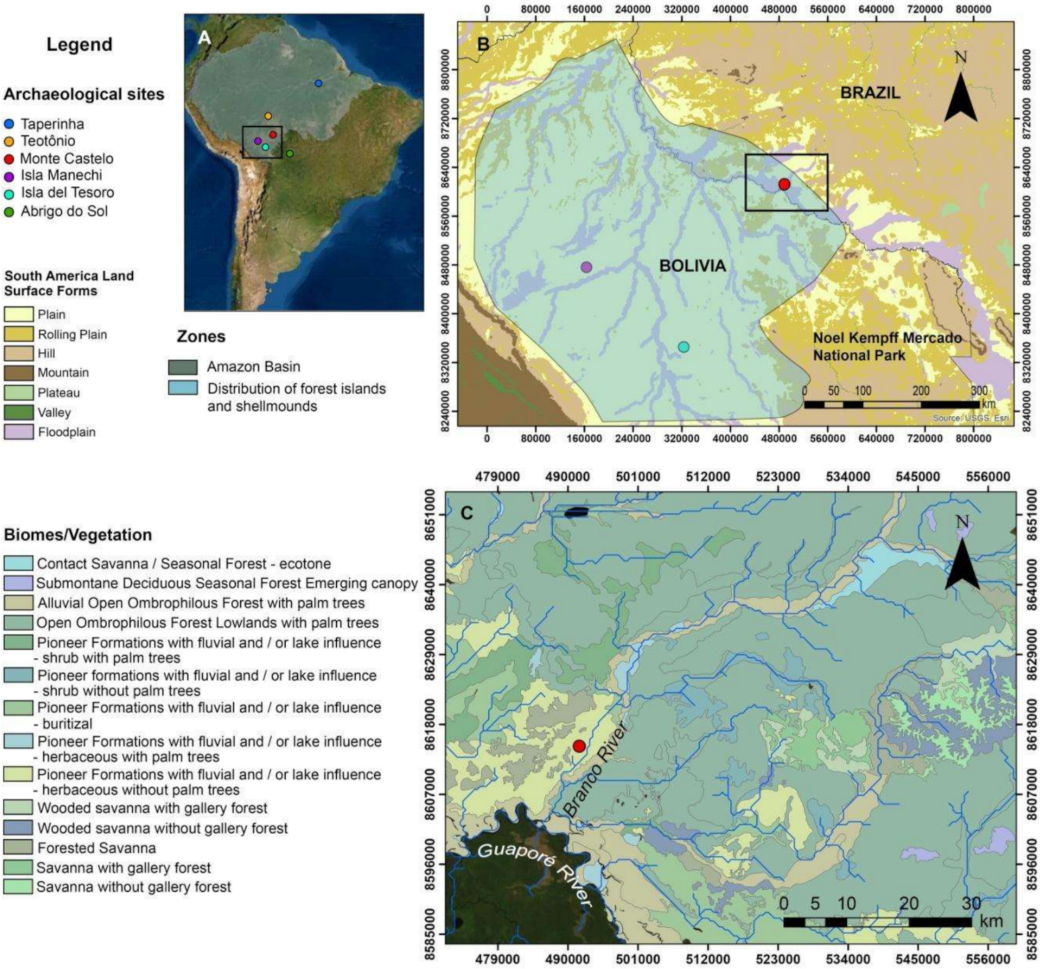

Figure 1. (**A**) Location of Monte Castelo shellmound and other mentioned archaeological sites. (**B**) Southwest Amazonia elevation model and the distribution of shellmounds and forest islands in the Guaporé Wetlands and Llanos de Mojos. (**C**) Vegetation of the Guaporé Wetlands and the location of the Monte Castelo shellmound (Elaboration: Lautaro Hilbert).

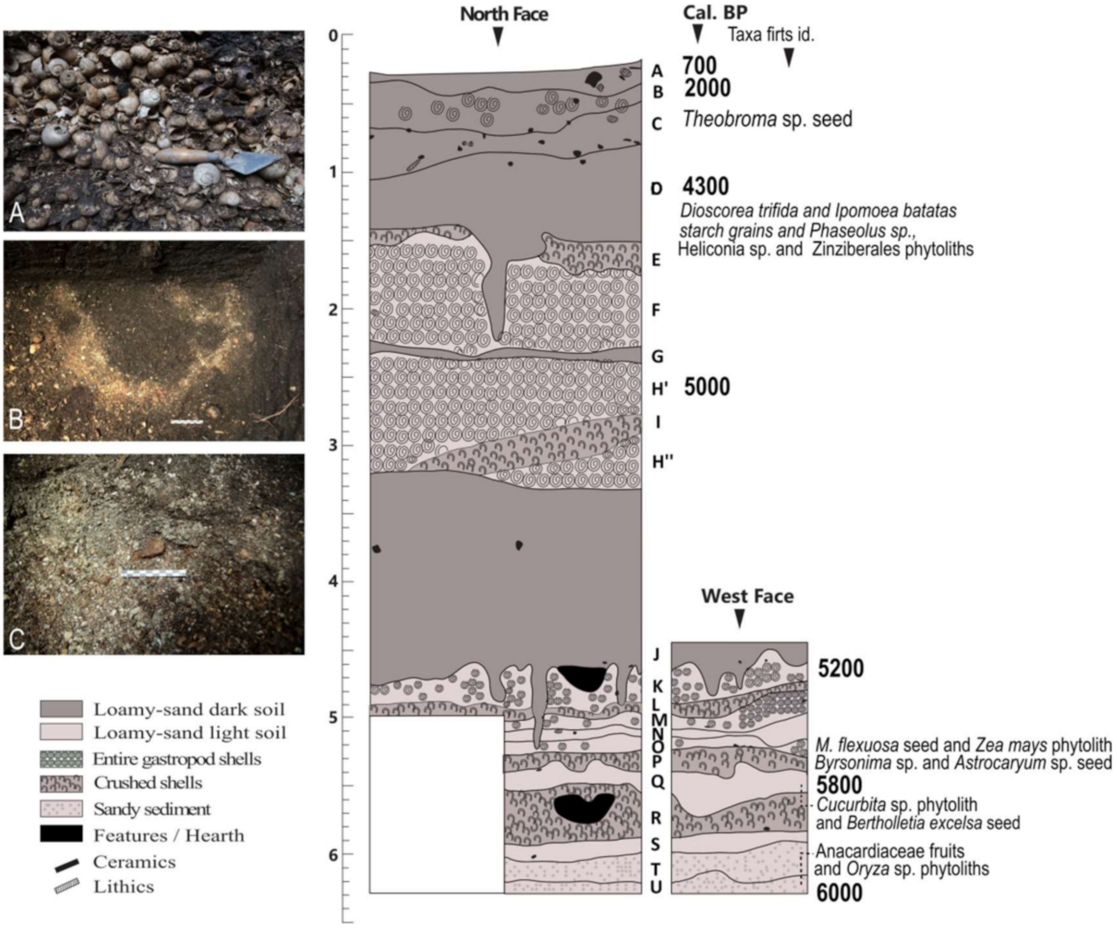

Figure 2. Monte Castelo shellmound excavation and stratigraphic profile with some of the plant species identified in this study. (**A**) Layer G matrix with entire Pomacea shells. (**B**) Hearth feature from layer J (dark soil without shells) visible in layer K (dark soil with shells). (**C**) Layer L matrix with crushed calcined shells.

When the site was first excavated in the 1980s by Eurico Miller, he also identified several other shellmounds and forest islands in the Brazilian wetlands and suggested that this landscape was first occupied by small hunter-gatherer groups camping on the margins of secondary rivers in the Early Holocene [2]. He named these occupations the Cupim phase, associated with flaked lithic and bone tools. For Miller, this phase was followed by climatic changes to more humid conditions that initiated the Sinimbu phase occupation, during which preceramic groups began constructing shellmounds in elevated areas and using them as seasonal logistic centers. This author also suggested that extreme periods of drought between 5000 and 4000yr BP led to the abandonment of these sites, and that subsequently, groups from outside of the Amazon colonized the region and continued shellmound construction. This diffusionist interpretation was based on the similarity between the richly decorated ceramics of the Bacabal phase occupations (ca. 4300–700 BP) and early ceramics of the Valdivia culture on the Ecuadorian coast [65] that would represent the introduction of agriculture to the region. While he had no archaeobotanical evidence about subsistence, the appearance of ceramics similar to manioc flour roasting vessels of contemporary indigenous groups around 2500 BP suggested to him an intensification of agricultural practices [2,65].

Since Miller's initial investigations, archaeological research in Southwestern Amazonia has intensified, and paleoclimatic records have been refined. The Monte Castelo site has been subjected to renewed research since 2011, together with more recent excavations at the sites of Ilha do Antelmo and Pau D'óleo [66–72], and other sites in the Bolivian Llanos de Mojos [69,70].

