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Paleoethnobotanical Analysis of Starch Grains and Phytoliths from Pre-Columbian Ceramic Residues in the Bolivian Amazon

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PALEOETHNOBOTANICAL ANALYSIS OF STARCH GRAINS AND PHYTOLITHS FROM PRE-COLUMBIAN CERAMIC RESIDUES IN THE BOLIVIAN AMAZON

by

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ABSTRACT

The Llanos de Mojos of the southwestern Amazon region of Bolivia once supported large Pre-Columbian indigenous populations who were regarded as skilled farmers, and whose agricultural pursuits are still documented on the landscape through tens of thousands of raised fields. Nevertheless, the plants that were cultivated on these fields that contributed to a large part of the local cuisine are not well understood. Microbotanical analyses using starch grains and phytoliths of food residues were conducted on 55 archaeological ceramic fragments from four forest islands in Mojos where people resided recurrently from cal BCE 1200 to cal CE ~1430. The results of these analyses identified and described several economic plants known ethnohistorically as cultigens in Mojos and several potential cultigens not yet known. The results indicate the cuisine of peoples in Mojos may have been composed of a rich variety of plants that were likely cultivated on the raised fields. In addition, this study identified damage to starch grains related to food preparation and contributes to our understanding of cooking techniques. Linking plants, cuisine, and material culture in this way enhances our understanding of subsistence strategies in the past, and potentially supports sustainable agricultural strategies to mitigate food insecurity in vulnerable communities today.

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INTRODUCTION

The goal of this work is to identify and describe economic plants that composed a major part of culinary traditions of indigenous communities in the Llanos de Mojos before European contact (CE 1492). Culinary practices can reveal much about a culture, including social practices and values, because food is often used as a marker of identity. A paleoethnobotanical approach, that focuses on human-plant interrelationships, provides a perspective for understanding past culinary traditions through the identification of food and food-processing techniques. Directing analyses toward starch grains and phytolith recovery from ceramics mitigates some of the obstacles of traditional macrobotanical analyses in places where macrobotanical remains typically do not preserve well in archaeological contexts (Chandler-Ezell et al. 2006).

The Llanos de Mojos, hereafter referred to as Mojos, is a seasonally inundated tropical forest savanna located in the southwestern Amazon region of Bolivia (Figure 1). It is characterized by the cycle of flooding and drought it experiences on a yearly basis. Earthworks were constructed and maintained here for hundreds, maybe thousands, of years before European contact, including forest islands, which people inhabited and occupied recurrently, and raised fields, on which people grew food. Forest islands are elevated mounds of earth with forest vegetation, often with raised fields in the surrounding pampas. Four forest islands in West Central Mojos—Estancita, Miraflores, San Francisco, and Santa Maria—make up the study area of this thesis. These forest islands are located near the Yacuma-Rapulo river confluence and the modern town Santa Ana del Yacuma.

Paleoethnobotany

Paleoethnobotany is the study of people-plant interrelationships in the past through the study of plant remains (Ford 1979:286; Pearsall 2015). Paleoethnobotany is essentially an archaeological approach (Pearsall 2015), even though it often draws on botany and ethnobotany as well. Often, paleoethnobotany is concerned with the social and cultural, in addition to the ecological contexts of plants and their relationships with humans. Human interactions with the plant world result in the deposition of four kinds of plant remains that paleoethnobotanists most often encounter: macroremains, starch grains, phytoliths, and pollen. Macroremains include larger plant tissues usually visible to the naked eye; starch grains are microscopic plant remains produced by plants for energy storage; phytoliths are microscopic opal silica bodies often deposited into local sediments; pollen often collects in lake sediments and can be used to determine people-plant histories in a landscape. All four types can be used to create a more complete picture of the way people interacted with the natural world around them, including what and how they ate.

Paleoethnobotany is vital to this research because plants are of fundamental significance to humans throughout time, regardless of subsistence strategy (Stuart 2018). According to Ford (1979:286), plant remains, more than any other type of archaeological data, express most aspects of societies and their involvement with both the external social and natural environments. Van der Veen (2014:800) asserts that plants are essential to human and animal life on earth because they create the oxygen we breathe, the food we consume, fibers for our clothes, building materials for shelter, fuel to keep us warm, and medicine to keep us healthy. It cannot be overstated how vital plants are to human existence and human culture. In Mojos, using a paleoethnobotanical approach has the potential to enhance our understanding of how people here

interacted with their environment by exploiting natural resources, how they moved and settled within the landscape, what they subsisted on, and how they ate meals, underlining the wide-ranging importance that plants have played in the lives of humans, past and present.

Foodways and Cuisine

Food, food systems (also referred to as foodways), and cuisine are essential to understanding culture because they encompass the full experience of sustenance framed through the specific lens of a given culture or social community. Cuisine has long been one of the most important markers of regional and ethnic identity (Dallen and Amos 2013:99); it allows for the expression of novelty and experimentation, or the reaffirming of structures and traditions. Cuisines are a mix of the tangible and intangible elements that contribute to the cultural values and characteristics of places or cultures (Dallen and Amos 2013). Tangible elements include the ingredients and spices that go into a meal, the vessels that meals are prepared and served in, tastes, and smells, while intangible elements include the values, beliefs, and traditions involved in creating meals. Food systems, different from the actual foodstuff, generally refers to the culinary sensory experience and eating practices of a people or region, as well as culinary sites, routes, and landscapes (Dallen and Amos 2013). In theory building, food systems have been used to illuminate broad societal processes such as political-economic values-creation, symbolic value- creation, and the social construction of memory (In Mintz and Dubois 2002; see also Mintz 1985; Munn 1986; Sutton 2001).

Human culture can be understood through foodways because “identity is an abstraction that permeates every human act” (Hastorf 2016; see also Castells 1999; Insoll 2007). Culinary practices reflect the values and ideologies of specific cultures, expressed by individuals through

the embodied and recursive acts of creating a meal. From the ingredients that make up a meal, to processing techniques, to serving order, culinary traditions reflect gender, family, age group, homeland, rank, occupation, and community (Sahlins 1976; Stahl 2002; Sutton 2001). Using food as a venue to understand cultures in the past can be a fruitful venture because culinary practices, recursive and embodied experiences, are materialized in meals. Because of its inherent materiality, food and cuisine allows archaeologists to see the immaterial facets of human culture through it. Finally, the daily practice of choosing ingredients, creating meals, and eating them (where and with whom), is folded into these recursive and embodied experiences that create and reaffirm a cultural or regional cuisine.

The role that food and cuisine plays in social settings in Amazonia is entwined with the centrality that the body plays in social life. "As the human body is highly susceptible to change and transformation, controlling what comes in and out of it, especially food and food-related substances, is of central importance (Rival 2005:106)." Rival's quote highlights the central importance that corporeality, and related to that, food, plays in Amazonian sociality. Costa (2018) examines how food and the act of feeding creates the kinship ties in Kanamari society. This is most evident after childbirth, when a newborn cannot be considered human, nor Kanamari, until it has been fed by its mother (Costa 2018:70). Keeping pets for the Kanamari is a similar relationship, where feeding animals similar fare as newborns (banana porridge, sweet manioc drink, or peach palm drink) transforms the animal from wild to domestic – a familiar pet (Costa 2018:33). While we should be careful not to make blanket statements about cosmology in Amazonia, research by Amazonian anthropologists has shown that how and what many Amazonians communities eat is related to who they are.

Current archaeological research in Mojos indicates communities of people relied on agriculture for hundreds, maybe thousands, of years to feed themselves. Communities intentionally chose crops which were related to general environmental requirements of each, and a crop's significance to the social fabric of these groups of people. For example, ethnographic records in Mojos indicate that maize beer, or *chicha,* was often used as a way to lubricate social reciprocity (Block 1994:94). Someone who needed assistance building fields may host a party for their community, where maize beer would have been flowing, and in return the community would come together to build these fields (Métraux 1942:81). Marcel Mauss (1925) studied a similar phenomenon in several Pacific islands including Melanesia and cultures in the Pacific Northwest, where the concept of reciprocity was first noted in anthropological theory. In addition, the role *chicha* and feasting play in mobilizing communal labor in the Andes has been documented for several decades now (Murra 1980; Allen 2002).

Food in the archaeological record often results in materials such as animal bones, shells, seeds, and microscopic remains such as stable isotopes, starch residues, and phytoliths. However, without connecting these materials to human culture they remain a list of findings at a site. Starch grains and phytoliths—microremains produced by plants—can be found on artifacts used to process or manipulate plant foods, such as ceramic vessels (Zarrillo et al. 2008), lithic tools (Perry 2005), and even squash and bottle gourds (Duncan et al. 2009). Their association with human activity allows researchers to examine cuisine and food systems in the past. In addition, while the purpose of constructing raised fields has been argued for as a flood mitigation strategy (Lombardo et al. 2011), it is likely that these fields were used for agriculture. Thus, this study provides indirect evidence of plant foods Pre-Columbian Amazonians were growing on these fields—and processing in forest islands.

Contemporary Applications

This research has the potential to address current issues over food insecurity that people face today. Food insecurity occurs when there is a reduction of quality or variety of available food, and/or when food intake is disrupted or reduced (USDA 2019). A majority of the population in Bolivia is considered at medium to high levels of vulnerability to food insecurity, and Bolivia also has the second highest rate of malnutrition in South America (IFPRI 2013; In Salazar et al. 2016).

However, in the past, large indigenous populations thrived in Bolivia, and specifically Mojos. These populations were considered skilled farmers (Métraux 1942; Block 1994), who grew a rich variety of crops, and grew enough to secure against poor harvests or droughts (Block 1994:23). The surplus of food that agriculture in the past provided is a sharp contrast to the statistics of contemporary Bolivian people, a majority of whom are vulnerable to food insecurity. After the Jesuits arrived in Mojos, they disrupted many parts of daily life for the local communities. Archaeology is useful in thinking about these issues because it reveals past subsistence strategies that once existed here, and these subsistence strategies have the potential to alleviate food insecurity and empower vulnerable Bolivians today through food.

Using the concepts outlined here, this thesis will attempt to answer the following questions:

1. What economic crops were people in Mojos processing and consuming during the Pre- Columbian period?
2. Is it possible to reconstruct plant cuisine from the evidence of foods recovered from the artifacts? If yes, how does that cuisine manifest in the archaeological record? If no, what more do we need to know in order to reconstruct cuisine?

3. How do the results of this paleoethnobotanical study enhance our understanding of the peoples of Mojos?

BACKGROUND

Geography of the Llanos de Mojos

The Llanos de Mojos is a seasonally inundated tropical savanna located in the Beni Department, Bolivia (Figure 2). It covers roughly 110,000 km^2 of land between the Andes to the west and south and the Brazilian Shield to the east and north (Walker 2008:927). The general climate in Mojos can be characterized by high, stable temperatures, high humidity, and intense variability in rainfall between summer and winter months (Denevan 1966:9). Summer months (December to April) bring on intense rainfall that cause slow-moving rivers to back up and inundate large areas of land (Walker 2004), turning Mojos into a huge inland sea (Lathrap 1970:41). Seasonal flooding is the result of two different processes: 1) local precipitation that raises the water table and 2) the overflow of the Mamoré and its tributaries (Walker 2004; Langstroth 2011; Lombardo et al. 2011:503; Van Valen 2013:9).

Vegetation is regulated by the cycle of flooding and drought that characterizes Mojos. Three vegetation-topography units persist here: *alturas, semi-alturas,* and *bajíos* (Langstroth 2011:183) *Alturas* are elevated landforms, usually natural levees, with evergreen and deciduous plant species. *Semi-alturas* are levee backslopes that can experience inundations, but support deciduous and woodland forests, cerrados, and pampas. *Bajíos* are interfluvial basins and experience inundation on a regular basis. Grasses and other wetland genera dominate this kind of topographic unit (Langstroth 2011).

Archaeological features such as raised fields, forest islands, fish weirs, and causeways are a result of past human activity that still shape the landscape today. Tens of thousands of agricultural fields have been documented across Mojos in various shapes, such as platform

fields, ditch fields, and mound fields (Denevan 1966). Fish weirs and causeways both appear as jagged lines along the landscape; fish weirs were used to trap fish, and causeways likely served as a form of passage for travelers on foot during the wet season (Erickson 2010). These features typically occur in the savannas or *bajíos.* Forest islands are discrete, elevated mounds (*alturas* or *semi-alturas*) in the savanna where human domestic activities took place in the past (Walker 2018). Due to the elevation, forest islands are conspicuous across the savanna because trees and denser vegetation tend to concentrate on these locales. Raised fields are often found adjacent to forest islands, further evidencing the related nature of these two types of archaeological features.

Study Area

Four forest islands make up the study area of this thesis: Estancita, Miraflores, San Francisco, and Santa Maria (Figure 3). Based on current evidence, over 75 percent of visited forest islands contain evidence of human activity on them (Walker 2018:42). The four forest islands chosen for this study contain evidence of long-term human occupation based on archaeological evidence, and are all adjacent to raised fields.

Estancita

Estancita (-13.707105°, -65.452331°) covers seven hectares and is near the Yacuma river and Quinato Wetland (Walker 2018) (Figure 4). It was excavated in 2011 and 2012 (Walker et al. 2011; Walker 2018). Radiocarbon dates range from cal CE 700 to cal CE 1200 (Walker 2018:49), across two different occupation periods (Estancita I and II). Estancita has both raised fields and a ring ditch, the latter of which is associated with the later phase. Vegetation on Estancita includes several economic plants such as motacú, tacuara, chonta, mango, and other

fruit trees (Walker 2018:59). Nine ceramic fragments were sampled for residue analysis, taken from two excavation units less than 200 meters apart.

Miraflores

Miraflores (-13.704758°, -65.624029°) was excavated in 2019 (Figure 5). It is about 35 hectares and located 21 kilometers northeast from Santa Maria and Santa Ana del Yacuma, and situated just north of a large *curiche* (swamp) between the Omi and Yacuma rivers. Miraflores is currently inhabited by a local community of about thirty people (Walker et al. 2019). The forest island rises about two meters above the surrounding pampas. Several economic crops thrive on the forest island, including banana trees, mango trees, yuca, and motacú. No radiocarbon dates are currently available. Seven ceramic fragments were sampled for residue analysis, taken from the two units excavated in 2019.

Two excavation units were undertaken at Miraflores during the summer of 2019. Unit 1 was located in the northeast part of the island, and at the top of a rising slope where the highest point of the island is located. This area is open and grassy because it is an old field, surrounded by motacú palms. Unit 1 measured 2 x 2 meters. Unit 2 was located on the Northeast side of Miraflores, at the bottom of the edge of the forest island where it is not as elevated compared to Unit 1, and thirty meters north of Unit 1. The location for Unit 2 was chosen due to a high density of ceramics recovered in that area from shovel tests. Unit 2 also measured 2 x 2 meters. After a rain during the 2019 field season a significant observation was noted: while the rain water in Unit 1 drained quickly, the rain water in Unit 2 did not drain due to the high clay content in this unit, meaning, Unit 2 had higher clay content than Unit 1. This is significant due to the history of these two locations. Unit 1 was placed on what was once an agricultural field, suggesting that using this space for agricultural production may have changed the soils.

San Francisco

San Francisco (-13.779327°, -65.461562°) is a forest island located about five kilometers south of Santa Maria and Santa Ana del Yacuma (Figure 6). It has a diameter of 150 meters. San Francisco rises over a meter above the surrounding fields and savannas. Test excavations confirm that the island soils were artificially enriched in the past, bearing a dark color, carbon, and ceramics (Walker 2018:60). Walker (2018) hypothesizes that this may have even been where the Mission of Santa Ana was originally located prior to its current site. Radiocarbon dates for San Francisco date from cal BCE 1200 to cal CE 200 (Walker 2018:48).

Two trenches were excavated in 2013 at San Francisco. These trenches revealed that most of the elevation of this forest island is artificial; layers of anthrosols accumulated over time through long-term human occupation (Walker 2018:60). Eight ceramics were sampled for residue analysis.

Santa Maria

Santa Maria (-13.746505°, -65.458490°) covers about 12 hectares and is located less than three kilometers west of the modern town Santa Ana del Yacuma (Figure 7). In its current incarnation the forest island serves as shelter for cattle from the elements due to its elevation and forested vegetation compared to the surrounding savanna. Radiocarbon dates recovered from Santa Maria range from 1186 BP to 545 BP. Vegetation on the forest island includes species from Aracaceae (palms), Malvaceae (ceiba), Musaceae (banana), and other woody trees both of economic and wild origin. Santa Maria was excavated in 2018, where 31 ceramics were sampled from two test units for this study. Two excavation units were opened at Santa Maria. Unit 1 is located on the North-South transect of the island, and its location was chosen based on the density of ceramic fragments recovered from shovel tests. Both units measured 1 x 2 meters and located approximately 30 meters apart from one another on the North-South axis.

Archaeology of the Amazon

Archaeological investigations in the Llanos de Mojos began with Erland Nordenskiöld's travels throughout South America, including much of the rest of the Amazon, during the early 20th century (Denevan 2009:210). While many of his publications regarding Mojos are written in Swedish and difficult to obtain, Denevan (2009) provides a useful summary that recounts some of the significant points of Nordenskiöld's texts and his impact on Amazonian archaeology.

According to Denevan (2009:210), although Nordenskiöld was not an archaeologist by trade, he documented many of the archaeological features he encountered throughout his travels in Bolivia, including various types of agricultural fields, and large burial mounds near Trinidad. Nordenskiöld ventured beyond simply recording what he saw during his travels, and argued that the people who constructed large earthworks in Mojos were well-adapted to their environment, an idea that ultimately rejected later philosophies of environmental determinism in cultural development (Denevan 2009:217[Nordenskiöld 1916]). Nordenskiöld's work is still relevant to current research in Mojos.

Decades after Nordenskiöld's accounts, a central theoretical debate amongst early archaeologists working in Amazonia during the 20th century developed around whether or not the environment could have sustained large populations of people in the past. Betty Meggers and Clifford Evans, both archaeologists working in Amazonia, argued that nutrient-poor oxisols and ultisols that cover a majority of Amazonian *terra firme* limit successive cultivation, and ultimately the soils were too poor for large populations; the Amazon was thus what Meggers calls a "counterfeit paradise," the same phrase she coins as the subtitle for her influential publication (Meggers 1971). Instead, Meggers and Evans theorized that Tropical Forest Cultures

were constrained from cultural development by the poor soils present in the Neotropics, and that Pre-Columbian Amazonians could not organize beyond simple bands and tribes (Meggers 1954). The elaborate ceramics that were excavated by Meggers and Evans at Marajó Island were interpreted as the result of cultural transmission from the highlands (Meggers 1954:808).

Donald Lathrap offered a different perspective on Tropical Forest Cultures, which he suggested spread from Central Amazonia along rivers due to population pressures circa 3000 BP, and consisted of "a way of life supported by intensive root-crop agriculture" (Lathrap 1970:47), thus in Lathrap's view, Amazonian peoples were not limited by poor soils. Instead, Lathrap looked to accounts by European explorers, who noted large indigenous populations with extensive political units, powerful chiefs, and an economic system that encompassed large-scale agriculture and long-distance trade along river systems (Lathrap 1970). While later research would prove some of Lathrap's theories incorrect, such as his Cardiac Model of population spread across Amazonia (1970, 1977), much of his work has influenced research in Amazonia. Lathrap was correct that Pre-Columbian Amazonian cultures successfully managed forest and agricultural resources, and other scholars such as William Balée would argue that cultures were not constrained by their environment (Balée 2013:38).

In 1966 William Denevan's seminal book on Pre-Columbian earthworks in the Llanos de Mojos influenced some of Lathrap's ideas, as well as later research in the Amazon for decades to come. Outlining the geographic area, indigenous cultures, and archaeological features of Mojos, Denevan (1966) was one of the first to conduct an in-depth, comprehensive geographic study in Mojos. Furthermore, Denevan published aerial photos of the earthworks in his book, the first time anyone had exhibited the scale of these earthworks. Denevan continued to publish on

Bolivian earthworks (1993; 2001; 2009), and supports Lathrap's theory that large indigenous populations in Amazonia congregated near rivers (Denevan 2001).

This thesis builds on archaeological work done by Clark Erickson (1995, 2008, 2010; Erickson and Balée 2006a; Erickson and Balée 2006b; Erickson and Walker 2009) and John Walker (2004; 2008; 2011; 2012; 2018). Erickson, who has worked in several regions across Bolivia and throughout Mojos, examined how the Pre-Columbian communities of Mojos domesticated the landscape. Landscape domestication is the concept that "so-called natural environments" are really the product of a long history of human manipulation and management of the local environment maintained by the collective knowledge of indigenous communities through history (Erickson 2006:236). This concept is rooted in historical ecology, and espoused by scholars such as William Denevan (1966, 2001), William Balée (1998, 2006, 2013), Darrell Posey (1985), and Clark Erickson (2006, 2010). Landscape domestication—and historical ecology, more broadly—is a response to adaptationist models that claim human diversity in any given ecosystem is a response to environmental pressures (Erickson 2006:237). In other words, human culture and society are the sum total of reactions to environmental pressures, rather than humans actively working within and shaping their surroundings. As Erickson (2006) mentions, adaptationist models have been critiqued for being reductionist and teleological. Historical ecology convincingly argues for human cultures playing an active role in shaping their environment and imbuing it with layers of meaning and history over time.

Domestication of individual species and entire landscapes by Pre-Columbian peoples is relevant to the discussion of cuisine in domestic spaces because subsistence likely drove at least some of these domestication processes within Amazonia. Pre-Columbian farmers heavily modified the mosaic landscape of the Bolivian Amazon, creating an engineered landscape that

reflects the historicity of this intensive people-plant relationship (Erickson 2006). In relation to the research presented in this thesis, landscape domestication, as defined previously, is important to discussions of food because the raised fields used for agriculture have been argued as part of a larger process of domestication by Pre-Columbian communities (Erickson 2006; Walker 2004; 2011). In the following section, I turn to the cultural landscape of Mojos.

Ethnographic Records of Peoples in Mojos

Mojos is one of the most diversified cultural and linguistic areas in South America (Denevan 1966:40; Hill and Hornborg 2011:2). Early Jesuit accounts list dozens of distinct cultural groups living in the Beni, although much of the cultural distinctions were soon obscured under the Jesuits, who gathered many of these groups together and made Mojo the compulsory language (Métraux 1942:55; Denevan 1966:40). Six major tribes/chiefdoms have been recognized since the eighteenth century: the Arawak Mojo and Baure, and the linguistically unclassified Cayuvava, Canichana, Itonama, and Movima (Denevan 1966:40). [1]

The Jesuits described the Mojo and the Baure as the most powerful and populous groups in the savanna (Eder 1985[1791]). Padre Eder, specifically, spent time with the Baure during his time in Bolivia, and his chronicles provide some of the richest descriptions of the communities he encountered (1791). Barnadas (1985) offers a useful translation, and this text is the source for both Métraux (1942) and Denevan (1966). The Mojo and Baure are described as efficient food producers, cultivating large raised and ditched fields, as well as skilled fishermen and hunters. They lived in large villages which were mostly autonomous, though the existence of causeways

[1] 1 The terms “tribes” and “chiefdoms” are used in this paragraph due to the original sources’ phrasing, however, these terms are no longer typically used to refer to pre-Columbian communities in Amazonia.

and canals in Mojos territory suggests cooperation between communities. Each village was led independently by a headman or *cacique*. Second in importance were the shamans, as the Mojo had a fairly involved religious system as well as village gods and ceremonial temples (Denevan 1966:46; Lathrap 1970:161; Walker 2008:927). Mojo crafts were ornate and beautiful. Textiles were made from both bark and cotton thread. It is also noted that they produced beautiful wood carvings, although Padre Eder (1985[1791]:146) maintained that the greatest skill of the Mojo was featherwork. The Mojo also maintained far-reaching trade networks that extended throughout Amazonia and into the foothills of the highlands. While the Jesuits considered the Mojo and Baure as fairly similar, the Baure were noted for building well- constructed plazas and streets surrounded by palisades and walls (Denevan 1966:45-50).

Less is written about the Cayuvava and Movima. The Cayuvava resided west of the Río Mamoré and north of the Río Yacuma. According to Padre Zapata (Denevan 1966 [1693]), there were about seven Cayuvava villages, each totaling about 1800 people each, and ruled by a chief who called himself Paititi. They were skilled at warfare, though not much else is recorded about them. The Movima, living along the Río Yacuma and southward along the ríos Rapulo, Mata, and Apere, are described derisively by Padre Bolivar in 1621 as "naked barbarians addicted to witchcraft." Other accounts describe the Movima as fishermen, hunters, and farmers. Their territory, along with the Cayuvava (though less than the Movima), contains the highest concentration of raised fields and other earthworks (Denevan 1966).

Denevan (1966) suggests that it is unlikely the Movima were responsible for these features, though it is possible they may have experienced dramatic cultural and economic changes by the time of European contact. Orbigny (1946:201) spoke more highly of the Movima, claiming that they were nearly identical to the Mojo, though these statements should be

understood in the context that Jesuit missionaries coming to South America valued qualities that were familiar: e.g. wearing clothing. However, if that were true, then it would seem likely that the Movima were in fact responsible for the earthworks found in West Central Mojos (Denevan 1966:51-53). This is significant because the people who lived in Mojos in the past, such as the Movima, used earthwork construction as one of many strategies in domesticating their landscape (Erickson 2006). Nevertheless, it is likely that several of the cultural groups mentioned above participated in constructing earthworks across Mojos due to their varying types (e.g. raised fields versus ditched fields) and wide geographical expanse, and domesticated the landscape to suit a variety of needs.

Paleoethnobotany in Mojos

Interest in paleoethnobotany in Mojos has been growing since the 1990s (Erickson 1995; Chevalier 2002; Prümers 2004; Prümers and Winker 1997), but extensive paleoethnobotanical analyses have lagged behind. Two major publications in recent years provide the basis for our understanding of past people-plant interrelationships in Mojos (Dickau et al. 2012; Whitney et al. 2014). Dickau et al. (2012) examines both macrobotanical remains and microbotanical remains from archeological contexts in Southern Mojos, near the modern city Trinidad (Figure 8). The results of this study produced a variety of economic taxa, including amaranths (Amaranthaceae/Caryophyllaceae), bean (Fabaceae), maize (Poaceae), manioc (Euphorbiaceae), palms (Arecaceae), peanut (Fabaceae), squash (Cucurbitaceae), and yam (Dioscoreaceae). This broad suite of cultivars recovered from this study indicate that people in Mojos were growing and consuming a large number of plants, besides maize. This is significant because assumptions about maize and intensive agriculture often go hand in hand. Archaeologists often use maize in

the archaeological record as a shorthand for intensive agriculture and furthermore, an indicator of sedentary, large-scale civilization (see Raymond and DeBoer 2006). As Dickau and colleagues illustrate, culture and agriculture in Mojos are not reliant solely, nor heavily, on maize.

Whitney et al. (2014) conducted pollen and phytolith analyses on raised fields in West Central Mojos to better understand agricultural management by peoples in this area before European contact. Pollen results taken from oxbow lake cores indicate that people in Mojos were growing maize since at least 310 A.D., and charcoal presence indicates anthropogenic burning in relation to maize cultivation (Whitney et al. 2014:238). Phytolith analyses provides evidence for the interpretation that peoples in Mojos cleared lands of gallery forests before raised field construction began. This is further supported by the resurgence of *Curatella americana* L. (sandpaper tree) after the decline of human activity in this area, suggesting forest regrowth (Whitney et al. 2014:238). This study is significant in relation to this thesis because it argues that maize was a staple crop at El Cerro, a large forest island about 60 kilometers north of the Yacuma-Rapulo river confluence, thus indicating that maize was likely cultivated in several places across Mojos before European arrival. Furthermore, Whitney et al. (2014) establish that raised fields were continuously cultivated over several centuries, supporting a longstanding relationship between people and plants in Mojos.

METHODS AND MATERIALS

Microremains: Starch Grains

Starch grains are semi-crystalline aggregates composed of polymers of the six-carbon sugar D-glucose (Pearsall 2015:341), and serve as the primary energy storage mechanism for plants (Pearsall 2015:342). Some starch acts as a short-term energy reserve for plants, while other starch serves the function of long-term energy storage. This long-term energy is stored in seeds and underground storage organs, in stems, tree sapwood, and fruits, and is targeted by humans for consumption (Pearsall 2015:342). Formation of starch granules is controlled by the genetics of plant families and species, and distinctive granule shapes (Figure 9) and other traits produce diagnostic granules in many species (Pearsall 2015:342).

Starch grains have been known to science since the beginning of the 20th century (Reichert 1913), but they were not used in archaeology until the late 1970s (Pearsall 2015; Torrence and Barton 2006; Ugent et al. 1981, 1982). Despite this lag, significant leaps in research have been made using starch grains in the archaeology of the Americas. Research concerning starch grains ranges from diet and cuisine (Chandler-Ezell et al. 2006; Zarrillo et al. 2008), ritual practices (Duncan et al. 2009), domestication and agriculture (Piperno et al. 2000; Dickau et al. 2012), and land use practices (Pearsall 2015:341).

During the process of photosynthesis, plants convert sunlight into potential energy. This process takes place within the chloroplasts of the plant, and results in a simple sugar called glucose. Glucose acts as the foundation for all other nutrition that the plant requires, such as protein, fat, and complex carbohydrates. Some glucose is transported from the chloroplasts to specialized starch plastids called amyloplasts. Amyloplasts convert the glucose into storage

starch designed for long-term energy storage for the plant (Torrence and Barton 2006:35). Storage starch is targeted by humans for consumption because of its high caloric and nutritional value (Pearsall 2015:342).

Anatomy of a Starch Granule

A starch grain begins to accumulate layers of amylose at its center, which is called the hilum. It is commonly found near the center of the granule, but this is not always true for all species (e.g. yam and potato, which both form eccentric hilums). Lamellae are growth or accretion layers, and are often visible under a microscope. Fissures, striations, ridges, and vacuoles (open hila) are also found in some species (Torrence and Barton 2006:40). Starch granules can also come in a wide range of shapes, such as discs, spheres, ovals, elongated forms, kidney-shaped forms, polyhedral forms, and irregular forms. This variety aids in identification, as starch granule shape is also determined by plant taxonomy (Torrence and Barton 2006).

The morphology of a starch granule is largely dependent on the genetic composition of a plant (Torrence and Barton 2006:39). The details of morphological features, such as the position of the hilum within the granule, thickness of accretion layers, general shape of the granule, and other physical traits are consistent within taxonomic groupings (Pearsall 2015:370). These traits often make starch grains diagnostic to taxa at the family, genus, and species level.

While starch granules can vary in shape and size, generally they can be distinguished from other microscopic plant remains (such as phytoliths), diatoms, and other organic and inorganic substances (Torrence and Barton 2006:40). Starch grains are most easily identified under polarized light. Because of their semi-crystalline structure, starch grains show strong birefringence, appearing very bright against the dark background of a polarized light (Pearsall

2015; Torrence and Barton 2006). Additionally, starch grains exhibit an extinction cross, also known as a "Maltese cross," when viewed under polarized light (Figure 10). This extinction cross is centered on the hilum, which distinguishes starch grains from other microremains and can also act as a diagnostic trait among starch taxa (Pearsall 2015:342).

Starch Grain Deposition

Understanding how starch grains entered the archaeological record is crucial in understanding the relationships between human plant use and starch granules (Beck and Torrence 2006:53). Different pathways have been suggested, such as directly from the starchy plant part into the soil (decay of tubers); by being consumed or altered by people, then discarded (decay in a midden); and by deposition on artifacts used to process starchy tissues (Pearsall 2015:346; Torrence and Barton 2006). Deposition of starch into soils, either intentionally by human activity or unintentionally through natural processes, can introduce doubt on whether starch deposition on artifacts is truly a reflection of human activity, or rather a result of natural processes. Studies by Therin (1998, 2006) assessed the vertical movement of starch through sediments via rainfall: i.e., once starch is in sediments, does it migrate up or down through the soil column with rain? The results concluded that movement of starch grains, while variable, was extremely limited (0.01-0.3 percent of starch per 100 mL irrigated) (see Therin 1998, 2006; Pearsall 2015:348). A complimentary study by Haslam (2009) found that only a limited number of starch grains moved any distance through the matrix. Most tellingly, results from studies by Piperno and Holst (1998), Pearsall et al. (2004), and Duncan et al. (2009) argue for in situ deposition of starch on artifacts as a result of direct contact, and a study by Williamson (2006) concluded that starch does not migrate from soils onto artifacts (Pearsall 2015:349). Finally,

Pearsall (2019:34) argues that “starch does not have a natural dispersal mechanism,” and that its primary mode of deposition into the archaeological and environmental record is directly through human activity. Thus, the current body of evidence would argue that starch grains in the archaeological record are reflective of human activity, and rarely migrate from in situ deposition.

Further analysis into starch grain pathways and deposition have found that artifacts in fact provide some protection to starch from bacteria, fungi, and other organisms in the soil. These microorganisms produce starch-degrading enzymes and seek out starch because it is a high-energy food source (Beck and Torrence 2006:79). However, starch trapped in the pits, cracks, and crevices on course-grained materials such as grindstones and ceramics are often not consumed by these microorganisms. In addition, residues on the tools and artifacts themselves, where starch is located, provides some protection from decay as the starch is sealed in and kept from further exposure to moisture, heat, or abrasion (Beck and Torrence 2006:84; Pearsall 2019:35). Finally, the general hardiness and persistence of starch grains, when shielded appropriately by artifacts, allows for long-term survival after deposition.

Major Developments in Archaeological Starch Grain Analysis

Humans have long targeted starch-rich plant tissues for food (Torrence and Barton 2006:27; Pearsall 2015:341). Despite the value of starch-rich plants to human diets, it was only until recently that starch grain analysis became common in archaeology. Research in ancient starch has become more sophisticated in the last 20 years, and its applications are wide-reaching. Modern systematic archaeological studies of starch were pioneered by Donald Ugent (1994, 1997), whose work used the diagnostic characteristics of starch to amplify the identification of

desiccated remains of tubers recovered from sites in South America (Torrence and Barton 2006:29). Additionally, his results concluded that ancient starch can preserve on artifacts, and that through its distinctive properties, starch can be used to identify the kinds of plants used in the past (Torrence and Barton 2006:29).

Other major strides in starch grain research were made with studies into starch grain morphology (Torrence and Barton 2006:29). Work by Ugent (Ugent et al. 1984), Loy in Australia (Loy 1994; Loy et al. 1992), and parallel work in the Americas by Dolores Piperno and Irene Holst (1998, 2004; Piperno et al. 2000) established how diagnostic features of starch grains could be used to identify plant taxa in archaeological contexts. Piperno et al. (2000) discuss the specific diagnostic characteristics of manioc, yam, arrowroot, and maize starch granules, and also provide the earliest direct evidence for root crop cultivation in the Americas at the time of publication.

In New World archaeology, both Piperno (2006) and Pearsall (2015) have developed comprehensive handbooks for the identification of phytoliths and starch grains. These handbooks provide extensive references of plant taxa microremains, standardize methods for both paleoethnobotanical macroremain and microremain recovery, and add to the body of work by addressing several questions concerning paleoethnobotany, including origins of agriculture, economic plant domestication, and human diet. Both of these texts act as handbooks that are often referred to by paleoethnobotanists for procedural questions, as textbooks for paleoethnobotany classes, and in the case of Piperno's 2006 book, specifically for identifications of phytoliths.

Besides writing handbooks fundamental to paleoethnobotany in the New World, both Pearsall and Piperno have made prescient interpretations about large-scale people-plant

relationships, such as early domestication of maize as a domestic crop in preceramic Valdivia (Pearsall 1978; 2002), using phytoliths to reconstruct the paleoecology of Neotropical settings (Piperno 1988; Piperno et al. 1991), and theorizing that tropical lands between southwestern Mexico and the southern rim of the Amazon Basin acted as the origin of New World agriculture (Piperno and Pearsall 1998a). Much of both Pearsall's and Piperno's work set the groundwork for other paleoethnobotanical work today.

Following in Piperno and Pearsall's footsteps, Zarrillo et al. (2008) published on evidence for maize in the Early Formative site of Loma Alta in southwestern Ecuador where starch grains were recovered from charred residues on ceramic vessels. This study confirmed the presence of maize in southwestern Ecuador almost a thousand years earlier than previously thought (5300-4950 cal B.P.), significantly altering the timeline of agriculture in Ecuador, and South America more generally. Additionally, Zarrillo et al. (2008:5006) recovered evidence of incorporation of maize at Loma Alta into both ceremonial and everyday use. The pioneering methodology developed for starch analysis by the authors of this study established a precedent for artifact residue sampling. A similar methodology was adapted for the study of residue of ceramics from the Bolivian Amazon.

Phytoliths

Phytoliths are inclusions of biogenic opal silica that occur in stems, leaves, roots, and inflorescences of plants (Pearsall 2015:254). The silica that forms phytoliths is carried up through groundwater into the plant, and they occur in stems, leaves, roots, and inflorescences of plants. In many plant families and genera, phytoliths are diagnostic and rarely redundant between families, meaning phytoliths can be used to identify plants accurately in the archaeological

record (Pearsall 2015:254). One major strength to phytolith analysis is the resistance of phytoliths to decay over long periods of time. This level of preservation makes them ideal to examine frequencies of phytoliths in various sites at various times in the archaeological record (Piperno and Pearsall 1998a:35).