Excavations carried out at the highest point of the Monte Castelo shellmound to a depth of 6.3 m have revealed a complex stratigraphy made up of occupation and construction layers labeled A to U, from surface to base (Figure 2) [10,67,71]. Layers U through S (Cupim strata, dated at 6000 cal. BP) are discrete occupation layers that represent settlement debris intercalated with activities related to the preparation of the initial occupation platform [71]. These layers contain lithic artifacts and burnt clay in a matrix of crushed shells and sandy-loam sediment. The Sinimbu strata (R to J) are alternating layers of crushed calcined shells (probably constructive) and dark-colored soil horizons containing few shells and abundant charcoal. These date to between 5800 and 5200 cal. BP. The next set of associated layers are I to E and are mainly constructive strata built over ca. 200 years (5200 to 5000 cal. BP), consisting of thick (50–90 cm) layers of entire shells (H and F) interspersed with thinner (ca. 10 cm) layers of crushed calcined shells (I and E) and dark soil (G) that are possibly occupation surfaces. These layers present smaller quantities of ceramic and lithic material and variable amounts of carbonized remains, although G presents no cultural artifacts and few small charcoals. In the current study, we refer to these layers as the "Sinimbu–Bacabal transition". Bacabal ceramics appear in high densities from layer D, which is also where several primary burials have been excavated, showing that the site was initially used as a cemetery in the early Bacabal period. The recovery of large quantities of ceramics and faunal remains characterize the Bacabal strata (D to B) that are dated between 4300 and 2000 cal. BP. Meanwhile, layer A (700 cal. BP) also contains remains from a farm present atop the site between 1970 and 1980, as well as the remnants of temporary camps made by indigenous groups that still use the site as a hunting spot until today.

2.2. Monte Castelo in Its Past and Present Environmental Setting(s)

The dominant vegetation currently surrounding the shellmound is seasonally flooded savanna and dense alluvial forest, but large areas of palm-dominated, open ombrophilous forest also occur locally [72] (Figure 1C). Roughly 20 km to the northeast of Monte Castelo is the starting point for an area of *serras* where terra firme savannaformations occur, interspersed with restricted patches of seasonal semideciduous forest [72]. Paleoecological research is ongoing at the Monte Castelo site, but paleoenvironmental studies in neighboring Bolivia [5,73–78], as well as the results of stratigraphic analyses [10,49], stable isotope analysis on ceramics [71], and zooarchaeological data [67] (see Section 2.3), suggest that site occupation spanned a period of intense climate change that had important consequences for local river dynamics and ecosystems.

In the central and western portion of the neighboring Llanos de Mojos, ca. 300 km southwest of Monte Castelo, pollen and phytolith records demonstrate the presence of savanna and wooded vegetation during the Middle Holocene dry period ca. 8000–4000 BP [53,79]. Large expanses of buried paleosols dating to ca. 4200 cal. BP attest to an increase in precipitation at the start of the Late Holocene which, coupled with a period of greater tectonic activity, led to an abrupt increase in river dynamism which stabilized ca. 2000 BP, leaving behind the seasonally flooded forest–savanna mosaic that characterizes the region today [78]. Meanwhile, lake records from the Guaporé-Iténez region, located atop the Brazilian shield just 100 km from Monte Castelo, show that terra firme savanna (*cerrado*) vegetation dominated this region since at least ca. 6000 cal. BP, to be largely replaced by humid-evergreen forest ca. 2000 cal. BP [75]. These findings echo those from Noel Koempff National Park in southeastern Bolivia (Figure 1C), another 300 km south, where lake records attest to the establishment of humid evergreen just 2000 years ago [73,76]. According to these studies, the Late Holocene was the wettest period of the last 50,000 years in southwest Amazonia, and these wetter conditions stimulated a southward expansion of Amazon rainforest at the expense of largely savanna-dominated ecosystems. Such forest expansion would have begun earlier at lower latitudes (i.e., with the beginning of precipitation increase ca. 4000–5000 BP), but only reached its southernmost extent in Bolivia ca. 3000–2000 cal. BP [73,76]. Forest expansion 2000 cal. BP is also documented in the cities of Vilhena and Pimenta Bueno, several hundred kilometers north and east of Monte Castelo in southeast Rondônia, Brazil. Stable carbon isotope studies attest to an expansion of grassy (C_4) savanna vegetation during the drier Middle Holocene between 7000 and 2000yr BP, after which C_3 (forest) vegetation was re-established [80,81].

From the available evidence, we anticipate that the beginning of shellmound occupation at Monte Castelo (6000 cal. BP) took place in a drier-than-present climate that started to become increasingly wetter sometime after 6000 cal. BP as the southward migration of the Intertropical Convergence Zone brought more seasonal rains to Southwestern Amazonia and the tropical Andes [82]. Initial site construction took place below the current peak flood level, suggesting that the seasonally flooded landscape surrounding the site was established after its initial occupation [49]. Isotopic analysis of ceramic artefacts present throughout the site's stratigraphy indicates a shift to younger clay sources during the Bacabal phase (post-4300 cal. BP) potentially related to an increased distribution of recent sedimentary deposits [71]. A further suggestion for the occurrence of flooding comes from the rapid addition of constructive layers H to F in the shellmound stratigraphy, which separate the Bacabal (4300 cal. BP) and Sinimbu (ca. 5200 cal. BP) occupational strata (Figure 2). If it is confirmed that this construction was a response to local rising water levels, it would be contemporary with similar changes in river activity documented in the Llanos de Mojos [78].

2.3. Mobility, Seasonality, and Cultural Interactions: The Evidence So Far

Interpretations of local environmental dynamics, seasonality, and patterns of group mobility from archaeobotanical records are complemented with existing information on these topics informed by material culture and faunal analysis at Monte Castelo. Recent studies of ceramics and other clay remains have identified in situ development of ceramic technologies [49,71]. Intentional clay preparation in the Sinimbu phase has been confirmed from petrographic, chemical, and isotopic data that also point to a diversification in the chemical composition of clays in the Sinimbu phase. This is suggestive of either an amplification in the areas where raw materials were procured or an expansion of regional trade networks, concurrent with a time when the shellmound took on larger proportions (ibid). Ceramics of the Bacabal phase were produced using different manufacturing techniques and stylistic repertoires. These data not only testify to Southwestern Amazonian shellmounds being primary places for pottery innovation in the Middle Holocene but also question the concept that mobile groups were not engaged in pottery making. Such an interpretation approaches the ethnographic accounts that point to cyclical and fluid relations between cultural activities and temporary versus fixed habitation models [21,24,83].

During the Late Holocene, interactions among local groups of the Guaporé and Llanos de Mojos flourished in an apparent network formation. From ca. 2000 BP onwards, numerous archaeological sites appear in the upper to middle Guaporé, including those on the forest islands of the Guaporé Wetlands, and numerous ceramic sets such as Corumbiara, Pimenteiras, Galera, Aguapé, and Poaia are encountered [41,49,66]. The Ilha do Antelmo and Fazenda Limeira forest island sites (respectively, 25 and 150 km from Monte Castelo) contain both Bacabal and Pimenteiras ceramics, suggesting not only that shellmounds and natural islands were being simultaneously occupied during the Bacabal phase, but that there was a strong degree of interaction between the producers of Bacabal and Pimenteiras ceramic sets [66]. The Jasiaquiari ceramic phase, largely found in *zanja*(ring ditch) sites of the Bella Vista region on the Bolivian side of the Guaporé-Itenéz River basin, dates to between ca. 600 and 400 yr BP, and its producers were also likely incorporated into the cultural network that spanned both sides of the current border between Brazil and Bolivia [66,69,70,84]. The comparisons of the ceramic phases from Brazilian and Bolivian areas suggest the presence of a multicultural regional interaction system which shared hybrid ceramic styles and vessel morphologies (mainly big globular vases) and technologies (e.g., *Druliauruguayensis* temper) that would have come about through social contact and communication [66,69,70].

Ichthyological assemblages from Monte Castelo also converge upon the use of an increasing diversity of areas for fish capture and changes in local hydrological dynamics in the Late Holocene. Prestes-Carneiro et al. [67] separate the fish assemblage into two chronological intervals: ~6000 to ~4400 cal. BP (layers U to G, Cupim and Sinimbu) and ~4300 to ~700 cal. BP (layers F to A, Bacabal). Species from swamps and open waters are predominant in the first intervals such as swamp-eels of the *Synbranchus* genus, which are burrowing drought tolerant species, and fishes of the Doradoidea family (medium- and small-sized catfish). This points to fishing in both swampy areas with shallow standing water and in rivers, streams, and lakes with circulating water. The predominance of swamp species suggests occupation of the shellmound during the dry season. From ~4300 cal. BP, there is an increase in both the quantity and diversity of fish, reaching a peak of 48 taxa in layer D. Increased diversity is associated with the use of additional types of capture areas, specifically flooded forests and major river environments. These findings bear upon both changes in the hydrological environment and human occupations. Late Holocene fishing in flooded forests and increased diversity in small catfish taxa suggest that the establishment of seasonal wetlands in the Middle Guaporé took place between the Sinimbu and Bacabal phases, which is consistent with paleoenvironmental records for increased precipitation [67]. The drought-tolerant taxa in the Mid Holocene fish assemblage question the idea that shellmounds were flood season occupations, and the changes in the Late Holocene to dry and flood season fish taxa are suggestive of longer term occupation [67].