Similar to starch grain research, phytoliths did not become incorporated into archaeological investigations until the 1970s (e.g. Pearsall 1978). Early archaeological applications were concerned with phytolith production, taxonomy and identification, and preservation that had yet to be explored up to this point. Piperno published one of the first comprehensive books on phytolith analysis in 1988 in an attempt to address these concerns. Subsequent publications concerning phytolith research has expanded the field's knowledge about phytolith production, taxonomy, identification, preservation, and morphology, among other things. Today, phytolith analysis is applied across disciplines, and especially among paleoethnobotany and archaeology, paleoecology, geology and limnology, and environmental science.

Current research in phytoliths has proven to be productive in the identification of domesticated plants, such as maize (Pearsall 1978; Piperno 1984). Specifically, Dolores Piperno's (1988; 2006) two books on phytoliths have proven to be foundational publications not only for research in the Americas, but globally as well. Phytoliths are particularly important in determining foodways when found on ceramic vessels, dental calculus, or coprolites, and understanding past human-environment interactions when studied within sediments (Pearsall 2015). Microbotanical remains such as starch grains and phytoliths are significant in regions like the Neotropics, and specifically in Mojos, where preservation of macrobotanical remains can be poor. Because phytoliths, and to some extent starch grains, are more likely to preserve in such an

environment, they offer archaeologists a new avenue to better understand people-plant relationships in this area.

It is clear that phytoliths play a significant role in understanding the paleoethnobotany of any site. Nevertheless, their significance to New World archaeology cannot be doubted, as phytoliths are resistant to acidic soils that often destroy other plant remains. Methods for starch grain and phytolith analyses have been developed over the past 40 years; the following methods used in this thesis are based on currently accepted standards laid out in Pearsall (2015).

Field Sampling and Collection

Artifacts from the study area were sampled in 2018 and 2019; 55 in total (Appendix C). Soil matrices were dry screened using quarter-inch screens and recovered ceramic sherds. Sampled artifacts came from several strata within the excavation units, and include ceramics assumed to be related to food processing or serving. Six grater fragments, eight fabric or basket impressed fragments, and seven fragments with visible paint make up the majority of utilitarian vessels (vessels that appear to have some functional use in cooking or serving) chosen for sampling. Ornamentation includes basket or fabric impressed, painted, and incised. Other notable features include what was suspected to be residue on the inside of vessel fragments. Additionally, a large, complete vessel was included in this study: a large, double-bodied vessel with a decorated face recovered in situ from Santa Maria (Figure 11). A number of plain ceramics made up the other 34 ceramics of the sample set. Plain ceramics in this case are defined as ceramic fragments with no apparent paint or incisions, and act as a control in this case, which is necessary so that starch residues can be compared between the two groups of artifacts (Perry 2005:415).

Recovery of starch grains from the ceramics followed standard processing procedures (Pearsall 2015:358-9). Distilled water and a sonicating toothbrush were used to loosen starch grains and phytoliths from unwashed artifacts. The supernatant was then decanted into individual, sterile test tubes and labeled with their provenience. Artifacts were washed and photographed afterward.

Laboratory Processing

Samples were exported and chemically processed at the University of Central Florida Paleoethnobotany and Environmental Archaeology Laboratory (PEAL). Chemical processing followed established procedures, including a brief dispersion using sodium hexametaphosphate followed by flotation with lithium metatungstate (LMT) (Duncan et al. 2009; Zarrillo et al. 2012).

Starch grain and phytolith extraction begins with placing samples in the centrifuge for five minutes at 3000 RPM. This is done to concentrate the sample toward the bottom of the test tube. After this is done, the remaining water is decanted and a 10% solution of sodium hexametaphosphate is added to the samples to deflocculate the starch and phytoliths from the surrounding matrix. The samples are then placed on a platform rotator for at least two hours, but samples may sit longer before continuing the following steps. After resting, the samples are rinsed with distilled water and centrifuged for five minutes at 3000 RPM. Rinsing is repeated as needed until the sodium hexametaphosphate is completely diluted from the samples.

Samples should have as little supernatant as possible to avoid lowering the specific gravity of the heavy liquid so that the starch grains can float when it is added to the sample. If necessary, the samples should be centrifuged again to concentrate the sample. Then very

carefully pipette off the supernatant leaving as little water as possible, but without disturbing the sample at the bottom of the tube. The heavy liquid (LMT, in this case) is prepared to 1.6 specific gravity, as this is the gravity at which starch grains will remain suspended in the solution and other, heavier particles will precipitate to the bottom of the test tube. Once prepared, 10mL of heavy liquid is added to each sample. Then, the samples are vortexed and centrifuged for five minutes at 3000 RPM. After centrifuging the samples, the supernatant containing floating starch grains is pipetted into new test tubes. These test tubes contain the starch extract, while the old test tubes contain the remainder.

After this process is complete, the starch extract test tubes are rinsed with distilled water and centrifuged for five minutes at 3000 RPM, carefully pipetting out the heavy liquid. Distilled water is added to reduce the specific gravity of the supernatant, allowing the starch grains to settle on the bottom of the test tube. After each rinsing cycle, more of the supernatant is pipetted out, as the heavy liquid is diluted toward the top and the starch grains are concentrated toward the bottom. This process is repeated three to five times or as many times as needed to remove the LMT. Once rinsing is complete, the starch extracts are mounted onto slides with glycerol for analysis. A Zeiss Axio Imager.A2 with polarization at an objective power of 400x microscope was used for this analysis, and images were captured using ZEN image analysis software[2].

Limitations of Microremains Analyses

While starch grain and phytolith residue analysis has unlocked new avenues of research for archaeologists, especially those concerned with ancient diet or paleoenvironmental questions, limitations exist within this sort of research. Starch grain production is not the same across taxa;

[2] See Appendix F for standard operating procedures.

even when starch grains are produced, they may not be diagnostic for identification purposes (e.g. *Oryza spp*.). In addition, the abundance (or lack thereof) of some starch taxa within an assemblage does not necessarily equate importance. For example, finding little or no *Capsicum* spp. starch does not accurately reflect its importance in the past because *Capsicum* spp. produces very little starch, however *Capsicum* spp. starch grains are very identifiable. In addition, different plant parts produce starch grains at disparate rates: roots and tubers produce abundant starch (e.g. manioc, potato, etc.), while fruits not (e.g. chili pepper, guava, squash).

On the other hand, maize kernels produce very high amounts of starch grains. For comparison, Giovannetti et al. (2008:2982) examined starch grain deposition patterns between *Prosopis* spp. (algarroba pods) and *Zea mays* (maize). The study found that in a 200 µl sample, *Prosopis* spp. produced between 19 to 41 starch grains, whereas maize produced 1,247,040 starch grains. This study highlights how these properties often bias the interpretations of the researcher, and can overinflate maize's importance in archaeological cultures due to its taphonomic properties. Overall, while starch grain residue analysis has made available new possibilities for better understanding people-plant interrelationships, it is important to keep in mind the limitations involved in this kind of research when interpreting the data. Nevertheless, starch grain residue analysis remains critical for paleoethnobotanists working in places like Mojos where microbotanical remains have a tendency to survive better than macroremains.

RESULTS

Summary

The results of this analysis of ceramic residues present several important New World cultigens within the assemblage, including achira (*Canna edulis* Ker Gawl.), arracacha (*Aracacia xanthorrhiza* Bancr.), arrowroot (*Maranta arundinacea* L.), common bean (*Phaseolus vulgaris* L.) maize (*Zea mays* L.), manioc (*Manihot esculenta* Crantz), sweet potato (*Ipomoea batatas* Lam.), and *urucu* (*Bixa orellana* L.). Family-level identifications of Cucurbitaceae (squash family), Dioscoreaceae (yam family), and Poaceae (grass family) also indicate potential economic plants utilized by the people of Mojos (Appendix D).

Identification of starches to taxon was determined using comparative samples at the University of Central Florida PEAL and by comparison to over 200 Neotropical starch grain taxa in a database developed by Neil Duncan and Deborah Pearsall at the University of Missouri-Columbia Paleoethnobotany Laboratory (Duncan and Pearsall n.d.). Starches were identified to family, genus, or species when possible. A conservative designation of "cf." was applied to identifications where the starch grain could be compared to or is similar to a known taxa (Lucas 1986) but does not fit all diagnostic criteria.

In addition, the analysis revealed several dozen unidentified starch morphotypes—starch grains that did not fit the diagnostic characteristics of known taxa. These unknowns are listed below with descriptions of each unidentified type. Note that types are not in sequential order, because as the analysis proceeded, some types were able to be identified. Their original numbers were deleted, rather than reassigning those numbers in order to avoid confusion. For some unidentified types, a tentative identification as root/tuber starch was made. In general, many root

tuber starches tend to be large (between 15-20 microns), ovate, with eccentric hila and visible lamellae. Dickau et al. (2012:365) also noted this pattern, remarking "This morphotype has only been seen in root tissues." Unidentified types are described below, and Appendix E presents representative images of each.

Type 1: Small (10 microns or less), spherical shape, bumpy surface, open hilum – weak to no cross, double outline. Seven starch grains were assigned to this morphotype in six contexts.

Type 2: Medium-sized (between 15-20 microns), spherical shape, open hilum – trapped in a linear formation in cellular tissue. Two starch grains were assigned to this morphotype in two contexts.

Type 3: Medium-sized (15-20 microns) Spherical/ovular shape with a central, closed hilum surrounded by radiating lamellae. Smooth surface, very weak cross, cf. *Dioscorea* spp. Six starch grains were assigned to this morphotype in three contexts.

Type 5: Small (10 microns), spherical-elliptical shape, smooth surface with closed hilum. Weak cross with thin, irregular arms. Probably Fabaceae but too small to ID. One starch grain was assigned to this morphotype in one context.

Type 6: Large (20 microns), spherical shape with possible edge damage. Bumpy surface, no double outline. Weak, broad cross with straight arms. One starch grain was assigned to this morphotype in one context.

Type 8: Medium sized (15 microns) spherical shape, no lamellae; irregular surface and closed, central hilum. Weak cross with broad arms. Four starch grains were assigned to this morphotype in two contexts.

Type 9: Large (20 microns), ovular shape, smooth surface with no fissure, but depressed, central vacuole hilum. Double outline, faint lamellae, broad straight cross. Six starch grains were assigned to this morphotype in three contexts.

Type 12: Large (18 microns), ovular shape with an elongated point. Bumpy surface, closed central hilum. Very irregular, wavy cross. Two starch grains were assigned to this morphotype in one context.

Type 13: Large (18 microns), hemispherical shape with a small "scoop" but which does not radiate from the hilum. Open hilum, some lamellae. Broad straight cross but with some irregularity. One starch grain was assigned to this morphotype in one context.

Type 14: Medium-sized (15 microns), spherical shape with smooth surface but bumpy edges. Lamellae present, closed hilum with straight cross. One starch grain was assigned to this morphotype in one context.

Type 17: Small (10 microns or less), spherical shape, facets, slightly bumpy surface. Closed, central hilum. Double outline. Cross exhibits thin, straight arms. Five starch grains were assigned to this morphotype in one context.

Type 20: Small (10 microns) spherical shape, closed central hilum. Smooth surface, lamellae present. Straight cross, indistinct. Two starch grains were assigned to this morphotype in two contexts.

Type 21: Large (20 microns), oblong-spherical shape with facets. Some damage at one of the facets. Distinct lamellae, offset hilum, eccentric, wavy cross. Root/tuber. Three starch grains were assigned to this morphotype in two contexts.

Type 22: Large (20 microns) Perfectly round shape, smooth surface, fissure across central hilum. Double outline, broad straight extinction cross. Cf. Fabaceae. Five starch grains were assigned to this morphotype in four contexts.

Type 23: Fairly large (17-18 microns), spherical, round shape, lamellae present. Closed, central hilum. Wavy, eccentric cross. One starch grain was assigned to this morphotype in one context.

Type 24: Fairly large (17-18 microns) spherical-irregular shape, compound grain. Large, open, depressed hilum, central. Compound granule smaller. Eccentric cross. Root/tuber. One starch grain was assigned to this morphotype in one context.

Type 25: Small (10 microns), hemispherical shape, smooth surface, with depressed, open hilum. Bright, straight cross. One starch grain was assigned to this morphotype in one context.

Type 26: Medium size (12-15 microns), spherical-irregular shape, slightly bumpy surface, depressed, open hilum. Bright straight cross, lacks distinguishing features. Two starch grains were assigned to this morphotype in two contexts.

Type 27: Medium size (15 microns), spherical, round shape, smooth surface, strong double outline. Closed, central hilum. Broad, straight cross. Indistinct. One starch grain was assigned to this morphotype in one context.

Type 29: Large (18-20 microns), rectangular shape, faceted, with roughened, bumpy surface. Open, central vacuole hilum. Eccentric, wavy cross. Three starch grains were assigned to this morphotype in two contexts.

Type 30: Large (18-20 microns), ovular shape with several facets. Bumpy surface. Double outline, some lamellae visible. Central closed hilum. Wavy, eccentric cross. Root/tuber. One starch grain was assigned to this morphotype in one context.

Type 31: Large (20 microns) spherical shape, bumpy surface, T-shaped fissure along central hilum. Straight cross, right angle. One starch grain was assigned to this morphotype in one context.

Type 32: Large (20 microns), spherical-round shape, smooth surface except for damage on edges. Central, slightly open hilum. Unidentifiable due to edge damage resulting in lost cross and other diagnostic features, but consistent shape and size across the grains. Three starch grains were assigned to this morphotype in one context.

Type 33: Very large (25-27 microns), spherical shape with extreme, regular facets appearing on the entire grain. Smooth surface, lamellae visible. Central, depressed, vacuole hilum. Slightly eccentric cross. One starch grain was identified to this morphotype in one context.

Type 34: Medium-sized (15-20 microns), irregular, angular shape, with protuberance. X-fissure across central hilum, straight extinction cross. One starch grain was assigned to this morphotype in one context.

Species Ubiquity, Abundance, Percent Presence, and Richness

Species ubiquity, abundance, percent presence, and richness analyses were applied to the starch grain assemblage. These measures are often applied to species within an ecosystem in ecology, but they can also be useful as a quantitative approach in paleoethnobotany to understand how taxa associated with artifacts are distributed throughout an assemblage, which may enhance interpretations of economic importance or culinary preference.

Abundance as used here is meant to represent the total number of starch grains per taxa throughout the assemblage, e.g. *Zea mays* was the most abundant taxon at Santa Maria because it had the highest number of starch grains present. Ubiquity represents the number of artifacts upon

which a taxon is found in the assemblage, e.g. *Zea mays* was the most ubiquitous taxon at Santa Maria because it was found on most of the artifacts. Percent presence measures the percentage of artifacts upon which a taxon appears and is calculated by dividing the number of samples of a specific taxon (or a taxon's ubiquity) by the total number of samples (Pearsall 1983; Hastorf and Popper 1989). Figure 12 displays the calculations of percent presence of taxa within the four forest islands.

Richness of the starch taxa was also calculated for each forest island (Figure 13). Richness is simply a measure of the number of different types found at each forest island. Richness is expected to increase with sample size and the pattern generally holds in the data here (Peilou 1977; Pearsall 1983:130; Lepofsky and Lertzman 2005). Diversity is another measure that takes into account the number of individuals as well as the richness, but was not calculated here because sampling effort from each forest island differs, and diversity scores are highly influenced by the number of samples recovered (Pearsall 2015:386). As Pearsall (2015:148) advises, approaches that require more rigor than the dataset is capable of should not be applied. Results from each forest island are presented below.

Estancita

A total of nine ceramics were studied from Estancita for residue analysis. Fourteen starch taxa were recovered, five of which were identified to family or species level (Table 1). These include: Maranta/Calathea (both are starchy root/tuber genera in the Marantaceae family and produce overlapping starch types). Poaceae, arrowroot, maize, and manioc. Starch grains tentatively identified to maize and to manioc were also recovered. The other nine taxa are made up of unidentified morphotypes. Maize represents the most abundant taxon, with 18 maize starch

grains identified, in addition to 5 starch grains tentatively identified to maize. Manioc was the most ubiquitous taxon, appearing on two ceramics. Manioc also represents the highest percent presence at Estancita, occurring on 22% (n=2) of the samples (Figure 14). In addition, tentative identifications consistent with manioc starch but lacking diagnostic features compose a further 11% (n=1) presence. If taken together, manioc is present on 33% (n=3) of the samples within Estancita. The other taxa represented are consistently between 10% and 15% presence within the assemblage. Unidentified types are also represented between 10% and 15% presence. The highest percent of starch grains present are unidentifiable and/or damaged starch grains, between 30% and 35% (n=3).

Miraflores

A total of seven ceramics were sampled from Miraflores for residue analysis. Thirteen taxa were identified at Miraflores, four of which were identified to family or species level (Table 2). These include: Poaceae, achira, maize, and manioc. Starch tentatively identified to maize and common bean were also recovered. The other nine taxa are made up of unidentified morphotypes. Damaged and/or unidentified starch was the most abundant kind of starch at Miraflores, with three starch grains identified. Type 22, an unidentified taxon, was the most ubiquitous here, appearing on two ceramics. Type 22 also presents as the taxon with the highest percent presence, at 28.5% (n=2) (Figure 15). Although Type 22 could not be positively identified, it shares characteristics with starches produced in the Fabaceae (bean) family. The positively identified taxa are equally distributed across the samples at 14.2% (1 ceramic each). Damaged and/or unidentifiable starch grains represent almost 45% of the starch present at Miraflores (n=3).

San Francisco

A total of eight ceramics were sampled from San Francisco for residue analysis. Twelve taxa were positively identified at San Francisco, seven of which were identified to family or species level (Table 3). These include: Fabaceae, Poaceae, maize, and *urucu.* One starch grain was tentatively identified to the Cucurbitaceae family. Tentatively identified sweet potato and maize were also recovered. The other five taxa are made up of unidentified morphotypes. Poaceae was the most abundant starch at San Francisco, with 10 starch grains identified to this family. It was also the most ubiquitous, appearing in six contexts. Poaceae presents as the taxon with the highest percent presence: 75% of the samples contain Poaceae starch (n=6)(Figure 16). Tentatively identified maize starch and tentatively identified sweet potato starch were found on 25% (n=2) of the samples, and the other identified taxa were found on 12.5% (1 ceramic each) of the samples. Damaged and/or unidentified starch grains represent 75% of the starch present at San Francisco (n=6).

Santa Maria

A total number of 31 ceramics were sampled from Santa Maria for residue analysis. Santa Maria is the most species rich of the four forest islands, with 25 taxa positively identified here, thirteen of which were identified to family or species level (Table 4). These include: Poaceae, achira, arracacha, arrowroot, common bean, maize, manioc, and *urucu.* Two starch grains tentatively identified to the Cucurbitaceae family, and one starch grain was tentatively identified to genus-*Dioscorea* spp. Four starch grains were tentatively identified to sweet potato. Maize was the most abundant starch at Santa Maria, with 35 starch grains identified. Maize was also the most ubiquitous, appearing in eight of the ceramics. Maize and tentatively identified

maize starch were present on 15.6% of the samples (n=8) and Poaceae starch was present on 13.7% (n=7) of the samples (Figure 17). Tentatively identified manioc starch was present on 7.8% (n=4) of the samples, and diagnostic manioc starch was present on 1.9% (n=2) of the samples. Combined, manioc starch was present on 9.7% (n=6) of the samples at Santa Maria, and 11.7% (n=6) of the samples containing Type 1 starch. Arrowroot and *urucu* were each present on 5.8% (n=3) of the samples.

Ceramic Graters

Ceramic graters in Amazonian archaeology are traditionally associated with root crop agriculture, and manioc, more specifically (Lathrap 1970; DeBoer 1975; Perry 2005). Graters are a specific type of preparation utensil that feature lithic "teeth" in some cases as the abrasive characteristic (DeBoer 1975; Perry 2005), or in other cases may feature a furrowed surface (Kamienkowsi and Arenas 2017) against which roots, tubers, and/or rhizomes would have been grated against.

Six graters were included in this study: UCF0021B, UCF0033B, UCF0046B, UCF0048B, UCF0049B, and UCF0076B. These graters feature a furrowed surface (Figure 18). One or more starch grains were identified on four of the six graters. Both UCF0048B (n=19) and UCF0049B (n=17) were some of the most productive samples in the assemblage; only two other ceramics in the assemblage were more productive: UCF0047B (n=52) and UCF0077B (n=33). Overall, 42 out of 229 starch grains were identified on these graters. That accounts for 18.3% of all the starch grains identified in this study. In addition, these grater ceramics had the some of the most variety of taxa identified upon them. For example, both UCF0048B and UCF0049B had 8 distinct taxa identified upon them. UCF0046B had 3 taxa identified, and UCF0021B had 2 taxa

identified. UCF0033B and UCF0076B had no starch grains identified, and zero taxa identified. These results seem to indicate that ceramic graters in West Central Mojos would have been multi-purpose, multi-plant tools rather than only used for one type of plant, such as manioc.

Phytoliths

Phytoliths present in the assemblage are potential indicators of environmental and economic resources. Bilobate phytoliths typical of both Poaceae and Bumbusoideae were ubiquitous and abundant throughout the assemblage. In addition, phytoliths identified as Cyperaceae were also commonly encountered. Both grasses and sedges are common in Mojos, but both also may have economic presence.

Arecaceae (palm family) phytoliths were encountered throughout several samples. These phytoliths, spinulose spheres (Figure 19), may represent economic use of palms, as palms were used for many purposes. Two phytoliths belonging to Marantaceae, nodular spheres (Figure 20), were recovered in two samples. The Marantaceae family includes arrowroot and calatheas, economically significant root/tubers in the Neotropics (Chandler-Ezell et al. 2006:116). Although maize starch grains were both abundant and ubiquitous throughout the assemblage, phytoliths diagnostic of maize were not encountered.

Most of the phytoliths identified in the assemblage were found on samples from Santa Maria. An occasional bilobate was seen on the samples from Estancita, Miraflores, and San Francisco.

DISCUSSION

Summary

The results of this analysis suggest that communities within the study area of Mojos relied on a rich suite of plants as sources of food. This is evident in the number of identified and unidentified taxa present on ceramic samples. It is also significant that while some identified taxa are present across all four forest islands (e.g. Poaceae), many taxa are only found on one or some forest islands instead of all four. For example, manioc starch was not recovered on samples from San Francisco, but maize and Poaceae are more highly represented there.

Some of the uneven distribution of taxa may reflect sampling and/or taphonomic processes. Sampling effort is positively correlated to richness and evenness of taxa (Peilou 1977; Pearsall 1983:130; Lepofsky and Lertzman 2005). For example, Santa Maria contains the highest richness of starch types out of the four forest islands, but this may be the result of greater sampling effort rather than a true reflection of richness in comparison to the other forest islands. Because Santa Maria was originally the sole focus of this study, the sample set from this forest island is higher (n=31); Estancita (n=8), Miraflores (n=7), and San Francisco (n=8) were sampled the following year.

Taphonomic processes should also be considered when regarding the assemblage. While ceramics have shown to provide some protection from decay (Beck and Torrence 2006; Pearsall 2019), it is possible that starch grains may been destroyed over the centuries. This would be more significant if the starch grains destroyed came from plants that are typically not high starch grain producers (*Capsicum* spp.), thus erasing evidence of their presence within the assemblage. While this possibility should be considered, ceramic samples all come from similar

environmental contexts, so they are comparable in that regard, however, ceramics from Estancita and San Francisco were recovered from bags of unwashed ceramic artifacts from previous excavation units, while ceramics from Miraflores and Santa Maria were recovered directly from excavation specifically for this study. Taking into account sampling effort and taphonomic processes, the starch grains recovered from the sherds are considered evidence of the use of plants represented through processing and/or serving in regard to meals and cuisine. The starch grain assemblage from ceramics in Mojos can be used to answer the research questions posited here.

What economic crops were people in Mojos processing and consuming during the Pre-Columbian period?

Métraux (1942:59) compiled a list of several cultivated crops the Jesuits recorded when they arrived in Mojos: manioc (both sweet and bitter varieties), maize, sweet potatoes, pumpkins, gourds, beans, peanuts, arracacha, cayenne pepper, papayas, tobacco, cotton, bananas, and sugarcane. Interestingly, bananas and sugarcane, both non-indigenous crops in the New World, must have already been introduced to Mojos by the time the Jesuits arrived. This study of ceramic residues confirms the use of several taxa mentioned by the Jesuits, such as arracacha, common bean, maize, manioc, sweet potato, and possibly gourd. The study also revealed several other taxa identified that are not listed by Métraux (1942) including: achira, arrowroot, yam, and *urucu.* In addition, there are 34 unidentified starch types that represent potentially important resources yet unknown.

The results indicate local communities that occupied these forest islands were relying on a rich suite of cultigens in their cuisine. Many of these cultigens have a long history of documented use in Mojos. The ceramics in this study date from the cal BCE 1200 to cal CE

~1430 across the four forest islands. In addition, the 34 unidentified starch types suggests that the local peoples of West Central Mojos (and perhaps, even across the entire landscape of Mojos) had significant knowledge of the local flora, and could have cultivated taxa that were used in the past, which fell out of use by the time Jesuit missionaries recorded cultigens in Mojos. These starch types may represent culturally significant plants, but comparative material is needed to identify them.

The most striking pattern that arose from the data was that maize was the most ubiquitous and abundant taxa represented. There is paleoethnobotanical evidence that maize was used in West Central Mojos since at least 310 CE, and was likely one of many crops grown on the fields (Whitney et al. 2014). Poaceae, the grass family, was the most ubiquitous and abundant family represented. One reason for this result is that starch grains identified to Poaceae are actually maize starch grains, but belong to varieties of maize that we do not have comparatives for. Another reason may be that although no ethnobotanical sources for Mojos exist regarding wild grasses, many grass seeds are edible and could have been included in the local cuisine in the past. This study provides a significant link between the crops on raised fields and the foods that communities occupying forest islands ate; people in the past were likely growing crops on nearby fields, and preparing and eating them in forest islands. In addition to maize and Poaceae, manioc is also abundant and ubiquitous throughout the assemblage, suggesting that it also played a significant role in the diet and cuisine of these communities.

These results are similar to those presented by Dickau et al. (2012), where a wide variety of plant taxa are represented. Maize, manioc, squash, yam, unidentified root/tubers, and palms were recovered in both that study and this one. This commonality may be indicative of a suite of cultigens commonly cultivated throughout the entire region in the past. They may also reflect

staple crops in Pre-Columbian Mojos cuisine that transcend cultural or linguistic boundaries. Interestingly, both studies recovered high levels of unidentified root/tubers (Dickau et al. 2012:365). This may suggest that root/tubers made up the basis of meals in Mojos, and further supports ideas that communities in Mojos farmed and subsisted on a myriad of plants in the past. Differences are also present. Dickau et al. (2012) report microbotanical evidence for peanuts (*Arachis hypogoea* L.), chili pepper (*Capsicum* spp. L.), Heliconiaceae (heliconia family), and cotton (*Gossypium* spp. L.), none of which were recovered here. On the other hand, arracacha, arrowroot, common bean, *urucu,* and tentatively identified sweet potato are recorded here but not by Dickau et al. (2012). These disparities are likely a result of sampling rather than local differences in cuisine, but more research should be undertaken before this point is concluded. Overall, the results here and those presented by Dickau et al. (2012) work together to build up a larger image of what cuisine and foodways consisted of in the past.

The richness of starch taxa in the assemblage offers an insight into what past communities consumed, which runs contrary to assumptions made about Neotropical cultures relying solely on maize or manioc. The presence of maize in assemblages comes with implicit assumptions about social complexity and agricultural intensity. As Raymond and DeBoer (2006:337) aptly remark, "Maize has been afforded a privileged role in the histories of New World cultures." While maize does present as the most abundant and ubiquitous taxon, this does not necessarily reflect its importance in the past (Raviele 2011:2711; In Pearsall 2015:378). Maize produces far more starch grains than most other taxa, and macroremains of maize cobs also preserve in the archaeological record better than other taxa (Giovanetti et al. 2008). The richness of identified taxa and potential foods represented by the unidentified taxa in the assemblage indicates a wide variety of plants were cultivated and consumed in Mojos and is

contrary to the idea of a reliance on a single cultivar. While beyond the scope of this thesis, social complexity in Mojos may not have relied on mono-cropping maize or manioc. In summary, the results of this study indicate that people living on forest islands of West Central Mojos utilized a wide variety of plants, some not recorded in the historical records.

Is it possible to reconstruct plant cuisine from the evidence of foods recovered from the artifacts? If yes, how does that cuisine manifest in the archaeological record? If no, what more do we need to know in order to reconstruct cuisine?

Cuisine is a mix of the tangible and intangible elements that contribute to the cultural values and characteristics of places and cultures (Dallen and Amos 2013). Cuisine is also the art of cooking (Villing and Spataro 2015:1). Teasing out a culture's cuisine from the archaeological record can be challenging because we must interpret the intangible from the material record of the past. Despite these challenges, some facets of cuisine in Mojos can be gleaned in the evidence of foods recovered from the ceramics used to process, cook, and eat them.

Starch grains are subject to alteration during processing and cooking (Babot 2003; Henry et al. 2009; Lamb and Loy 2005). Damage observed on maize starch grains indicates that this crop was processed through methods such as grinding, pounding, or other abrasive techniques (Babot 2003). Dried maize may have been ground into a flour prior to cooking. However, maize processed at these four forest islands may have been for *chicha* (maize beer) production, as *chicha* production was an important aspect of cuisine in Mojos during historic times (Eder 1985[1791]:XLI; Métraux 1942:73; Denevan 1966:100; Block 1994:23). The practice of making *chicha* likely extends into antiquity. *Chicha* can be made in various ways (Barre 1937; Cutler and Cardenas 1947; Nicholson 1960; Jennings et al. 2005; Hayashida 2008) but maize kernels are often ground into a flour before being masticated or boiled. The damage identified on maize

starch grains is consistent with grinding and milling, two actions required to take on maize for *chicha* production. Eder (1985[1791]) reported indigenous peoples in Mojos making and drinking *chicha* in his accounts. Denevan (1966:100), citing Padre Castillo (1906:310), a Jesuit, also reports the making and consumption of *chicha* and claims the Mojo limited maize consumption to celebrations and fermentation for *chicha.* Other ethnohistorical records reviewed by Métraux (1942:73) indicate *chicha* was produced by lightly roasting grains which were then pounded with a mortar, roasted a second time, and then masticated and spit out by the women before being boiled for a full day and then transferred to large jars to ferment. The saliva would activate the fermentation process that is crucial to turning maize into *chicha.*

Alcohol in Mojos would have played an important social function. Block (1994:23) discusses how alcohol was used on special occasions, such as feasts or parties. Métraux (1942:81) discusses how the Kanichana would have "long drinking bouts" as "a reward for those who had helped clear a man's fields." Eder (1985[1791]:XLI) discusses how individual families in Mojos were required to contribute *chicha* for community celebrations. Maize beer takes precedence in the ethnohistorical records, although some mention of manioc beer is made in passing in Barnadas' translation of Eder (1985[1791:88]). Métraux (1942:73) also quotes Marbán (1898:138), who remarks that indigenous communities he engaged with preferred to boil *chicha* out of manioc, although this was over 100 years after Eder's account, and makes no mention of the people he (Márban) was referring to. What can be understood about the production of alcohol in Pre-Columbian Mojos?

Based on the ethnohistorical records it is likely that both manioc and maize beer were brewed, although the indigenous communities of Mojos at the time of European contact may have preferred maize beer. This preference may go as far back as 310 CE, when land was cleared

in West Central Mojos for fields that contain evidence of maize (Whitney et al. 2014). This preference is contrary to other indigenous peoples in the Amazon, who preferred manioc beer, such as the Cubeo (Goldman 1979), or the Tatuyo of Colombia (Pearsall 2014). This preference may be due to maize's high sugar content. A modern maize stalk contains 15 to 20 grams of sugar (Smalley and Blake 2003:679). This sugar could easily be fermented into alcohol. Additionally, it is also possible that beer made from maize may have produced a higher alcohol content by volume than beer made from manioc or other root tubers. This may have shifted preferences over time toward maize beer.

Manioc starch was identified in three out of the four forest islands studied. Manioc is an important Amazonian crop. Based on current molecular data, "the domestication of manioc took place in Amazonia, likely in northern Matto Grasso, Rondônia and Acre states in Brazil, and adjacent areas of northern Bolivia" (Clement et al. 2010:77). The importance of manioc in contemporary lowland Amazonian cuisine is unrivaled. Its hardiness, reliability, and low-maintenance labor requirements make it an ideal candidate to provide the majority of carbohydrates for communities living in the Neotropics. Manioc is an important crop that also bears symbolic importance. In some lowland Amazonian examples, manioc gardens are associated with sexuality; it is where unmarried couples have sex and where babies are born (Saunders 2005). In addition, "the process of planting hard manioc cuttings in soil is itself seen as sexual imagery" (Saunders 2005:58). For the Kanamari of Amazonia, manioc is fed to newborns to make them human, and wild animals are made house pets by feeding them manioc (Costa 2018:70). In both instances, manioc is used as a vehicle to make the unfamiliar familiar, or bestow Kanamari identity. Finally, ethnohistorical accounts by Jesuits in Mojos report that both sweet and bitter varieties of manioc provided the dietary staple (Block 1994:23).

The high percent presence of manioc within the forest islands suggests that manioc played an important economic and culinary role in Mojos. Ethnohistorical accounts of the Mojo state they boiled or roasted manioc tubers in ashes. Bitter manioc was grated, dried in the sun, and roasted (1942:61). The presence of manioc starch on ceramic grater fragments indicates communities occupying forest islands in West Central Mojos were grinding and/or grating manioc. It is also possible that manioc was, like maize, transformed into chicha but further evidence is needed.

Maize and manioc would have been the staple crops for people in Mojos. This is supported by ethnohistorical accounts, results presented by Dickau et al. (2012), and finally, by the percent presence of these taxa in this study. However, as the results indicate, these communities would have also relied on a wide variety of other cultivars. Achira, an edible rhizome, is hypothesized to have been domesticated in South America, along the fringes of the rain forest in Colombia (Gade 1966; Pearsall and Piperno 1998). The role achira played as a food source in the archaeological record is largely unknown, although achira was likely eaten in a similar fashion to manioc: roasted in an oven and eaten fresh, or prepared into a flour for later use. In Mojos, achira starch was found on a ceramic grater, suggesting that achira was prepared by grating in addition to being eaten fresh.

The presence of arrowroot starch in several samples indicates that arrowroot was prepared and eaten by people in Santa Maria along with manioc. Arrowroot produces small tubers in its roots where long-term starch for the plant is stored. Its history as an economic crop is not well-understood as ethnographic records regarding arrowroot are scattered and lack detail (Pearsall 2014). It is believed that arrowroot was one of the first root/tubers to be domesticated in the Neotropics, but fell out of favor with the introduction of manioc and maize (Chandler-Ezell

et al. 2006; Pearsall 2014). Based on extant and past ethnographic accounts, Pearsall (2014:221) concludes that arrowroot would have had several uses, both for consumption as well as ritual or magic, such as for the Island-Carib in Dominica. Some of the South American Neotropical cultures discussed in Pearsall (2014:223), such as the Tatuyo in Colombia use arrowroot as a supplement to manioc, or use it in the process of making manioc beer.

Sweet potato, yam, and arracacha would have also provided starch for people in Mojos. Sweet potato was boiled (Métraux 1942:61), but yam is not mentioned, although it likely would have been boiled or roasted as well. Sediment cores taken near El Cerro, a forest island approximately 56 kilometers north of Santa Maria, recorded sweet potato pollen circa AD 1320 (Whitney et al. 2014:239), but the context in which the sweet potato starch grains tentatively identified in my study would suggest that this crop was being cultivated several centuries prior, up to 1185-1050 cal BP (or, AD 765 – AD 900). This would push back the confirmed use of sweet potato in West Central Mojos by several centuries, and indicates a long history of use and consumption. Less is known about arracacha. Métraux (1942:61) writes that the Mojo ate arracacha raw, although its presence on grater fragments indicates that it was likely prepared as well as eaten raw.

Urucu (commonly referred to as annatto in English), has been targeted by peoples in the Amazon for its intense red pigment since at least European contact (Moreira et al. 2015:128). To date, the only archaeological evidence of *urucu* in Amazonia comes from the Llanos de Mojos, dated to 2400 BP (Erickson 1995). In the present study, several *urucu* starch grains were identified at two forest islands, San Francisco and Santa Maria. The dates for these forest islands vary, but taken together, the results suggest that *urucu* was used in Mojos for at least several centuries. Its presence on ceramics may be reflective of the process of extracting the pigment

from the seeds, which Eder reports in Mojos (Eder 1985[1791:78]); alternatively, *urucu* may have also been consumed in the past, as Chácobo Indians today cook the seeds in butter and eat them (Boom:1996:18).

The phytoliths identified in the assemblage also suggest that palms were being processed. In Amazonia, palms provide wood for construction, thatch made from the fronds for roofs, mats, and hammocks. The fruits of palms are also popularly consumed today. Palm phytoliths in this study could not be identified to the genus or species level, but several economic species may have been used in the past, such as chonta (*Astrocaryum* spp.), motacú (*Attalea phalerata*), and peach palm (*Bactris gasipaes*) (Smith 2015). These palms would have been a major component of the local cuisine, although it is unknown how they were processed as a food source.