Recently published papers already attest to the relevance of plant management and cultivation in Monte Castelo, including a local rice variety, squash, and maize from at least 5200 cal. BP [56]. Rice harvesting is shown by an increase in the proportion of phytoliths from glumes in relation to those from leaves and stems that begins in layer J (the last strata of the Sinimbu package). Subsequently, human selection pressures, likely from cultivation, influenced the size of glume phytoliths, beginning in layer E and increasing in a statistically significant fashion throughout the rest of the Bacabal layers (D–A) [56]. A second set of studies has focused on the description and taxonomic identification of drupaceous fruits that occur throughout the entire site occupation (layers T to A) based on specific seed analysis through light microscopy and X-ray micro-CT [50,85]. Posited as belonging to the Anacardiaceae family, although their use is unknown, these fruits stand out from the majority of other macro-remains for not being carbonized. The remains do, however, present some indications of mineralization processes that are being studied and that could provide some answers about their elevated frequency in the archaeobotanical record of the site [50].

3. Material and Methods

3.1. Macrobotanical and Phytolith Analysis of Sediments

3.1.1. Sampling

For the analysis of macro (carbonized plant remains) and micro (phytoliths) archaeobotanical remains, we collected sediment samples directly from the profile exposed at the end of excavations carried out in 2014 and 2016 (Figure 2). Eleven liters of soil were collected from each layer (A to U) by excavating two columns in the north profile measuring 20 × 5 cm wide. Bulk samples weighing ca. 200 g were also collected for phytolith analysis from the same profile.

A total of 231 L of soil were water screened using geological 2 mm and 0.5 mm sieves to recover carbonized wood, seeds, fruits, and tubers. This method [86] results in the division of remains according to size, facilitating subsequent sorting. These samples were the same as those used for aforementioned zooarchaeological analysis and were manually sorted at the Laboratory of Tropical Archaeology (University of São Paulo) to separate out archaeobotanical and other archaeological remains. The results presented here are based on carbonized remains $\geq$2 mm (Figure 3).

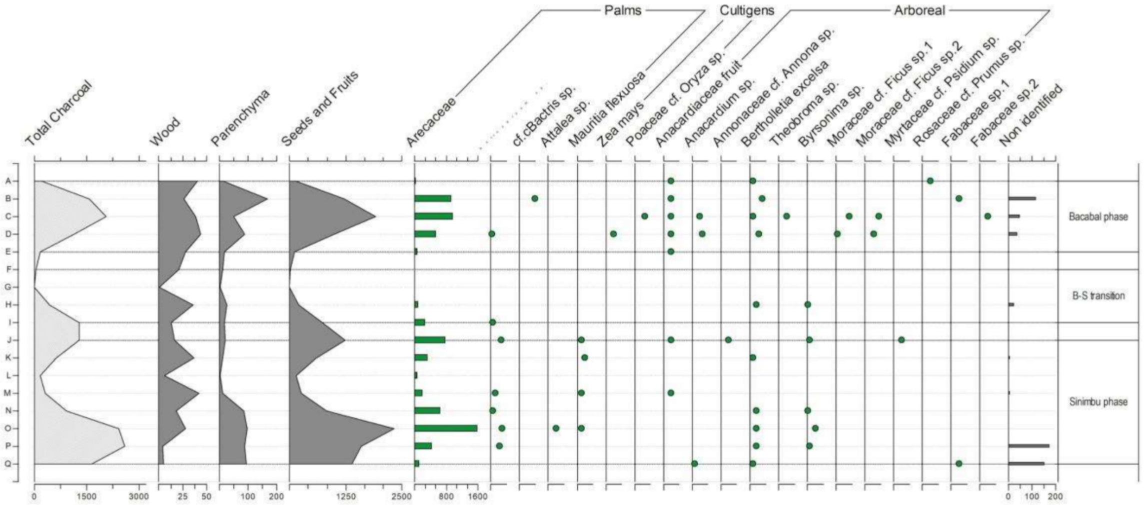

Figure 3. Macrobotanical C2 diagram of relative quantity of plant parts divided in wood, parenchyma, seeds, and fruits. Dots indicate the presence of identified taxa along the layers A to Q.

Phytolith analyses of layers A to J were carried out at the University of Exeter using the wet oxidation method [87], the results of which have already been published [56]. The method used 100 g of soil which was deflocculated with sodium hexametaphosphate and removed of all clays before being sieved into “sand” (125–250 um) and “silt” (<53 um) fractions, creating two subsamples. Carbonate removal was then carried out using hydrochloric acid (37%) and organic matter was removed using nitric acid (67%) heated at 100 °C. Phytoliths were then separated using zinc bromide heavy liquid (specific gravity 2.30 g/cm^3) and were mounted using Entellan mounting medium [56].

Phytolith analyses of layers K to U were carried out at the University of São Paulo using the ultrasonic bath method devised by Lombardo et al. [56]. This method substitutes the nitric acid for organic matter removal with hydrogen peroxide (30%), and both organic and clay dispersion are aided with the use of an ultrasonic bath set to 60 °C. Phytoliths were separated with zinc chloride heavy liquid (specific gravity 2.30 g/cm^3) and mounted in Permount mounting medium (for combined results, see Figure 4).

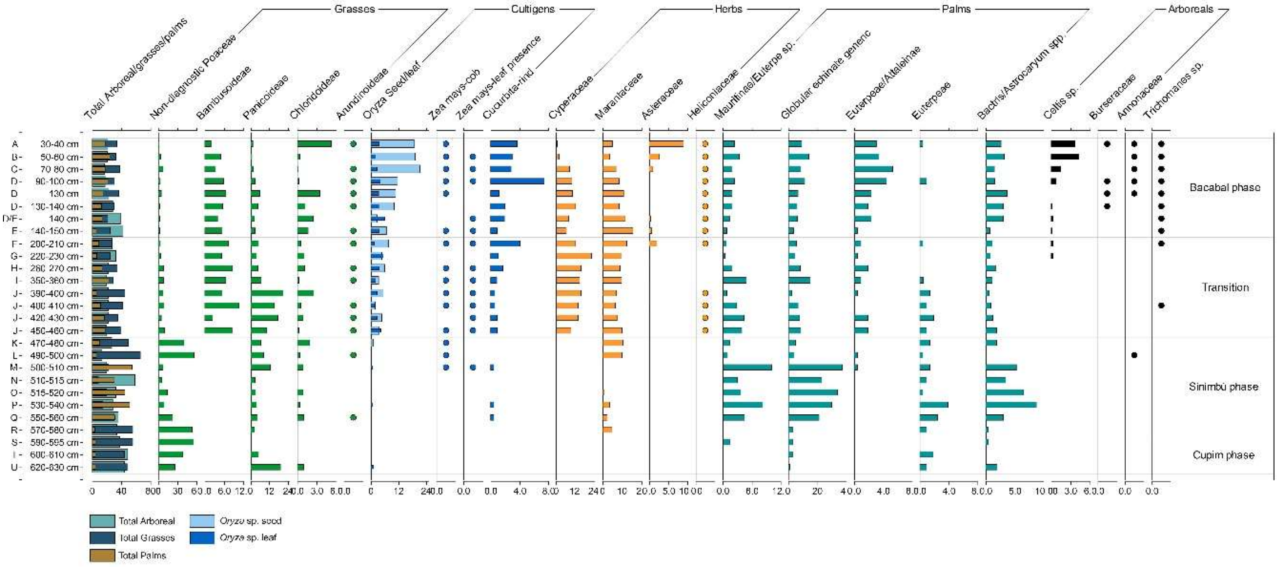

Figure 4. C2 Diagram showing the relative frequencies of phytoliths encountered throughout the stratigraphy of the Monte Castelo shellmound from layer A to U. Dots indicate the presence of data for particularly scarce taxa.

3.1.2. Extraction and Identification

Macro-remains from each archaeological layer were counted and weighed in order to compare ecofact density and highlight potential differences in preservation between strata. Non-carbonized plant remains—mainly roots and small grass seeds—were not included in the analysis, since they likely represent modern contamination. Wood charcoal fragments were quantified to compare with quantities of non-wood remains to provide possible insights about the use of fire at the site. Wood was not included in the taxonomic analysis. Carbonized seeds, fruits, and tubers were organized into morphotypes by format, size, tissues and structures present, and diverse anatomical characteristics that could include: for seeds, endosperm density and structure, seed coat layers, testa ornamentation, and raphe, micropyle, hilum, caruncle, funicle, and/or cotyledon placement; for woody endocarps, including pyrenes, organization of loculi, the density and structure of vascular bundles, germinating and plugged pore placement, and scars of mesocarp fibers (Figure 5A–C); for fruits, calyx, pedicle, peduncle, locules, vascular bundles, and exocarp ornamentation; and for tubers, the organization of vascular bundles. Modern reference collections were essential to confirm taxonomic identifications. Archaeological remains were compared with the botanical reference collections at the Laboratory of Tropical Archaeology (University of São Paulo) and the Curt Nimuendaju Archaeological Laboratory (Federal University of Western Pará), as well as consulting the available literature.

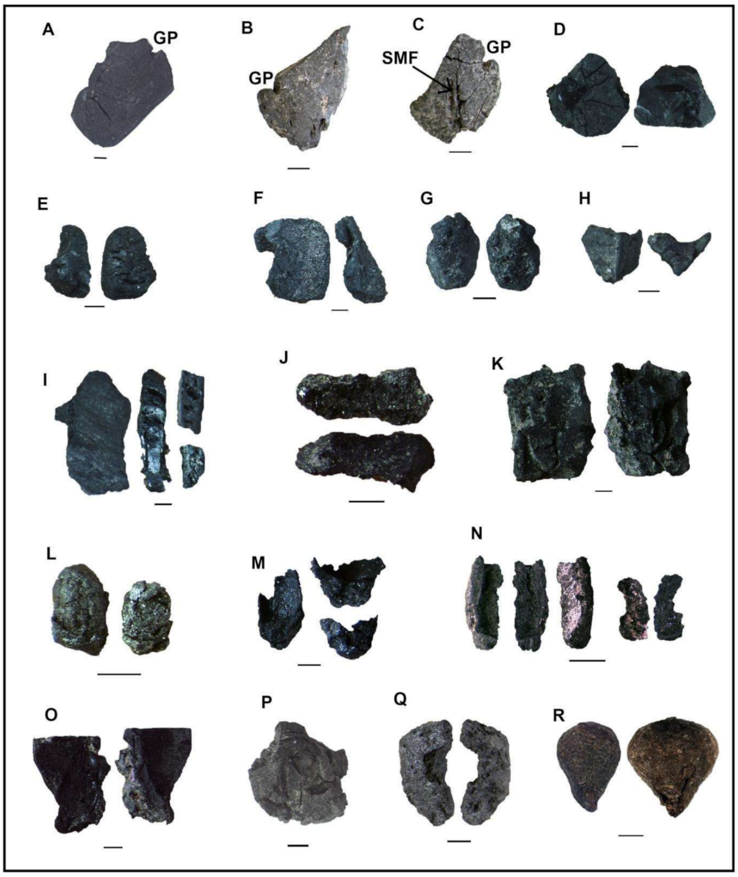

Figure 5. Macrobotanical remains recovered from Monte Castelo sediments. (**A**–**C**) Non-identified morphotypes of Arecaceae endocarps, indicating germinating pore (GP) and the scars of mesocarp fibers (SMF). (**D**) *Astrocaryum* sp., layer O. (**E**) Fabaceae cf. Mimosoideae, layer O. (**F**) *Byrsonima* sp., layer N. (**G**) *Annona* sp., layer J. (**H**) *Bertholletiaexcelsa*, layer H. (**I**) *Anacardium* sp. layer D. (**J**) *Zea mays*, layer D.(**K**)*Theobroma* sp., layer C. (**L**) Myrtaceae, morphotype 3. (**M**) *Oryza* sp. husk, layer C. (**N**) *Oryza* sp. seed, layer C. (**O**) *Anacardium* sp., layer C. (**P**)*Mauritia flexuosa*, layer B. (**Q**) Fabaceae, layer B. (**R**) *Anacardium* sp. mineralized drupe identified from layers A to U.

Phytoliths were counted under magnifications of 400 or 500× (for the silt fraction slide) and 200× (for the sand fraction slide) using a Carl Zeiss Lab A1 microscope. In each case, 200 phytoliths were quantified and the remainder of the slide was scanned for crop phytoliths. Identifications were made using reference collections housed at the Archaeobotany and Paleoecology Laboratory (University of Exeter) and at the Institute of Geosciences (University of São Paulo), as well as a large base of the published literature.

Stratigraphic diagrams of these results were made using C2 software (version 1.7.7, manufactured by Steve Juggins at Newcastle University, Newcastle, United Kingdom) [88].

3.2. Starch Grain and Phytolith Analysis of Ceramic Residues

Eight unwashed ceramic fragments belonging to the Bacabal phase were separated for starch grain and phytolith residue analysis. Five of these (MC-4 to MC-8: four bases and one vessel wall) were recovered from layer D, between 90 and 113 cm below surface; a further two (MC-2 and MC-3) from layer B (one base and one vessel wall) at 53 cm below surface; and one from (MC-1) layer A (vessel wall found 34 cm below surface).

Extraction and Identification

Two subsamples—"wet brush" and "scrape"—were extracted from each ceramic artefact for microbotanical testing following the methods described in Pearsall [86], Coil et al. [89], and the International Code for Starch Nomenclature (2011). The wet brush sample was collected by cleaning the interior of the ceramic fragment with a toothbrush and distilled water to remove sediment adhering to the artefact. This sediment was then concentrated into a test tube through repeated rounds of centrifugation (2000 rpm for 5 min). Extraction then adapted the procedure of Coil et al. [89] for multiple microfossil extraction: starch grains were first separated from the sediment using cesium chloride (specific gravity 1.8 g/cm^3), washed, and mounted onto microscope slides using a 50:50 mixture of glycerin and distilled water. The remaining sediment was then washed and subjected to the ultrasonic bath procedure for phytolith extraction described in the previous section.

The scrape sample was collected immediately after the wet brush sample by using a razor blade and/or needle to extract residue from imperfections present in the interior of the ceramic object, identified using a binocular loop microscope. This residue was collected with tin foil and mounted directly onto a microscope slide in 50:50 distilled water: glycerin solution. All of the equipment used for starch grain analysis were previously sterilized using an autoclave, and extraction took place in a laboratory that had been thoroughly cleaned the day before. Hydrogen peroxide was used to clean work surfaces.

Samples were analyzed using a Carl Zeiss Lab A1 microscope under 400× and 630× magnification, and photographs were taken using Zen 2.3 image processing software. For the starch grain extractions, the entirety of the slides was scanned for archaeological starch. Starch grains were taxonomically identified using the starch grain reference collection housed at the Geosciences Institute (University of São Paulo) and the published literature. Alongside taxonomically important morphological characteristics, the types of damage displayed on each starch grain were also recorded and compared with the published literature (see Section 4.2). Quantification procedures for the wet brush phytolith samples followed those described in Section 3.1.

4. Results

4.1. Macrobotanical and Phytolith Analysis of Sediments

4.1.1. General Observations

The macrobotanical assemblage of the Monte Castelo shellmound (Figure 3) is mainly composed of carbonized remains of seeds, fruits, and parenchymatous plant parts, although the presence of mineralized Anacardiaceae seeds is also notable throughout the stratigraphy. A total of 16,680 carbonized remains were classified (Table S1), and the majority of these (97.6%) were food remains (seeds, fruits, and parenchymas). Three segments of the stratigraphic sequence present peaks of charcoal density that were recognized based on total amount and percentage concentration: layers B to D, layers H and K, and layers O to Q (Figure 3).

The generally low percentage of wood charcoal recovered at Monte Castelo is different from the pattern observed in the majority of Amazonian archaeological sites, especially within ADEs [7,61,90,91]. In total, only 405 wood fragments were identified (2.4% of the total of carbonized remains; individual layers range between 0.2% and 38.9%). A further notable pattern across the profile is the predominance of palm (Arecaceae) seeds/pyrenes that total 7273 fragments (layers average 43% with a range between 0 to 75.4% Arecaceae). Most palms have woody endocarps that preserve well due to high concentrations of lignin [91].

4.1.2. Cupim Package (Layers U–S)

The Cupim package is dominated by almost equal quantities of grass and arboreal phytoliths that together, make up to 90% of the total phytolith count, while palms are <5% (predominantly globular echinates) (Figure 4). Within the grass counts, both lobate and scooped bilobate phytoliths were identified, produced by the leaves of Panicoideae and *Oryza* sp. grasses, respectively, but far more frequent are bulliform phytoliths that are diagnostic to family level only. Bulliforms are produced in greater quantities by grasses that suffer water stress [92], and their abundance might be expected due to the proximity of these initial occupations to the adjacent Branco river. In these layers, the presence of calcined drupes belonging to the Anacardiaceae family [50,85] is indicative of the local presence of open grasslands and arboreal plant management. For absolute and percentage numbers, see Supplementary Table S1.