In addition to food sources, several of these plants may have served a medicinal purpose, or may have belonged to both categories. For example, *urucu* is commonly used as a body paint, and can be eaten, but the Kayapo rub *urucu* on the bellies of pregnant women to reduce the pain of contractions (Duke and Vasquez 1994:31). Sweet potato also has medicinal properties, and used as a bactericide, fungicide, and laxative (Duke and Vasquez 1994:94). In Ecuador, among the Cayapa/Chachi, *Calathea* leaves are boiled to relieve pain after childbirth (Pearsall 2014:224). Additionally, Schultes and Raffauf (1990) list several uses of *Calathea* spp. in Northwestern Amazonia to treat infections, snake bites, mouth sores, sore throats, and even mixed with ayahuasca to see visions (In Pearsall 2014:226). These ethnobotanical examples illustrate that plants in Amazonia serve several purposes, and may have done so in the past as well.

Cuisine in Mojos was likely rich and complex, and this reflects the richness of starch types recovered from the ceramics. Staple crops such as maize and manioc may have made up

the majority of starch intake, and would have also provided sources for alcoholic drinks. Other starchy tubers like arracacha, sweet potato, and yam have different flavor profiles, textures, and colors, and would have been prepared similarly to manioc, or in other ways. Achira and arrowroot, crops that have been considered by archaeologists to have fallen out of use early on in time in favor of manioc (Pearsall 2014), appear in the assemblage alongside manioc. Maize as the main ingredient for *chicha* may have replaced an earlier manioc beer tradition. Communities in West Central Mojos may have favored manioc or maize for various reasons, but the cultivation of lesser known crops is strongly suggested by their presence in the residues. Palms also would have been targeted for their fruit, eaten raw, or prepared in various ways. All of these crops, and some that have yet to be identified, would have been consumed alongside fish and hunted game, such as monkeys and peccaries. A complete reconstruction of past cuisine may not be possible, but these results attest to a complex food system that relied on a wide variety of plants that would have been part of a rich culinary tradition.

How do the results of this paleoethnobotanical study enhance our understanding of the people of Mojos?

The ethnohistorical accounts by Jesuit missionaries provide the bulk of knowledge about the indigenous cultures living in Mojos, but these accounts are imperfect. Besides the religious and ideological biases of 17th century Europe that cast a pall over the facts they recorded, the ethnohistorical accounts only offer a snapshot into what life was like in Mojos during the 17th century. Archaeological evidence and paleoecological reconstructions indicate that Mojos was occupied by humans since at least cal BCE 4000 (Walker 2018), and land was being cleared for raised field construction since at least 310 CE (Whitney et al. 2014). Yet, without any direct evidence of what life was like for peoples in Mojos before the arrival of the Jesuits, current

understanding of daily life of the people in the past must be understood through the lens of colonialism.

Though some forays had been undertaken by the Spanish during the late 15th and 16th centuries, it was not until 1668 that Mojos was finally "settled" by the Jesuits and became an official mission province. One of the first major changes recorded involves the mass relocation of people from their homes to the newly established mission towns (Denevan 1966:31). In addition, the Jesuits "destroyed much of the native culture and replaced it with new languages, new crops and skills, and new traditions" (Denevan 1966:31). Due to its ubiquity, the Jesuits had chosen Mojo as the compulsory language for indigenous populations in several missions, though ethnic Mojo were found in only three of these missions—Loreto, San Xavier, San Ignacio, and perhaps Trinidad (Métraux 1942:55; Denevan 1966:40). Local peoples in Mojos were forced to cultivate Old World crops like rice, coffee, citrus, mango, and tamarind; cacao, though a New World crop, was not cultivated by the people living in Mojos until the Jesuits introduced it as well (Denevan 1966:32).

Colonial encounters were a time of upheaval for all parties involved. "In indigenous cultures any adopted foods were politically charged, as if eating the foods was incorporating the conquest" (Hastorf 2016:247). These monumental changes can still be seen today. Beans, though cultivated in Mojos before European contact, are rarely eaten in contemporary Mojos cuisine. Banana and mango trees can be seen on several forest islands, cultivated by communities that live there, such as Miraflores. Perhaps the most impactful change the Jesuits brought was the introduction of cattle and horses, which has made up the bulk of Bolivia's economy for hundreds of years (Denevan 1966:36). Still, some traditional dishes persist, such as *masaco*, a dish made from manioc, and *chivé*, a thick drink made from dried manioc flour and water. *Charque*, salted

and dehydrated meat, is made today from beef, but may have formed indigenously, although the word *charque* is derived from Quechua, a highland Andean language.

Archaeology can fill in the blanks before European contact. For example, the high richness of taxa in Miraflores, even though many of these taxa remain unidentified, reflects a community (or perhaps several communities moving across the landscape) that targeted a wide variety of plants and crops. This is especially apparent when comparing San Francisco, a forest island with low richness of taxa. Poaceae, maize, and sweet potato make up the highest represented taxa. Location of the forest islands may have something to do with this: Miraflores is nearby other large forest islands, adjacent to raised fields, and a large *curiche,* while San Francisco is a much smaller, isolated forest island in comparison (although it also has raised fields adjacent to it). Perhaps the relative distance from rivers or a *curiche* limited cultivation options, or perhaps the smaller community simply preferred a diet that revolved around maize.

The forest island with the highest taxa richness was Santa Maria. This is not surprising considering this forest island was sampled intensively. Twenty-five taxa were recovered from the Santa Maria assemblage. However, Miraflores and Estancita both display high taxa richness in comparison to the number of samples that make up each of their assemblages. Both of these forest islands are larger, and near bodies of water. While the chronology at Miraflores is still unknown, archaeological excavations at Estancita reveal that this forest island had two long-term occupations spread across the first and second millennium CE (Walker 2018:21). These long occupations may have allowed the community here to experiment with the local flora, and expand the suite of plants incorporated into their cuisine, or it might reflect the sophisticated agriculture regimes that were already in place. These possibilities may also hint toward Miraflores' occupation history and why this forest island also reflected a high richness of taxa.

If social identity is a lived experience, made up of daily habits and traditions, then it is clear that after European contact, social identity in Mojos was completely altered. The daily practices that accompanied meals must have changed drastically after indigenous peoples were forcibly moved to the missions. In addition, the rich variety of plant foods that would have made up meals — manioc, maize, sweet potato, pumpkin, gourds, beans, peanuts, arracacha, chili pepper, papaya, banana, sugarcane, and tobacco — were replaced with Old World crops that Jesuit tastes preferred (Block 1994:57).

Yet, some practices of indigenous communities of Mojos were preserved even after European contact. For example, Whitney et al. (2014:239) found maize and sweet potato pollen signatures in lake sediment cores, and concluded that both crops were cultivated on raised fields into the historic period and up to AD 1800. This is significant, because maize and sweet potato were cultivated before Jesuit contact, and continued to be cultivated even after contact and a major upheaval in cuisine. In addition, traditional dishes made from manioc, such as *masaco* and the drink *chivé*, still remain as essential parts of Mojos cuisine today.

Understanding cultures through archaeological means can be difficult because the concept of "culture" is not only a material one. However, foodways can be useful for archaeologists to pursue these concepts because identity is expressed through these material remains. Starch grains and phytoliths are relevant to these studies because their deposition on cultural artifacts reflects human intentionality: the choices that people made about what to eat. These choices build up into larger traditions, some of which have survived through time into the present. Other traditions, such as farming the land, have left monumental changes on the landscape that can still be seen today. Using paleoethnobotany has also revealed things that are not so obvious but still significant. The high amount of unknown plant types is significant

evidence of a higher richness of plants being utilized in the past than previously imagined. Many of these types may have been important in the past but fell out of use and no longer considered culturally salient, such as arrowroot and achira. It also indicates the need to increase comparative databases, as the full range of plants once used in the past is not always represented even in the best of databases. Nevertheless, it is evident that exploring foodways and cuisine in the archaeological record provides a unique understanding of peoples in the past. What we eat is who we are.

CONCLUSIONS

This paleoethnobotanical study uses starch grains and phytoliths from 55 ceramic residues to understand the relationship between people and food in Mojos. A wide variety of economic plants were identified within the assemblage, indicating that people occupying these forest islands were relying on a rich array of plants for their meals. Several of the plants identified are considered staple crops of the Neotropics, such as: maize, manioc, beans, and sweet potato, and palms. Other, less common taxa were also identified: achira, arracacha, arrowroot, squash, yam, and *urucu* (annatto). Thirty-four unidentified taxa were also distinguished in the assemblage.

Cuisine is a mix of intangible traditions and tangible ingredients coming together to create socially and temporally-salient meals. Reconstructing *some* of the cuisine in Mojos is possible based on this study. Many of the starch grains exhibit some damage, which is a result of preparation techniques, such as milling, grinding, pounding, or boiling (Babot 2003). Damage to maize starch grains may be a result of processing the kernels for *chicha.* Damage to other kinds of starches may be a result of boiling or roasting, especially in the case of root/tubers. Manioc may have served the function of a staple starch for the people occupying these forest islands, but the richness of the starch assemblage indicates that indigenous peoples in West Central Mojos were including and cultivating a wide suite of plants into their cuisine.

This study enhances our understanding of Pre-Columbian indigenous peoples of Mojos by distinguishing subsistence patterns before European contact. Colonialism changed the cultural and physical landscape by rounding up indigenous groups who were typically spread out across the savanna and forcing them to live in missions (Block 1994). While raised fields were still in

use during the Mission Era (mid-1600s-1767), the crops grown on these fields included many Old World crops that are still popular today. Horses and cattle became a large part of Bolivia's economy after their introduction, and ranching is still a major source of income for many people today (although this may be changing with the popularity of soybean farming). If one were to try to describe Pre-Columbian cuisine or subsistence patterns based on what is commonly eaten in Bolivia today, they would be inaccurate. Using starch grain and phytolith residue analyses, this study attempts to reconstruct the long history of cuisine and foodways that existed in Mojos prior to this tumultuous cultural shift.

This research has the potential to inform decisions about agriculture and subsistence in contemporary Bolivia. Food security has three key dimensions: (i) food availability, (ii) food access, and (iii) food use (World Bank 2008; FAO 2006; In Salar et al. 2016). Food insecurity occurs when there is reduced quality, variety, or desirability of diet, and/or when multiple indications of disrupted eating patterns and reduced food intake occurs (USDA 2019). As of 2011, 45% of the total population in Bolivia was below the poverty line (Salazar et al. 2016:34). According to the Ministry of Rural Development and Land (2014), 89% of municipalities in Bolivia are considered medium or high levels of vulnerability to food insecurity, and also has the second highest rate of malnutrition in South America at 21% (IFPRI 2013; In Salazar et al. 2016:34). Logan et al. (2019:421) argues that "archaeological data is essential to understanding long-term histories of food security." This research fits into the broader discourse of food security in Bolivia by revealing past subsistence strategies that could be applied toward modern-day issues. The agricultural sector in Bolivia employs 40.3% of the national labor force (FAOSTAT 2014; In Salazar et al. 2015:2), yet a majority of the population is considered vulnerable to food insecurity. Why does this disparity exist?

Food insecurity has often been framed within the lens of environmental actors, such as drought or fluctuating rain patterns, but this perspective fails to acknowledge histories of economic disenfranchisement that often leads to food insecurity for people (Logan 2016). Solutions to these issues are aimed at contemporary, non-human actors rather than at structural forces that have historically kept people powerless. Archaeology provides a longitudinal perspective into time that has the potential to unravel root causes of food insecurity in places. In respect to the research presented here, this thesis has provided a framework for better understanding what people ate and culinary traditions in Mojos. The rich suite of plant taxa implies that Pre-Columbian indigenous communities cultivated many plants on raised fields, rather than mono-cropping for one or two economic crops. The arrival of Jesuit missionaries disrupted this tradition, and forever shifted lifeways in lowland Bolivia.

Understanding alternative subsistence strategies to what is in place today is paramount for vulnerable people who are already suffering food insecurity. Scientists are at a consensus that there is an overall warming of the globe (climate change) caused by humans (Cook et al. 2016). Natural disasters in Bolivia are frequent, and the potential for climate change to exacerbate them should be seriously considered (Seiler et al. 2013:130). As the effects of climate change continue to magnify, vulnerable people will be the first to feel these detrimental effects. "History shows that extreme seasonal heat can be detrimental to regional agricultural productivity and human welfare" (Battisti and Naylor 2009:240). It is imperative that governing agencies and community leaders find ways to support sustainable efforts in assuaging food insecurity. In Bolivia, one way this may be done is by turning to past subsistence strategies and investing in communal rights over agricultural supplies.

Future directions to expand on this thesis are numerous. Larger excavation units on forest islands have the potential to elucidate settlement patterns or social organization like public gathering spaces and residences. A study combining both macrobotanical and microbotanical remains may reveal more data about plant use, although preservation of organic materials in the acidic soils here may prove to be challenging for macrobotanical recovery. Chemical analysis of organic compounds absorbed into ceramics may reveal plant signatures of cacao (*Theobroma cacao* L.), coca (*Erythroxylum coca* Lam.), ayahuasca (*Banisteriopsis caapi* [Spruce ex Griseb.], C.V. Morton, and *Psychotria viridis* Ruiz and Pav.), and/or black drink (*Ilex guayusa* Loes.), all of which are known to be used in the Amazon but cannot be sensed through starch grain or phytolith residue analyses (although pollen from *Ilex guayusa.* was recovered by Erickson in 1995, this is not definitive evidence of black drink, and further supports the need for chemical analysis of organic compounds from ceramics in Mojos). Finally, zooarchaeological analysis would be very useful in culinary or foodway studies as faunal material would tell us what kinds of animals Pre-Columbian indigenous peoples in Mojos regularly incorporated into their meals.

The wealth of data recovered about people-plant interrelationships in Mojos illustrates that a long tradition of plant cultivation existed here. While major climatic events in the past are still unknown, the yearly cycle of drastic drought and flood was weathered over the centuries by these populations. Incorporating some of their strategies into current agricultural regimes would support populations in Bolivia who are vulnerable to food insecurity in the wake of climate change. This study establishes a precedent for future projects to seriously consider paleoethnobotany in the research design.

APPENDIX A: LIST OF FIGURES

Figure 1 Map of Bolivia outlined in red (Google Maps)

Figure 2 Beni Department, outlined in red, located in northern Bolivia. The Llanos de Mojos is located in the Beni Department (Google Maps).

Figure 3 Location of the four forest islands that comprise this study area, marked in blue (ESRI ArcGIS Earth).

Figure 4 Estancita (ESRI ArcGIS Earth)

Figure 5 Miraflores (ESRI ArcGIS Earth)

Figure 6 San Francisco (ESRI ArcGIS Earth)

Figure 7 Santa Maria (ESRI ArcGIS Earth)

Figure 8 Map of the Llanos de Mojos and sites studied in Dickau et al. (2012) (ESRI ArcGIS Earth).

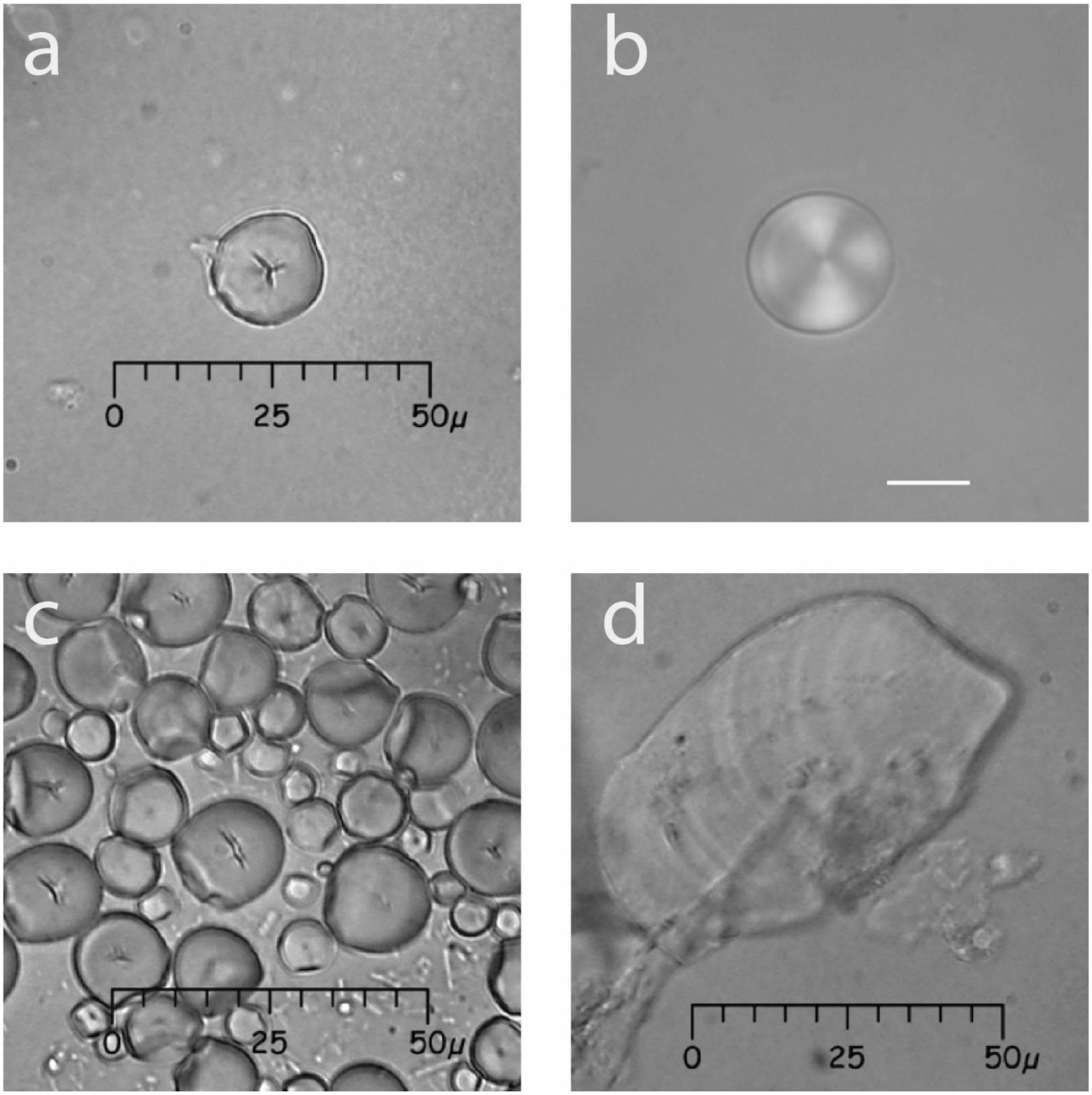


Figure 9 Diagnostic starch grains from UCF/MU Comparative Collection. a. Zea mays; b. Cucurbita ficifolia; c. Manihot esculenta; d. Canna edulis.