4.1.3. Sinimbu Package (Layers R–J)

Layer R, the first in the Sinimbu package, has a distribution of phytoliths similar to the preceding layers. Very different phytolith assemblages are observed between layers Q and M however, associated with the first dark-colored soils in the shellmound’s stratigraphy. Palm phytoliths increase from <5% to make up between 30% and 50% of the total count, a pattern largely driven by globular echinate phytoliths (including forms diagnostic to Euterpeae and Mauritiinae/*Euterpe* spp. (Figure 6A,B) with a smaller but concomitant increase in *Bactris/Astrocaryum* spp. cone phytoliths (3–8%, Figure 6C). *Cucurbita* sp. scalloped phytoliths (Figure 6D) are present in layers Q, P, and M, providing direct evidence of squash cultivation since at least 5800 cal. BP.

Layers Q to O also present peaks in the density and diversity of recovered macrobotanical remains. Between layers O and M, seeds of buriti (*Mauritia flexuosa*) were found, together with *Astrocaryum* sp. And *Attalea* sp. palm seeds, as well as several non-identified morphotypes of palm endocarp (Figure 5A–C) that indicate extensive use of this family, corresponding with the phytolith signal. Seeds of Brazil nut (*Bertholletia excelsa*) and nance (*Byrsonima* sp.), as well as two morphotypes of Fabaceae seeds, were also recovered, one of them probably related do the Mimosoideae subfamily, which includes several arboreal genera (i.e., *Acacia*, *Anadenanthera* and *Prosopis*) managed by indigenous groups nowadays. Within the phytoliths, layers O to M are also marked by the occurrence of maize cob phytoliths (Figure 6E). A maize leaf signal was identified in layer M (calculated using discriminant function analysis of 30 cross-shaped phytoliths [87] and is associated with a possible food processing area identified in layers M–K of the sampled profile.

Layer L presents the nadir of carbonized remains in the Sinimbu package and is composed mainly of small Arecaceae seeds fragments (61%). However, palm phytoliths decrease and there is a sharp increase in grass and Marantaceae phytoliths (Figure 6F–G). Layer K, also a shallow deposit (Figure 2), yielded a high percentage of seeds and palm endocarps (95%) including Brazil nut and *buriti* seeds.

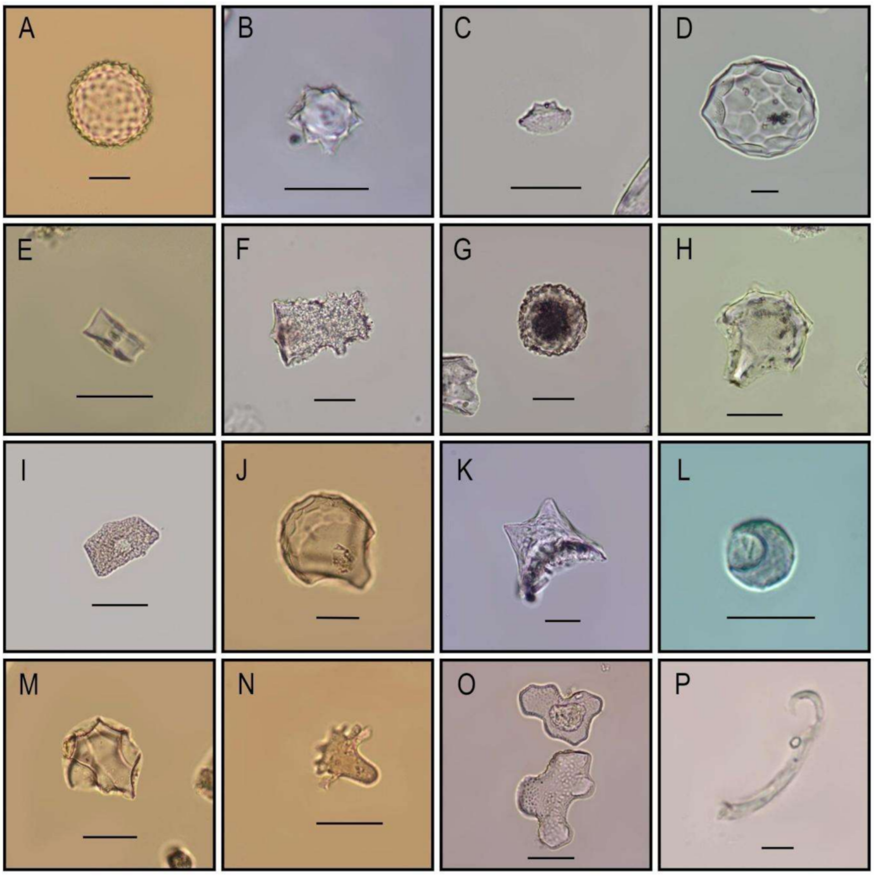

Figure 6. Phytoliths recovered from Monte Castelo sediment samples. (**A**) Euterpeae globular echinate phytolith with short, dense projections; (**B**) Globular echinate symmetric phytolith produced by Mauritiinae/Euterpeae tribes; (**C**) Conical phytoliths produced by *Bactris/Astrocaryum spp.*; (**D**) Scalloped phytolith from *Cucurbita* sp. rind; (**E**) Maize cob rondel; (**F**) Marantaceae seed phytolith; (**G**) Marantaceae leaf phytolith; (**H**) Bamboo (Bambusoideae) leaf bulliform phytolith; (**I**) *Cyperus* sp. achene phytolith; (**J**) Scalloped bulliform phytolith from *Oryza* sp. leaf; (**K**) Double-peaked *Oryza* sp. glume phytolith; (**L**) cf. *Trichomanes* sp. troughed phytolith; (**M**) Annonaceae leaf phytolith; (**N**) Burseraceae fruit phytolith; (**O**) *Celtis* sp. seed phytoliths; (**P**) cf. *Phaseolus sp.* trichomephytolith.

Layer J sees increases in palm endocarps (75.4%) and a slight increase in palm phytoliths from layer K. Seeds from soursop (*Annona* sp.) were recovered for the first time alongside phytoliths from bamboo (Bambusoideae) (collapsed saddles, chusquoid bodies, and flared bulliforms, (Figure 6H)). Panicoideae grasses peak and Marantaceae phytoliths continue (between 7% and 11%). There is also a much larger contribution of the wetland herb Cyperaceae (Figure 6I) that increases to between 10% and 25% of the assemblage; another non-grass monocot, *Heliconia* sp., is present in trace levels. The combination of these taxa suggests vegetation that occurs on a flooded savanna. It is unclear how much of layer J is constructive vs. occupational, and squash, maize (cob and leaf), and rice (leaf and glume, Figure 6J,K, respectively) phytoliths continue to be present throughout samples from this level, alongside *Astrocaryum* sp. and *buriti* seeds (Figure 5 D,P). For absolute and percentage numbers, see Supplementary Table S1.

4.1.4. Sinimbu–Bacabal Transition (Layers I–E)

The density of carbonized remains recovered in layers I to F fluctuate alongside pronounced differences in the matrix of these layers, suggesting both occupational and constructive layers. Layer H is in direct contact with layer J and presents about a third of the density of remains (432 in 11 L). While this layer is composed largely of gastropod shells, the macrobotanical assemblage is mainly represented by seeds, half of which are palms (including *Astrocaryum* sp.), with the presence of Brazil nut and nance (*Byrsonima* sp.). This layer is interrupted by layer I (c. 10 cm thick), which displays a density of carbonized remains (1293 in 11 L) comparable to layer J (c. 120 cm thick). Fifty-seven percent of this assemblage were endocarps and seeds of palms and fruits, including *Astrocaryum* sp., nance, and guava (*Psidium* sp.). The last is a fire-favored taxa that is potentially indicative of fire management. Layer G, composed mainly of dark soils and without shells or artefacts, yielded only three charcoal fragments, suggesting low intensity of human activity or another constructive layer. The layer F assemblage is among the least dense of the entire stratigraphy (54 fragments in 11 L) and is composed in almost equal parts of wood, parenchymas, and palm endocarps (38%, 37%, and 35%, respectively). Layer E has three times the density of carbonized remains, and half of these (50%) are palm endocarps; however, the proportion of wood (17%) remains higher than in the majority of the levels. Meanwhile, phytolith assemblages between layers I and F are very similar to those reported for layer J. Squash, maize, and *Oryza* sp. signals continue to be present throughout these layers, except in layer G (see Supplementary Materials for absolute numbers).