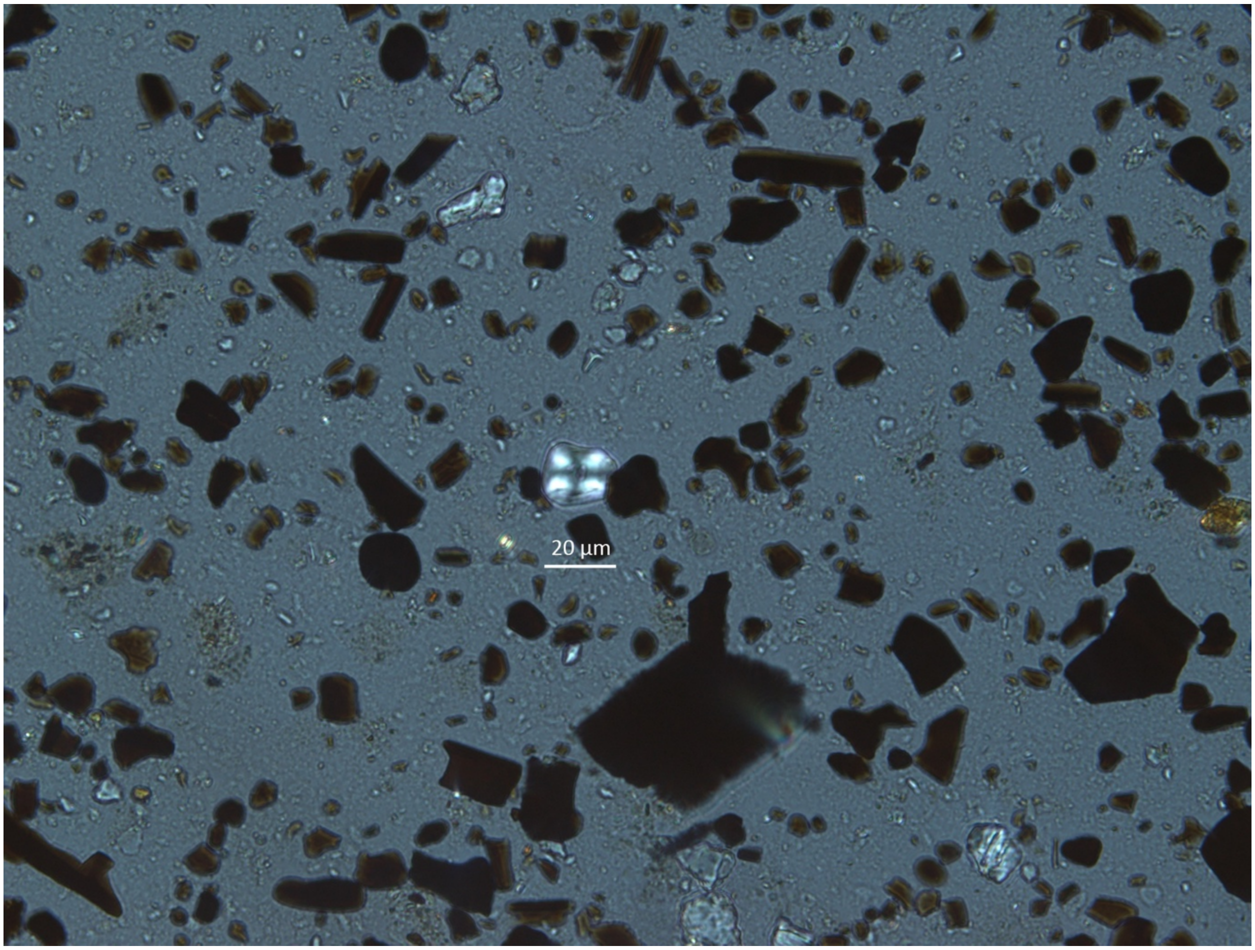


Figure 10 Example of maize starch grain exhibiting extinction (Maltese) cross under polarized light.

Figure 11 Double-bodied vessel, in situ (2018). Sample UCF0051B was taken from this vessel.