The less intensive discard of food waste registered in the macrobotanical remains in layers G to E is almost certainly related to episodes of shellmound construction that involved the addition of gastropod-rich material and sediments from the surrounding savanna (see Section 2.2). On the other hand, the continued presence of fish remains (although in low densities) alongside maize and rice leaf phytoliths throughout these thick, shell-rich deposits, complicates this interpretation. Until further studies are conducted, one or a combination of the following explanations can be suggested for these disparities: (1) some occupational activities occurred in situ during these construction episodes, (2) the material used for construction included, at least in part, cultural deposits from previous occupations, and (3) downward percolation of sediment and ecofacts has possibly taken place. Whatever may be the case, the observed variations within and between these archaeological assemblages of the Sinimbu–Bacabal transition layers seem to point to a more dynamic period of site formation and occupation that is quite possibly related to climatic variation between 5200 and 5000 cal. BP and increased local flooding [80,93]. For absolute and percentage numbers, see Supplementary Table S1.

4.1.5. Bacabal Package (Layers D–A)

Layers E–A witness a further decrease in grass phytoliths and a gradual decrease in both Cyperaceae and Marantaceae towards the top of this package while both *Heliconia* sp. and *Trichomanes* sp., a wetland fern (Figure 6L), are present in trace levels throughout.

In contrast, there is an increase in phytoliths from other useful species. Palm globular echinate phytoliths increase from 4.5% to 10.7%, and *Bactris/Astrocaryum* spp. from approximately 1% to 3.1% in the transition from layer E to layer D, while *Oryza* sp. glume phytoliths also increase both in number and size, demonstrating an on-site domestication process of wild rice (full results published in [56]). Squash phytoliths are also plentiful and present a peak at the top of layer D while maize cob and leaf phytoliths maintain a steady presence in most layers. Phytoliths from Annonaceae leaves (soursop family, Figure 6M), Burseraceae fruits (Figure 6N), and *Celtis* sp. (hackberry) seeds (Figure 6O) also point to the exploitation of these fructiferous taxa throughout the Bacabal occupations. Phytoliths of Asteraceae, a disturbance indicator, increase substantially in layer A, the most superficial layer of the site, which could be related to the 20th century farming activities.

Carbonized material increases abruptly in both density and diversity between layer E and layers D to B. The majority of the charcoal is from palm endocarps (47–60%) that, together with other seeds and fruits, make up an average of 86% of the macrobotanical remains. Meanwhile, the proportion of wood charcoal is consistently low (between 1.6% and 3.9%). The palm remains include *Bactris* sp. and *Astrocaryum* sp. that are also documented in the phytolith data (Figure 4). Further identified taxa are diverse including at least two types of Anacardiaceae, two types of Moraceae cf. *Ficus* sp., two types of Fabaceae, *Anacardium* sp. (cashew nut genus), Brazil nut, and *Theobroma* sp. (cacao genus).

These layers contain, for the first time, macro-remains of maize grains and rice husks, albeit in low quantities. The layer A assemblage echoes the aforementioned influence of postcolonial period activity at the area with an increase in wood frequency (19%) but a continued predominance of fruits and seed (74%), including palms (33.5%), Brazil nut, and Rosaceae cf. *Prunus* sp. For absolute and percentage numbers, see Supplementary Table S1.

4.2. Ceramic Residue Analysis

A total of 21 individual starch grains and 1large agglomeration (in MC-7) were recovered from the eight ceramic fragments analyzed (Table 1), the majority (n = 18) of which were isolated from the wet brush samples. Over half (n = 12) of all starch grains could not be taxonomically identified, either due to their absence in the published literature and/or because they were subject to processing damage. Indeed, most starch grains display signs of physical damage in the form of cracks (emanating from the hilum and/or margin of the grain), pressure facets, heat damage in the form of hilum openings (caused by water loss), hilum projections (dark-colored projections caused by toasting), flat relief (i.e., a weak extinction cross), and/or gelatinization (partial or total loss of 3D structure, see Cascon, 2017; ICSN 2011; Babot 2003; Henry et al. 2009 for further information on these definitions). The accumulation of these damages on the same starch grains or starch grains from the same artefact (e.g., MC-6) indicates that several plant foods were milled or pounded before cooking, and that both toasting and boiling were common.

Table 1. Table showing starch grain recovery from eight Bacabal ceramic fragments (MC 1–8). * = identified in the "scrape" sample; CONC = concentration. Abbreviations for starch grain damage: C = cracks; PF = pressure facets; FR = flat relief; HP = hilum project; HO = hilum openings; G = gelatinization.

Lab Code	*Cucurbita* sp.	*Dioscorea* sp.	*Dioscoreatrifida*	*Ipomoea batatas*	*Zea mays*		Unidentified		Total
					N	Damage	N	Damage	
MC 1							1	HO, FR	**1**
MC 2							1	PF, FR, HO	**1**
MC 3	1						1*	HO	**2**
MC 4			1		2*	C	1	C	**4**
MC 5		1		1*	2	FR	1		**5**
MC 6					1	HP, C	2	G, C, HO, FR	**3**
MC 7							CONC	G, HO, C	**CONC**
MC 8							5	G, HO, C	**5**

Maize starch grains were recovered from three artefacts (MC-4 to -6) belonging to layer D, and the co-occurrence of features indicating physical and heat damage suggests that this crop was processed and consumed in flour form (Figure 7A,B). Yam starch grains were recovered in two of the same artefacts (MC-4 and 5—both *Dioscoreatrifida* (Figure 7C) and *Dioscorea sp.* (Figure 7D)), alongside sweet potato (*Ipomoea batatas*, Figure 7E) in MC-5. MC-8 yielded the highest number of individual starch grains (n = 5), all of which remain unidentified. Similarly, of the four starch grains recovered from three ceramics pertaining to layers B and A, only one was identifiable as belonging to squash (Figure 7F).

A large agglomeration consisting of hundreds of starch grains was recovered from MC-7 along with individual forms from the same, unidentified species. The assemblage is composed of highly irregular starch grains with a range of forms (circular, quadrangular, pentagonal, and bell-shaped) and often a transverse or longitudinally aligned, jagged fissure at the hilum (Figure 7G [1–3]). Many also display both physical and heat damage (Figure 7G [4]).

The phytolith assemblages from the ceramic residues (MC 1–8) mirrored almost exactly those reported in the soils, both in terms of their diversity (which includes the presence of grass, arboreal, and palm phytoliths in every sample), and in the percentages in which they occurred. They are, therefore, interpreted to represent a "background" signal from the surrounding soils, rather than plants that were processed or contained in the ceramic vessels. This same phenomenon has been reported in similar analysis from other sites [7,9].

The one exception to this was the identification of a hooked trichomephytolith in MC-8 similar in size and morphology to those produced in the pods of common beans (*Phaseolus* sp., Figure 6P) [94]. This identification remains tentative, however, due to the occurrence of very similar phytoliths in the Panicoideae grass *Orthocladalaxa* [9,95].

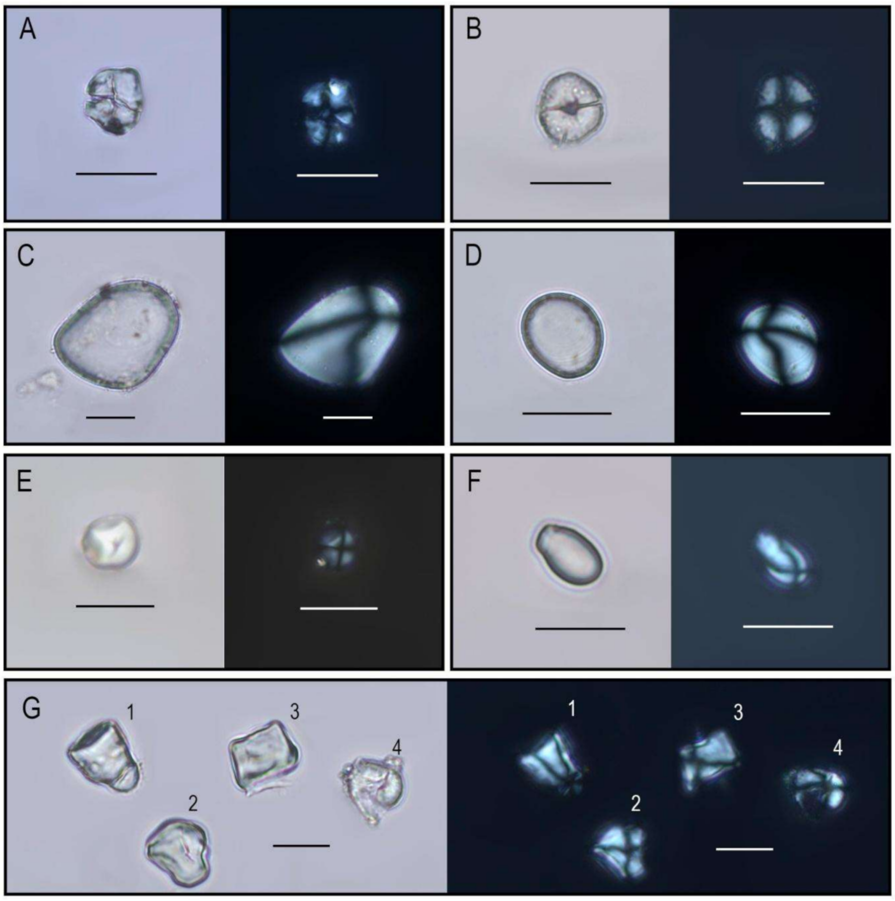

Figure 7. Selected starch grains recovered from Bacabal ceramic residues. (**A**) Maize with cracks emanating from the hilum, indicating physical damage (MC-4); (**B**) Maize exhibiting cracks and hilum projections, suggestive of physical and toasting damage (MC-6); (**C**) Domesticated *Dioscoreatrifida* (yam) (MC-4); (**D**) *Dioscorea* sp. (MC-5); (**E**) *Ipomoea batatas* (sweet potato) (MC-5); (**F**) *Cucurbita* sp. (squash) (MC-3); (**G**) Bell-shaped (1), sub-circular (2), quadrangular (3), and partly gelatinized (i.e., heat-damaged) (4) starch grains pertaining to a starch grain concentration (MC-7).

5. Discussion

5.1. Antiquity: The Long-Term History of Plant and Landscape Management and Its Implication to Historicity

Archaeobotanical data from the Monte Castelo shellmound, reunited and discussed in this paper, point to an antiquity of plant cultivation that goes back to its first occupations since the Cupim phase. This is perhaps not surprising given that people began cultivating plants in similar archaeological contexts in Bolivia at least 4500 years before Monte Castelo was occupied [5]. The exact relationship between the Monte Castelo shellmound builders and those of the Llanos de Mojos forest islands is still unclear, but it can at least be assumed that they formed part of a connected network of people based on archaeological similarities and proximity. Indeed, the period represented by the Sinimbu Phase at Monte Castelo (5800–5200 cal. BP) also correlates with a peak in radiocarbon assays from the Llanos de Mojos sites [46], suggesting that Monte Castelo was occupied during a period of increased cultural activity in the region.

Despite this, our data cover a period represented by extremely little archaeobotanical information, not just in Southwestern Amazonia, but in the Amazon basin in general. The clear and abundant evidence of plant cultivation in layers Q to J of the archaeological site (Sinimbu) show that cultivated plants were being extensively used and consumed before the Bacabal phase. We must thus recognize the history of plant cultivation here as a regional, long-term process dating back to at least the Middle Holocene.

Recurrent, long-term use of resources that have traditionally been treated as “wild” or “collected” species, points not only to continuity in human diet throughout the site’s occupation, but familiarity with these plants’ ecologies that would have been important for their management. This suggests a wide territorial use of different biomes during a long time spanning several centuries, complementing recent works that complexify the notion of collecting plants in order to include perennial plants and cultural niche construction.

Archaeobotanical data further contribute to discussions about the periodization of Amazonian occupations, including the concept of the “Formative”, which was used by Miller [2,41] in interpretations of the occupations at Monte Castelo. As trends in cultural development across the Americas were discussed in the 1950s, Willey and Phillips (1958) theorized a “Formative” stage marked by the emergence of sedentary village life based on a successful, and generally agricultural, economy, although they recognized early on that cultures of the preceding “Archaic” stage were not precluded from engaging in agriculture and plant domestication, nor in pottery production. Some Amazonian archaeologists subsequently essentialized the “Formative” as the period when agriculture, ceramics, and sedentary lifestyles were adopted and sociopolitical complexification was initiated [2,17,40,96,97]. At Monte Castelo, Miller interpreted the Bacabal phase ceramics as evidence of a cultural “Formative” brought about by the arrival of Valdivia culture populations migrating from the Ecuadorian coast [65]. The Amazonian Formative was subsequently applied as a means of associating often disparate occupations throughout the region, such that comparisons were drawn between Bacabal phase occupations, sites associated with ancient ceramics, and the emergence of ADEs in the Madeira river basin [2,98,99].

The continuity in practices of plant cultivation and management over the millennia at Monte Castelo demonstrates how traditional systems of periodization, historical stages creation, and the concept of the Amazonian “Formative” are unhelpful for understanding the long-term history of human occupation. Even in the slightly less essentialized definition proposed by Piperno and Pearsall ([44], p. 243) where the “Formative” refers only to the development of “truly effective agricultural systems”, evolutionary overtones of economic advancement are still apparent. The contradictions between such models and the archaeological and anthropological data coming out of the neotropics [100,101] thus suggest that new concepts and models must be developed to understand human history in the region (e.g., [20]).

One such conceptual framework that has already been discussed in relation to the Monte Castelo site is that of long-term indigenous history, whereby artefactual variability is assessed in terms of both changes and continuities that link past indigenous knowledge and practices with those of the present [49]. Monte Castelo is currently part of a land dispute between local indigenous groups, for whom both the shellmound and the broader Guaporé Wetlands constitute an important part of their traditionally occupied territories, and government agencies, who, since the 1980s, have demarcated the region a biological reserve (Rebio Guapore) and restricted indigenous settlement to the Rio Branco Indigenous Land, located ca. 50 km to the northeast. Archaeological studies at Monte Castelo can help to legitimize the indigenous land claims, since they demonstrate a persistence of place and territoriality that spans the last 6000 years [49]. This fact is echoed in the archaeobotanical data, which also demonstrate the exploitation and direct manipulation of plant species at both the local and regional scales: the biodiversity thus attempted to be conserved by demarcation was itself co-constructed by indigenous peoples over several millennia.

5.2. Diversification: Of Plants and Ecosystems in an Ecological Mosaic

Cultivation and management strategies at Monte Castelo were not limited to domesticated or cultivated plants, nor a single microenvironment within the ecological mosaic of the middle Guaporé river. Palms, Brazil nut, and nance are found in abundant quantities alongside the remains of domesticated crops such as squash and maize in the Sinimbu phase. In the Bacabal phase, the increase in recovery of domesticated, annual crops is accompanied by an increase in the diversity of non-domesticated, arboreal species. Evidence of sweet potato and yam consumption is seen for the first time in the Bacabal phase but this finding might reflect a recovery bias, since only Bacabal ceramics were analyzed for starch grains. Overall, the data suggest a strategy of broad-spectrum food procurement and production throughout the Sinimbu and Bacabal periods with no specialization upon a single plant species, echoing findings in ADE sites [8,94,102] and contemporary shell mounds located on the south and southeastern Brazilian coastline [103].

Table 2 summarizes edible plant presence data throughout the archaeological strata analyzed and (where possible) provides information on their ecologies and harvest season. The Cupim phase occurrence of palm phytoliths at the site corresponds well to the hypothesis that Monte Castelo was established atop a river levee, as in the modern landscape, these are common growth habitats for *Bactris* and *Astrocaryum* palms. The site's location adjacent to the Branco River (Figure 1C) would have provided a source of moving water year-round and the subsequent Sinimbu phase's archaeobotanical assemblage includes taxa that produce during different seasons. Higher palm abundance in the Sinimbu phase suggests more intensive exploitation and management of humid microenvironments such as the river levees and oxbows that would have been close to the site. However, other plants such as rice likely preferred swampy environments and there is evidence for Anacardiaceae [85] that thrives in dryer environments such as *cerrado*. The local occurrence of swamps is supported by the ichthyological data, which record the capture of largely mud-dwelling fish and fish from secondary rivers, likely the Branco, during this period [67]. Evidence for the exploitation of semideciduous forests that were probably distant from the site comes from both Brazil nut and Fabaceae (Mimosoideae) seeds, the former being the most abundant non-palm macrobotanical taxa in the Sinimbu package, extending the geographical reach of the food remains represented.

In the Bacabal package, the majority of the taxa remain (except *buriti* and nance) and there is an expansion in the range of edible species that grow in humid forested environments, among these Annonaceae, hackberry (*Celtis* sp.), fig (*Ficus* spp.), cacao (*Theobroma* sp.), and Burseraceae (Table 2). The addition of these taxa may reflect the Late Holocene geographical expansion of forested environments (and the establishment of humid evergreen forest specifically) that has been recognized at a regional scale in paleoecological studies (Section 2.2, [75,76]). The increase in terra firme forest taxa during this period, however, implies that people exploited a considerable territory when procuring food, since this vegetation is today located over 20 km to the north and northeast of Monte Castelo, where the seasonally inundated plains give way to higher land (Figure 1C). It is also possible that some of these taxa were transplanted and cultivated atop the Monte Castelo shellmound and other terra firme islands in the Guaporé Wetlands.

Diversified plant cultivation strategies, broad spectrum management, and generalist diets without specialization have been suggested by several authors to be the basis of resilient human occupations in the Late Holocene within a backdrop of demographic increase [14–16,34]. These data show that such strategies go back to at least the Middle Holocene in southwest Amazonia, attesting to an ancient and diversity-based food production system that still persisted in some regions well into the Late Holocene [9,14]. Environmental and climatic changes during the Middle to Late Holocene were faced through the incorporation of even more diverse plants and management areas and not through specialization or the intensification of a few cultivated species.