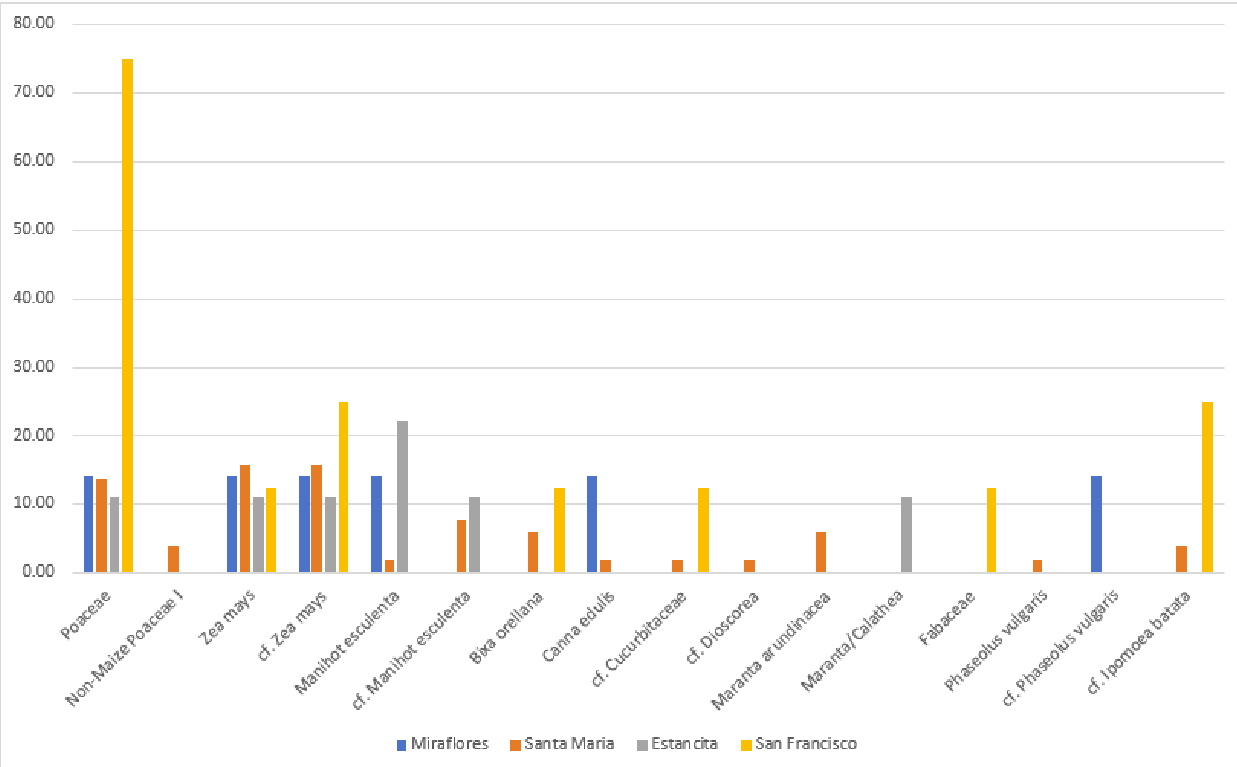


Figure 12 Percent presence of identified taxa within all forest islands

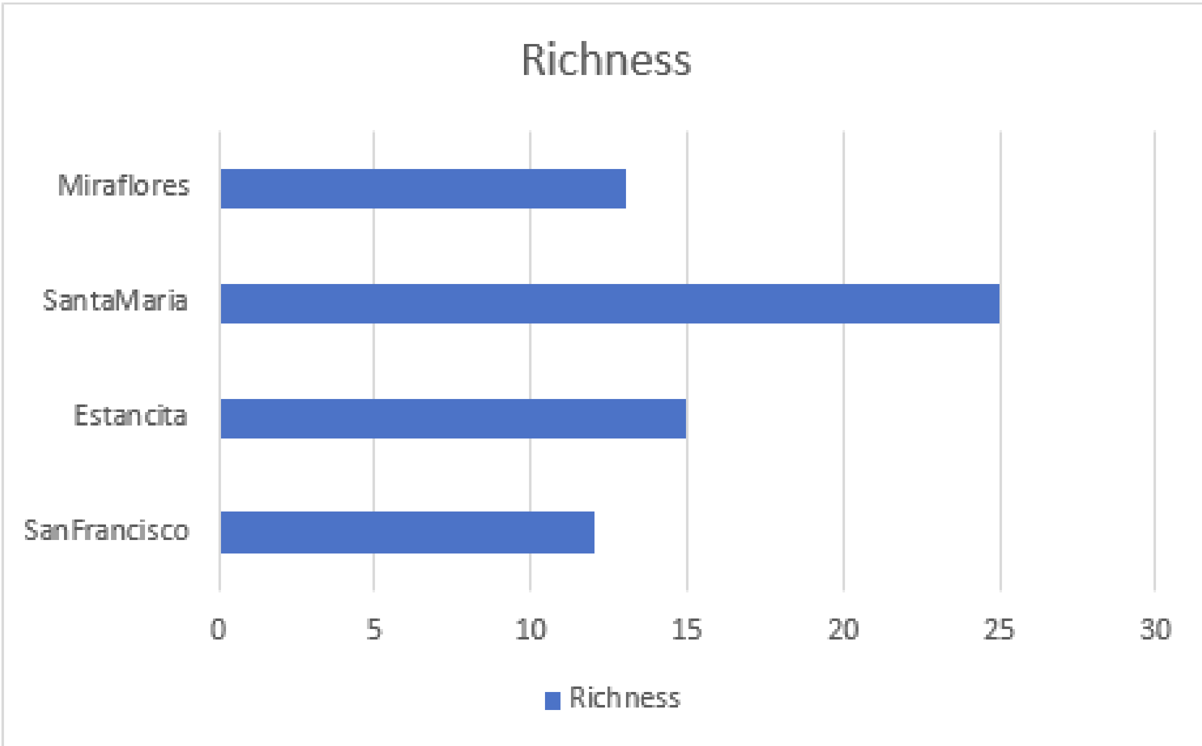


Figure 13 Richness of taxa within all forest islands

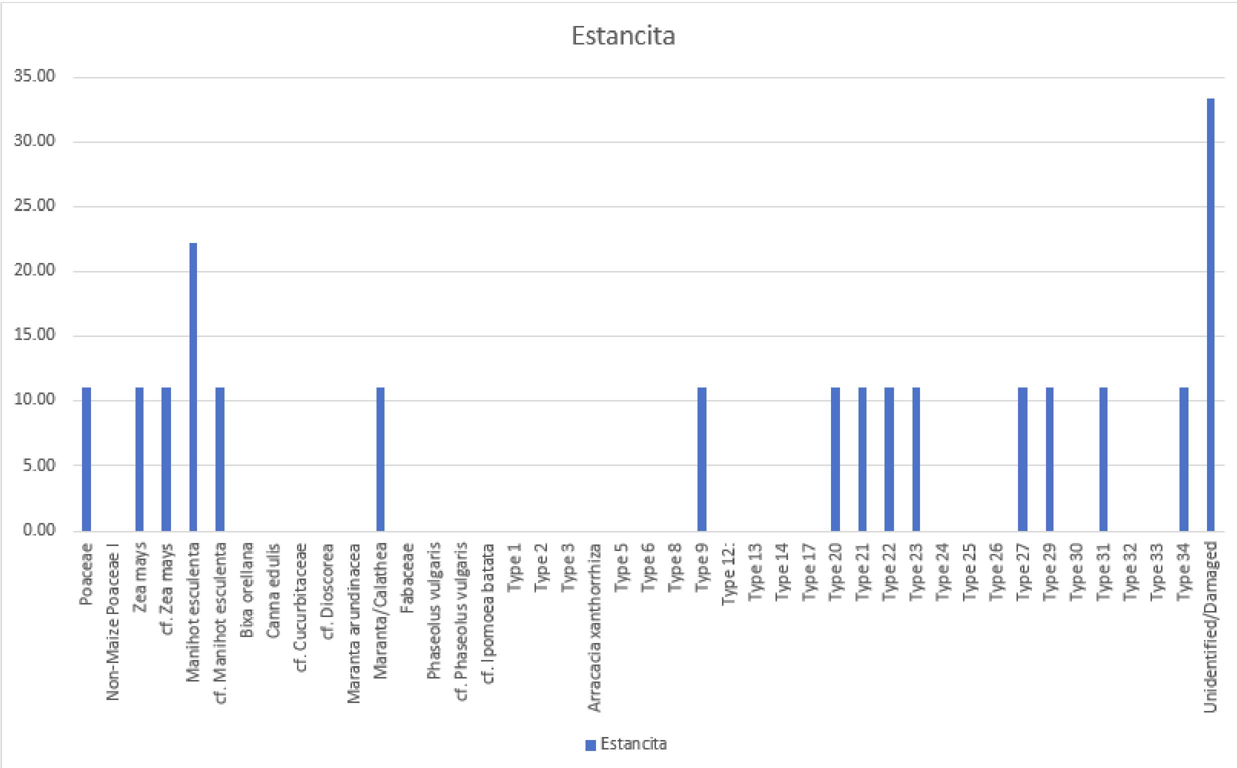


Figure 14 Percent presence of taxa in Estancita

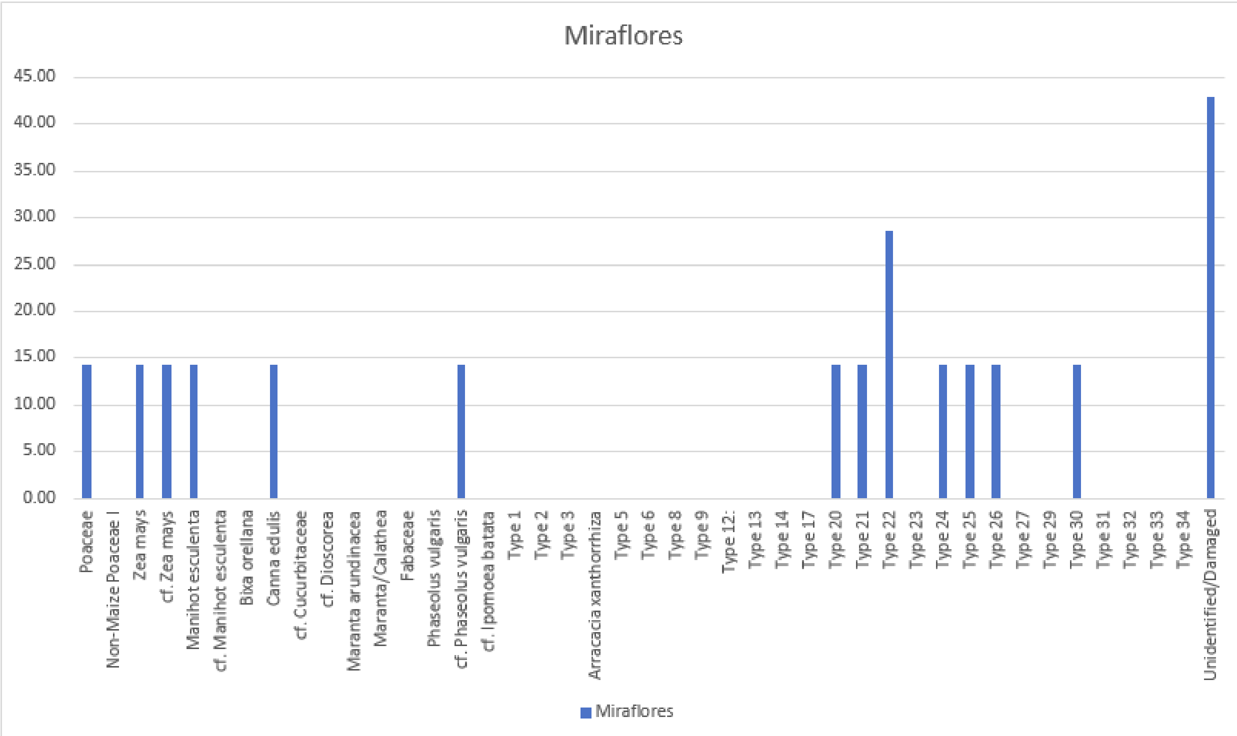


Figure 15 Percent presence of taxa in Miraflores

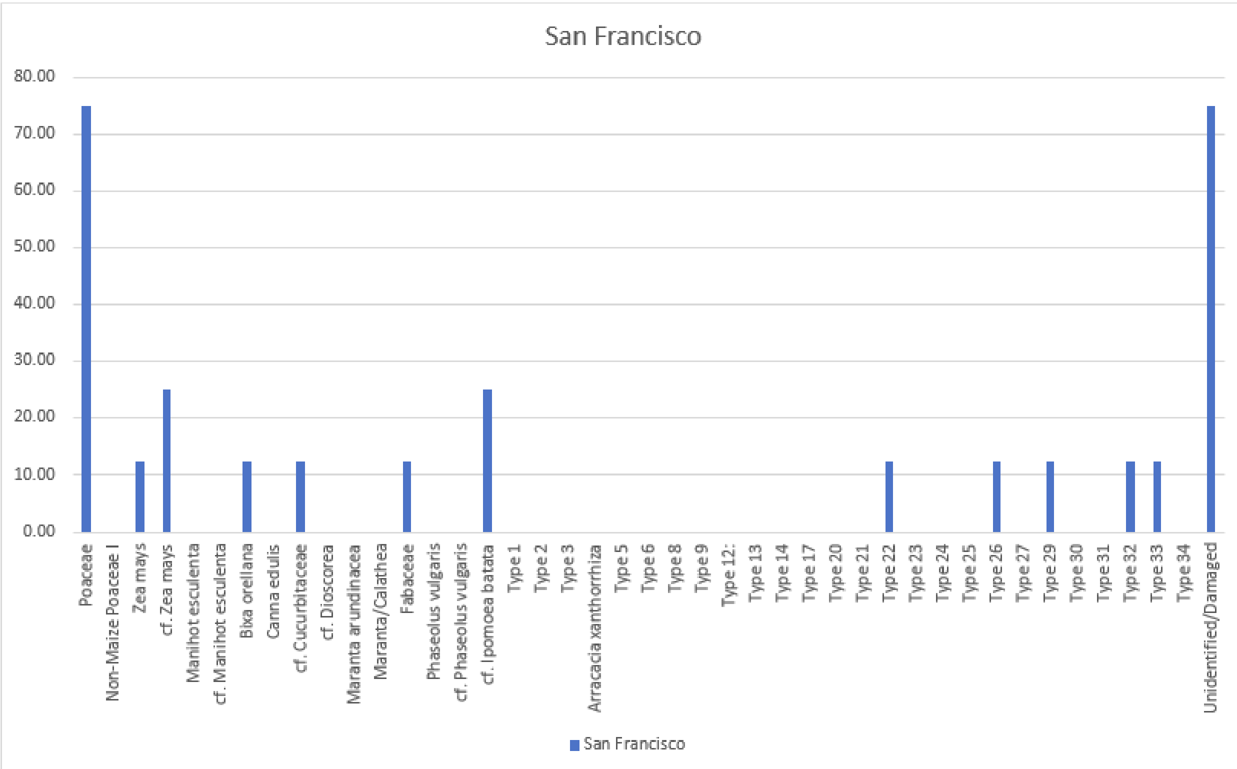


Figure 16 Percent presence of taxa in San Francisco

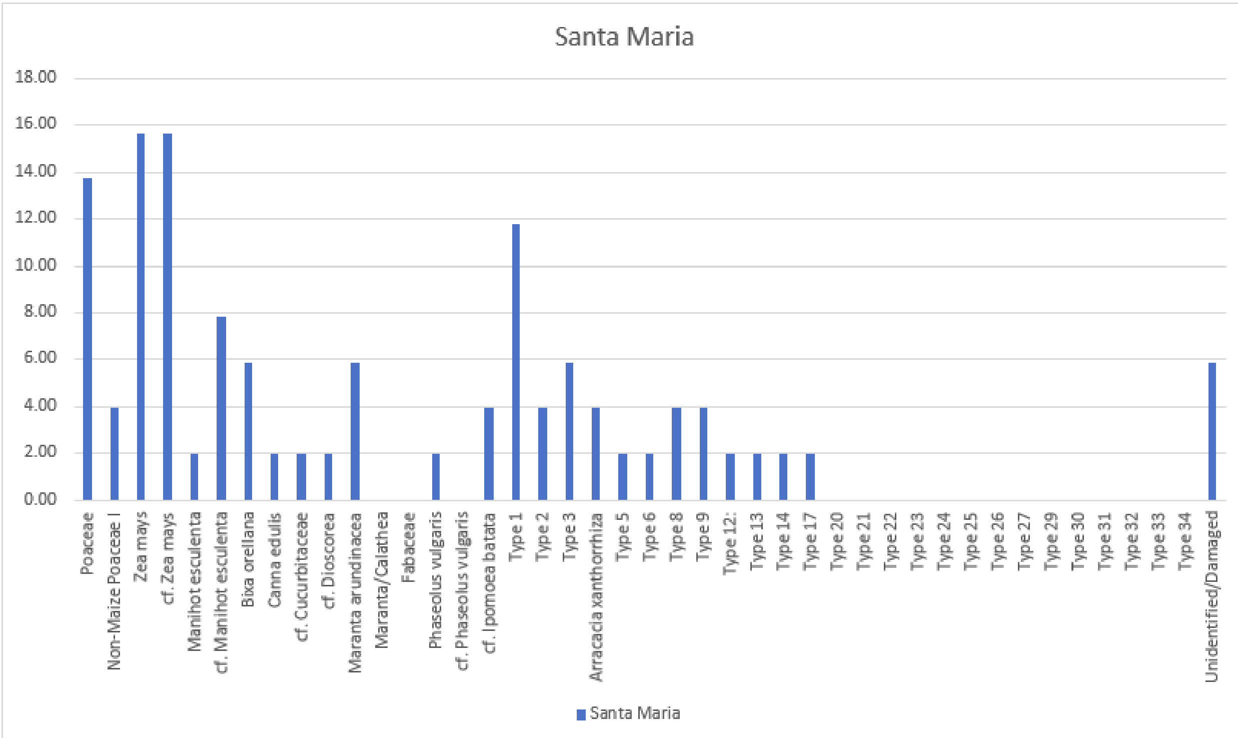


Figure 17 Percent presence of taxa in Santa Maria

UCF0021B

UCF0033B

UCF0046B

UCF0049B

UCF0048B

UCF0076B

Figure 18 Ceramic Graters in the assemblage.

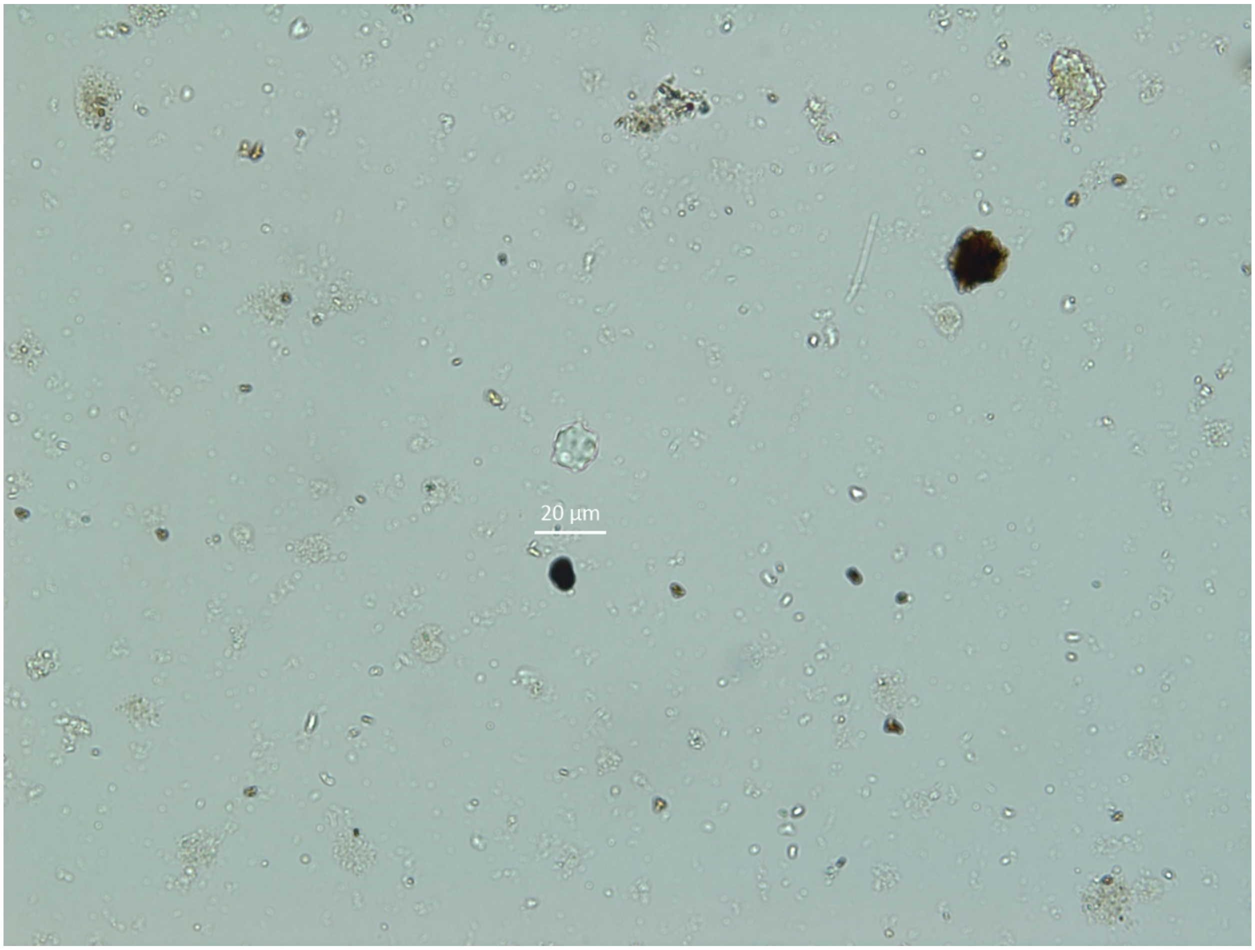


Figure 19 Arecaceae (palm) phytolith from sample UCF0025B.

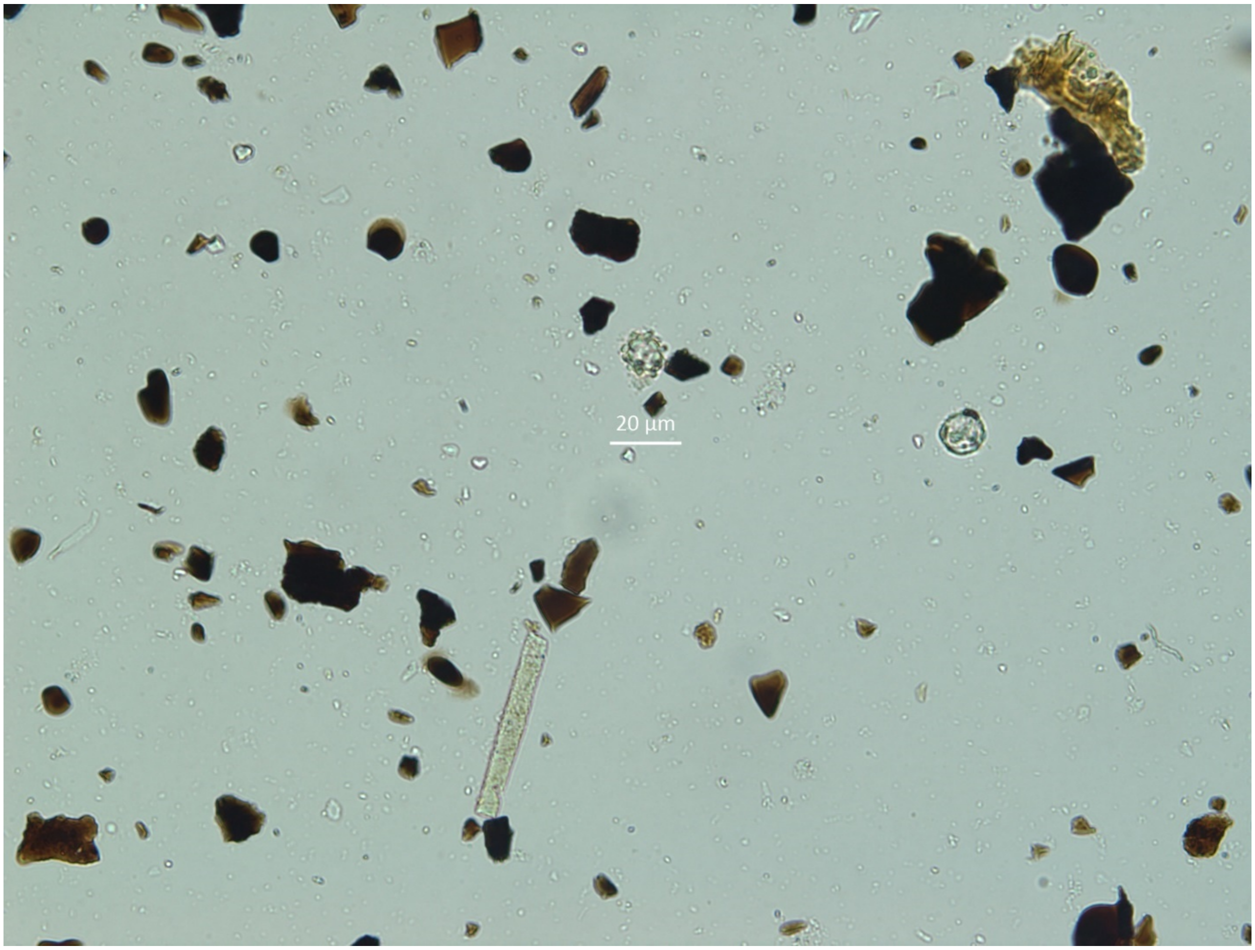


Figure 20 Marantaceae (arrowroot) phytolith from sample UCF0046B

APPENDIX B: LIST OF TABLES

Table 1 Starch Grain Taxa Present at Estancita

sample (UCF #)	**73**	**74**	**76**	**77**	**78**	**79**	**91**	**93**	**95**	**Abundance**	**Ubiquity**
Poaceae				1						1	1
Zea mays				18						18	1
cf. *Zea mays*				5						5	1
Manihot esculenta	1							1		2	2
cf. *Manihot esculenta*	2									2	1
Maranta arundinacea				1						1	1
Maranta/Calathea				1						1	1
Type 9							1			1	1
Type 20							1			1	1
Type 21				2						2	1
Type 22				1						1	1
Type 23							1			1	1
Type 27							1			1	1
Type 29	1									1	1
Type 31				1						1	1
Type 34				1						1	1
Unidentified/Damaged	1			2			2			5	3
Total:	5	0	0	33	0	0	6	1	0	45	

Table 2 Starch Grain Taxa Present at Miraflores

sample (UCF #)	97	98	99	100	102	103	106	Abundance	Ubiquity
Poaceae				1				1	1
Zea mays							1	1	1
cf. Zea mays					1			1	1
Manihot esculenta							1	1	1
Canna edulis							1	1	1
cf. Phaseolus vulgaris				1				1	1
Type 20					1			1	1
Type 21				1				1	1
Type 22	1			1				2	2
Type 24				1				1	1
Type 25			1					1	1
Type 26		1						1	1
Type 30				1				1	1
Unidentified/Damaged			1		1		1	3	3
Total	1	1	2	6	3	0	4	17	

Table 3 Starch Grain Taxa Present at San Francisco

sample (UCF #)	**80**	**81**	**82**	**83**	**87**	**88**	**89**	**90**	**Abundance**	**Ubiquity**
Poaceae		2	2	1		1	3	1	10	6
Zea mays				1					1	1
cf. Zea mays			1				2		3	2
Bixa orellana				1					1	1
cf. Cucurbitaceae				1					1	1
Fabaceae								1	1	1
cf. Ipomoea batata			1			1			2	2
Type 22				2					2	1
Type 26	1								1	1
Type 29		2							2	1
Type 32			3						3	1
Type 33			1						1	1
Unidentified/Damaged		1		1	0	1	4	2	9	6
Total:	1	5	8	7	0	3	9	4	37	8

Table 4 Starch Grain Taxa Present at Santa Maria

sample (UCF #)	**21B**	**22B**	**23B**	**24B**	**25B**	**26B**	**27B**	**28B**	**29B**	**30B**	**31B**	**32B**	**33B**	**34B**	**35B**	**36B**	**37B**	**38B**	**39B**	**40B**	**41B**	**42B**	**43B**	**44B**	**45B**	**46B**	**47B**	**48B**	**49B**	**50B**	**51B**	**Abundance**	**Ubiquity**
Poaceae					1		1											1				1					9	4		1		18	7
Non-Maize Poaceae I																	1	2														3	2
Zea mays	1	3									2															1	11	8	7	2		35	8
cf. Zea mays											1									1						1	2	1	1	1	1	9	8
Manihot esculenta				1																							1					2	2
cf. Manihot esculenta																			1								1	1		1		4	4
Bixa orellana																											2	1	1			4	3
Canna edulis																									1							1	1
cf. Cucurbitaceae											1																1					2	2
cf. Dioscorea spp.																											1					1	1
Maranta arundinacea																											2	1	1			4	3
Phaseolus vulgaris																					1											1	1
cf. Ipomoea batata																											3		1			4	2
Type 1	1										1								1					1		2	1					7	6
Type 2						1																								1		2	2
Type 3											1																3	2				6	3
Arracacia xanthorrhiza											1																		1			2	2
Type 5											1																					1	1
Type 6																	1															1	1
Type 8											1																		3			4	2
Type 9																											4	1				5	2
Type 12:																											2					2	1
Type 13																											1					1	1
Type 14																											1					1	1
Type 17																											5					5	1
Unidentified/Damaged																							1				2		2			5	3
Total:	2	3	0	1	1	1	1	0	0	0	9	0	0	0	0	0	2	3	2	1	1	1	1	1	1	4	52	19	17	6	1	130	

APPENDIX C: CERAMICS ANALYZED


UCF0021B


UCF0022B


UCF0023B


UCF0024B


UCF0025B


UCF0026B


UCF0027B


UCF0028B


UCF0029B


UCF0030B


UCF0031B


UCF0032B


UCF0033B


UCF0034B


UCF0035B


UCF0036B


UCF0037B


UCF0038B


UCF0039B


UCF0040B

Figure 21 Ceramics from excavation units in Santa Maria, excavated and sampled in 2018.

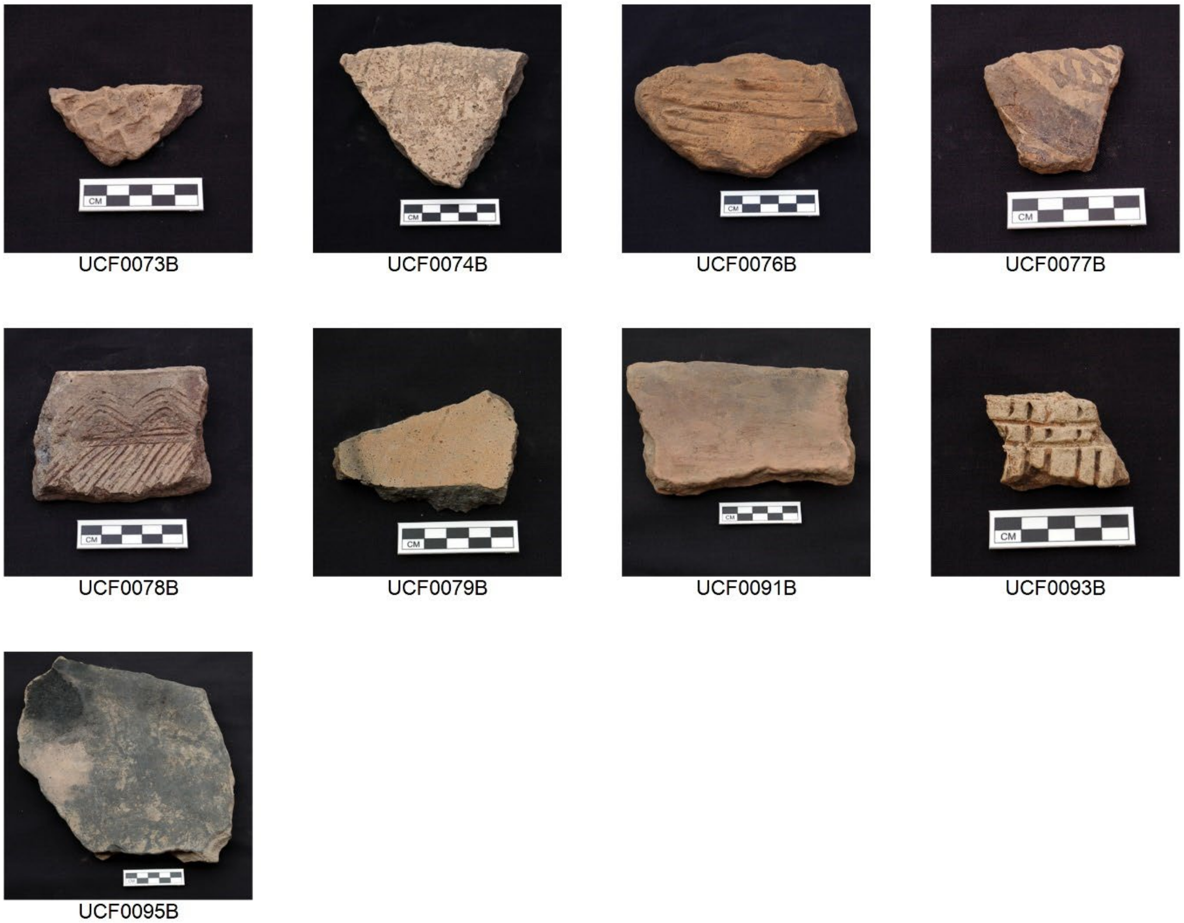


Figure 22 Ceramics from excavation units in Estancita, excavated in 2011 and 2012, sampled in 2019.