Table 2. Table showing occurrence data of edible plant species recovered in the Monte Castelo shellmound, together with their ecological niche (when not cosmopolitan species) and harvest season (wet and/or dry). Abbreviations: SI = seasonally inundated; TF = terra firme; semi-dec = semideciduous; ev = humid evergreen.

		Species	**Macro, Phytolith or Starch**	**Ecological Niche**	**Harvest Season**	**Cupim**			**Sinimbu**									**Transition**					**Bacabal**			
						U	**T**	**S**	**R**	**Q**	**P**	**O**	**N**	**M**	**L**	**K**	**J**	**I**	**H**	**G**	**F**	**E**	**D**	**C**	**B**	**A**
FRUIT-BEARING PERENNIALS	Cosmopolitan species	Annonacae	p	Multiple	wet and dry										X								X	X	X	X
		Annonaceae cf. *Annona* sp.	m	Multiple	wet												X									
		Arecaceae	m, p	Multiple	wet and dry		X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X
		Arecaceae *Astrocaryum* sp.	m	Multiple	wet and dry						X	X	X	X			X	X					X			
		Arecaceae *Attalea* sp.	m	Multiple	wet and dry							X														
		Arecaceaecf. *Bactris* sp.	m	Multiple	wet																				X	
		Arecaceae Bactris /Astrocaryum sp.	p	Multiple	wet	X		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
		Arecaceae *Euterpe/Oenocarpus sp.*	p	Multiple	wet and dry	X	X		X	X	X		X	X	X	X	X				X		X		X	X
		Fabaceae	m	Multiple	wet and dry					X		X												X	X	
	Species with specific habitats	Arecaceae *Mauritia flexuosa*	m	Gallery forest; SI savanna	wet							X		X		X	X									
		Malpighiaceae *Byrsonima sp.*	m	Cerrado; open forest; SI savanna	wet and dry						X	X	X				X	X	X							
		Anacardiaceae *Anacardium* sp.	m	Cerrado; open forest	wet and dry					X													X	X (cf)		
		Myrtaceae cf. *Psidium* sp.	m	Cerrado; open forest	wet and dry												X	X								
		Rosaceae cf. *Prunus* sp.	m	Gallery forest; semi-dec forest	dry																					X
		Fabaceae cf. Mimosoideae	m	TF forest (semi-dec)	wet and dry							X														
		Lecythidaceae *Bertholettiaexcelsa*	m	TF forest (Ev, semi-dec)	wet					X	X	X	X			X	X		X				X	X	X	X
		Cannabaceae *Celtis* sp.	p	TF forest (Ev, semi- dec); cerrado	wet																		X		X	
		Burseraceae	p	TF forest (Ev, semi-dec)	wet																		X		X	
		Malvaceae *Theobroma sp.*	m	TF forest (Ev)	wet and dry																			X		
		Moraceae cf. *Ficus sp.*	m	TF and SI forest (Ev)	wet																		X	X		
ANNUAL HERBS		Poaceae *Zea mays*	m, p, s	Cultigen	dry									X	X	X	X	X	X	X	X	X	X	X	X	X
		Poaceae *Oryza* sp.	p (glume)	Cultigen	wet												X	X	X	X	X	X	X	X	X	X
		Cucurbitaceae *Cucurbita* sp.	p, s	Cultigen	dry					X	X			X			X	X	X	X	X	X	X	X	X	X
		Dioscoreaceae *Dioscorea* sp.	s	Cultigen	dry																		X			
		Dioscoreatrifida	s	Cultigen	dry																		X			
		Convulvulaceae *Ipomoea batatas*	s	Cultigen	year round																		X			
		Fabaceae *Phaseolus* sp.	p	Cultigen	dry																		X			

5.3. Continuity vs. Discontinuity: Entangling Plants, Cultural, and Climatic Changes

Despite the aforementioned differences in the plant and animal species recovered between the Sinimbu and Bacabal occupations at Monte Castelo (and not to mention, in site stratigraphy and material culture), our data also demonstrate a degree of continuity in various aspects of the archaeobotanical records that cannot be ignored and which offer an alternative narrative to that of collapse and substitution due to climate change (sensu [14,41]).

Firstly, the recovery of both wet and dry season species in both Sinimbu and Bacabal occupations demonstrates a pattern of perennial, rather than seasonal, settlement at the shellmound site throughout its history. These findings agree with the ichthyological record, which calls for a replacement of the notion of "nomadic mobility" with "territorial mobility" in relation to these occupations [67]. A similar pattern of long-term territorial stability has been concluded for Middle to Late Holocene shell mound-building groups occupying the southern Brazilian coast [104].

Secondly, many of the plant species found in the Sinimbu occupations continued to be exploited throughout the Bacabal phase including squash, maize, rice, Brazil nut, and, especially, palms. It appears that, in both periods, the inhabitants of Monte Castelo exploited the full array of ecological niches, even though the distribution of such niches within both the local and regional landscape would have changed considerably when the modern flooding regime was established. It is possible that palms—the most abundant carbonized remains in almost every occupation layer—were among the very few species whose distribution remained less affected by these changes, since they are common to almost all vegetation types growing in the region today (including both terra firme and wetland environments). The exceptional abundance of palm remains reported here is seen in sites from all over lowland South America since the Pleistocene–Holocene transition [4,103,105].

In the case of rice, which has been exploited since the Cupim phase but only domesticated during the Bacabal phase [56], one could hypothesize that the complete seasonal inundation of what were once shallow swampy areas some time during the Sinimbu–Bacabal transition (a pattern reflected in the drop off of *buriti* palm remains, and the increase in fish capture in flooded forests and major river environments [67]), would have resulted in a reduced local distribution of wild rice stands that occur naturally in shallow swamps and wetland edges. This may have led people to start managing and/or cultivating these smaller populations more intensively, thus favoring the fixation of desired traits such as larger glume size, which can be detected in the phytoliths throughout the Bacabal phase [56]. Domestication, in this sense, could be the result of an effort to maintain a previously managed plant in the diet in the face of a changing environment, rather than a conscious process to increase crop yields.

Finally, our data also hint at continuity in on-site fire and food processing practices between the Sinimbu and Bacabal phases. The low wood charcoal density found throughout the shellmound's stratigraphy shows that fires that contributed to the archaeological records were not related to vegetation clearance but, instead, to local, circumscribed activities such as food processing or refuse burning, with food remains making up > 97% of the macro-remain assemblages. This is true despite the fact that we analyzed constant volume soil samples which better represent local fire management than archaeological features [58]. Our findings offer a stark contrast with coastal shellmounds in southeastern Brazil where food remains are on average just 4% or less of the macrobotanical assemblages [106]—a surprising result given the abundant evidence of food (particularly animal) consumption linked to mortuary feasts at these sites [104]. It seems that activities related to the processing and consumption of plant foods were more intensive at Monte Castelo, be they related to the funerary contexts or not. The presence of maize and rice leaf phytoliths throughout much of Monte Castelo's stratigraphy also supports a scenario of relatively intensive, on-site food processing practices from 5800 cal. BP onwards. Finally, the proportions of carbonized wood at Monte Castelo also contrast with those reported in ADE occupations in Central Amazonia [61] and the upper Madeira river [7](where they are on average 70%

of all carbonized remains), suggesting that quite different site formation processes were at work to produce the dark, nutrient-rich soils evidenced in the shellmound.

6. Conclusions

In this paper, we have attempted to discuss archaeobotanical data from the Monte Castelo shell mound and how they relate to ongoing debates over the indigenous history of food procurement and production and patterns of mobility and permanence in the Amazon basin during the Middle to Late Holocene transition. Our concluding points can be summarized as follows:

- Despite dramatic, climate-induced changes in local hydrological regimes and the distribution of exploited plant resources that occurred during the site's occupation, at no point do we recognize any abrupt changes to the processes by which humans acquired their food, emphasizing the resilience of Middle Holocene subsistence strategies in the face of changing environments.
- People continuously exploited a diverse range of cultivated, managed, and potentially wild species, thus there is no moment that could be interpreted as a transition to "agriculture" or an intensification of food production, but rather a tendency towards progressively diversified food assemblages.
- Occupations seem to have been perennial (i.e., distributed across both wet and dry seasons), but not permanent, throughout the site's history. The range of ecosystems represented by their plant remains, particularly in the Bacabal period, suggests that the site formed part of much larger human territories, as it does today for local indigenous groups.
- These observations lead us to reject traditional forms of dividing long-term history in the Amazon (particularly the existence of a Formative stage), as well as the supposed relationships between plant cultivation and settlement permanence.

Supplementary Materials: The following are available online at https://www.mdpi.com/2571-550X/4/1/8/s1, Table S1: Quantitative data for archaeobotanical remains recovered in Monte Castelo shellmound (charcoal, phytoliths and starch grains).

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