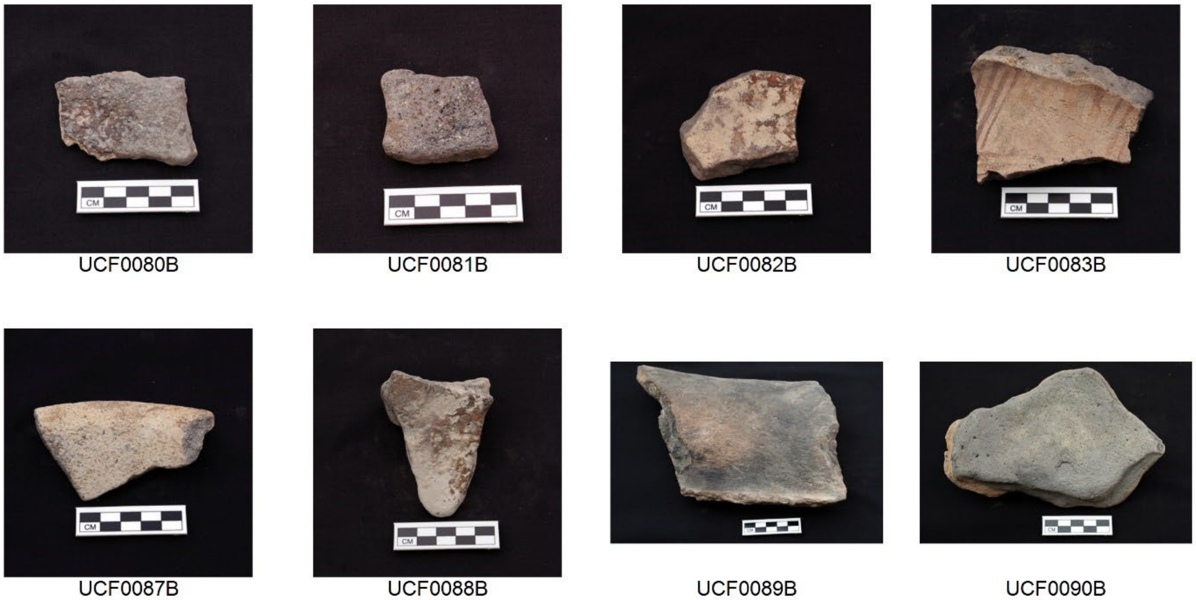


Figure 23 Ceramics from excavation units in San Francisco, excavated in 2013, sampled in 2019.

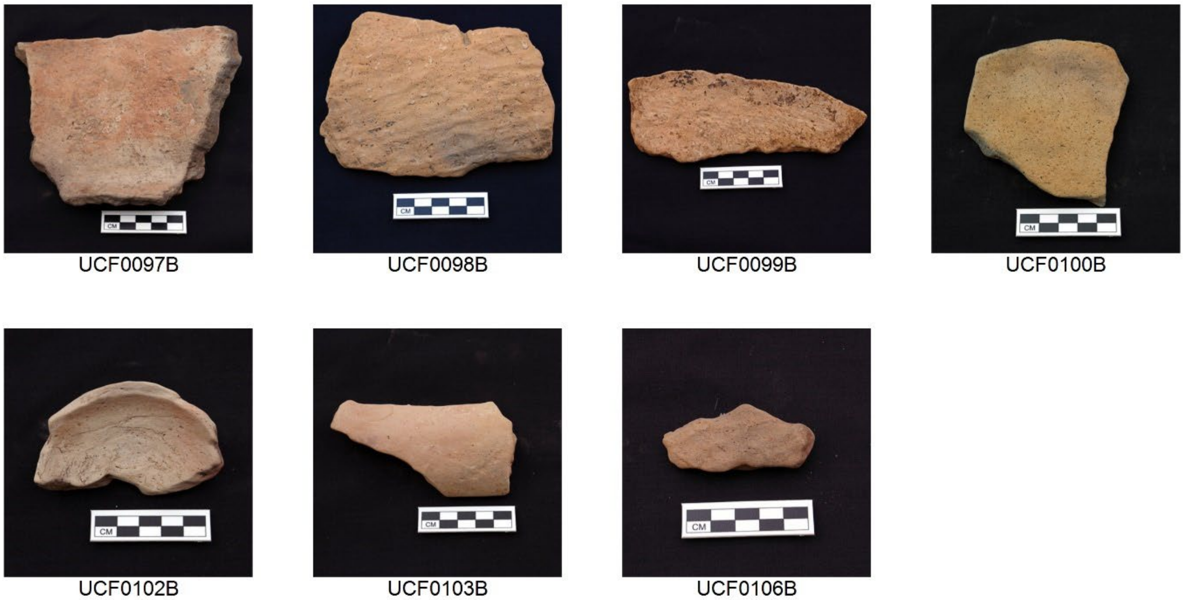
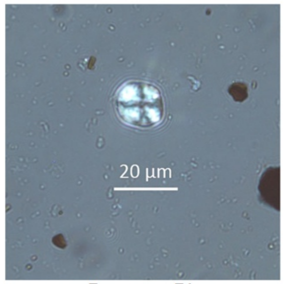


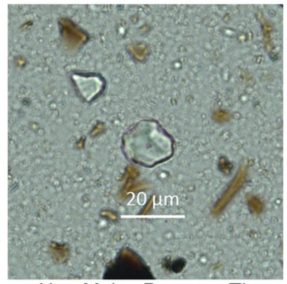
Figure 24 Ceramics from excavation units in Miraflores, excavated and sampled in 2019.

APPENDIX D: STARCH GRAINS IDENTIFIED TO TAXA

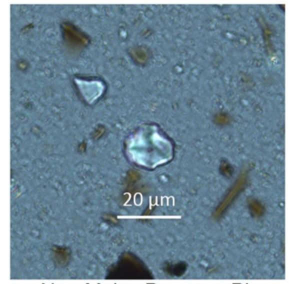
Poaceae TL



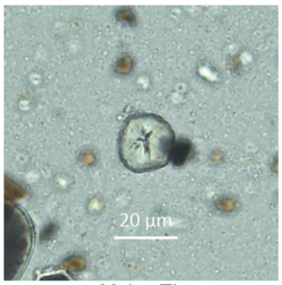
Poaceae PL



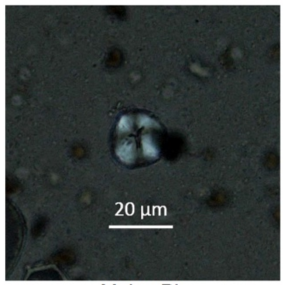
Non-Maize Poaceae TL



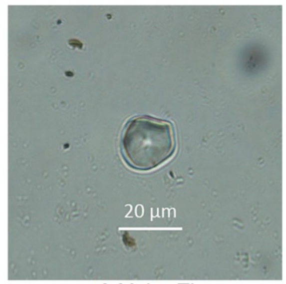
Non-Maize Poaceae PL



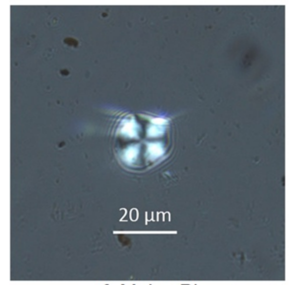
Maize TL



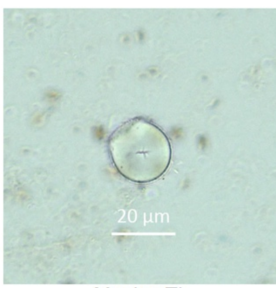
Maize PL



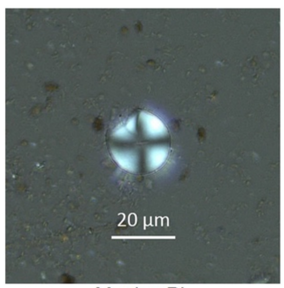
cf. Maize TL



cf. Maize PL

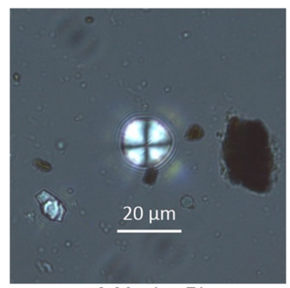


Manioc TL



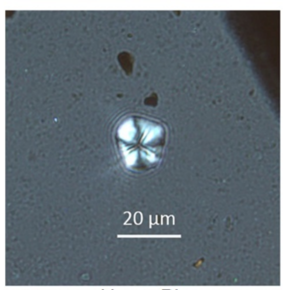
Manioc PL

cf. Manioc TL



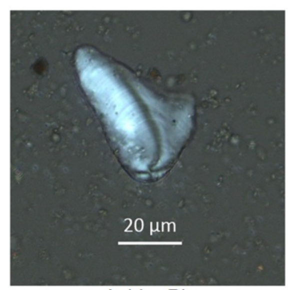
cf. Manioc PL

Urucu TL

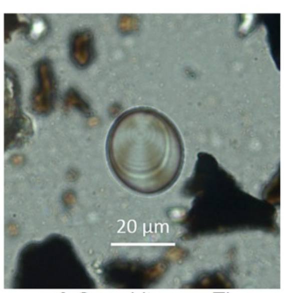


Urucu PL

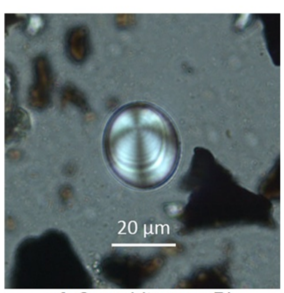
Achira TL



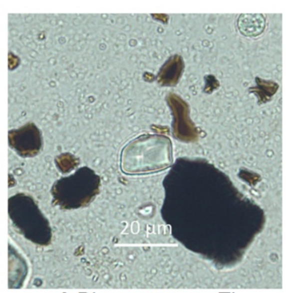
Achira PL



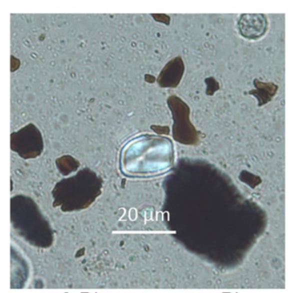
cf. Cucurbitaceae TL



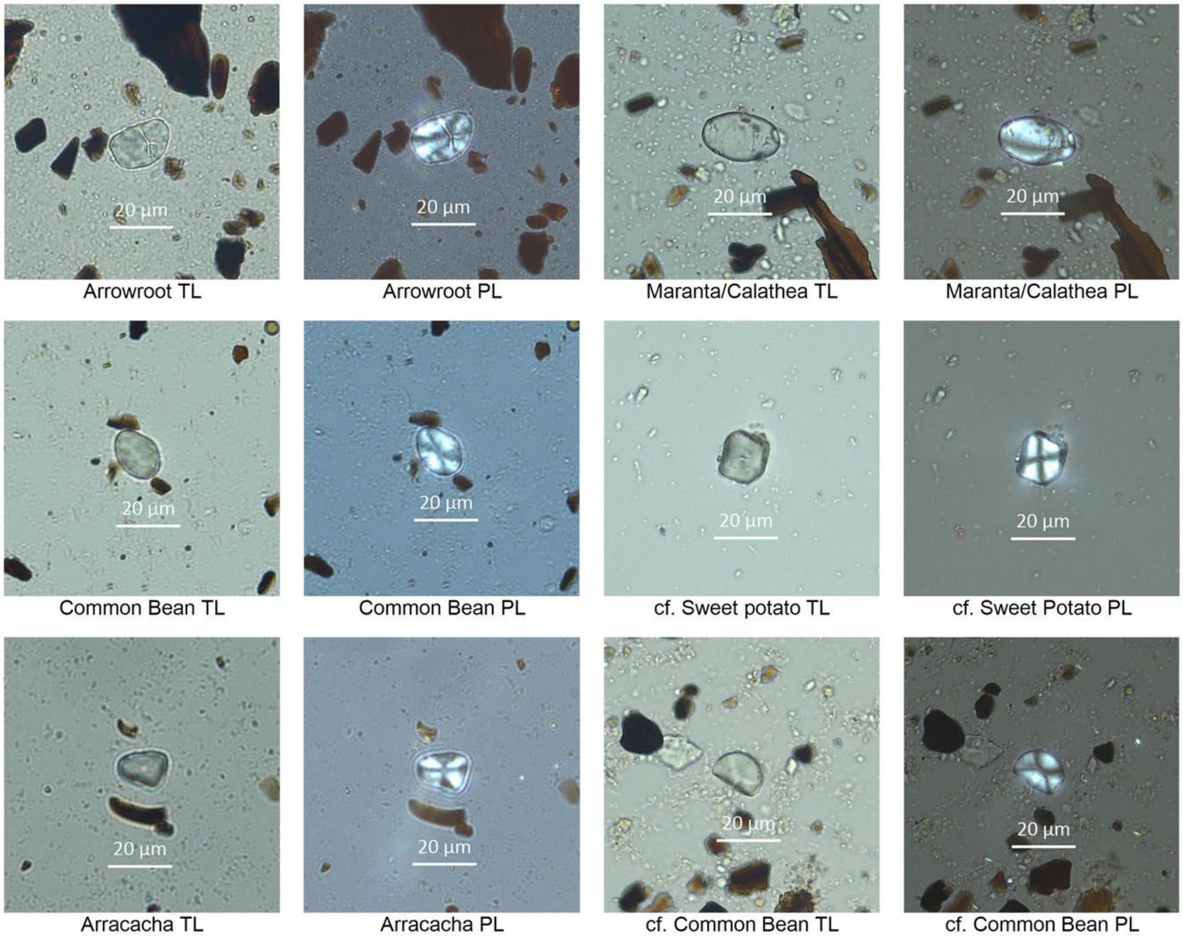
cf. Cucurbitaceae PL



cf. Dioscorea spp. TL



cf. Dioscorea spp. PL


20 µm
Arrowroot TL
Arrowroot PL
Maranta/Calathea TL
Maranta/Calathea PL
Common Bean TL
Common Bean PL
cf. Sweet potato TL
cf. Sweet Potato PL
Arracacha TL
Arracacha PL
cf. Common Bean TL
cf. Common Bean PL

APPENDIX E: STARCH GRAINS NOT IDENTIFIED TO TAXA

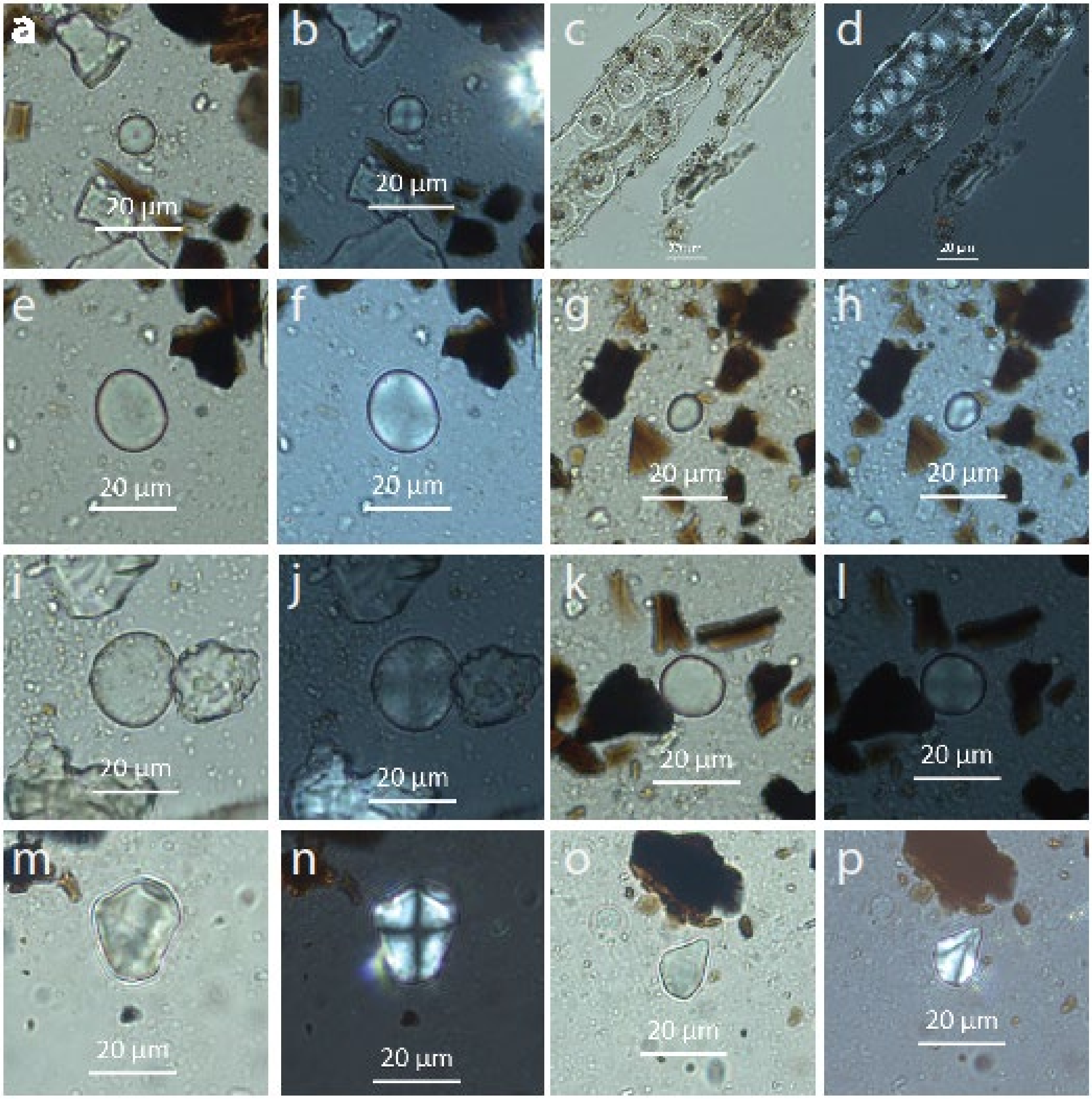


Figure 25 Unidentified Types pictured in transmitted light and polarized light. a,b.) Type 1; c,d.) Type 2; e,f.) Type 3; g,h.) Type 5; i,j.) Type 6; k,l.) Type 8; m,n.) Type 9; o,p.) Type 12.

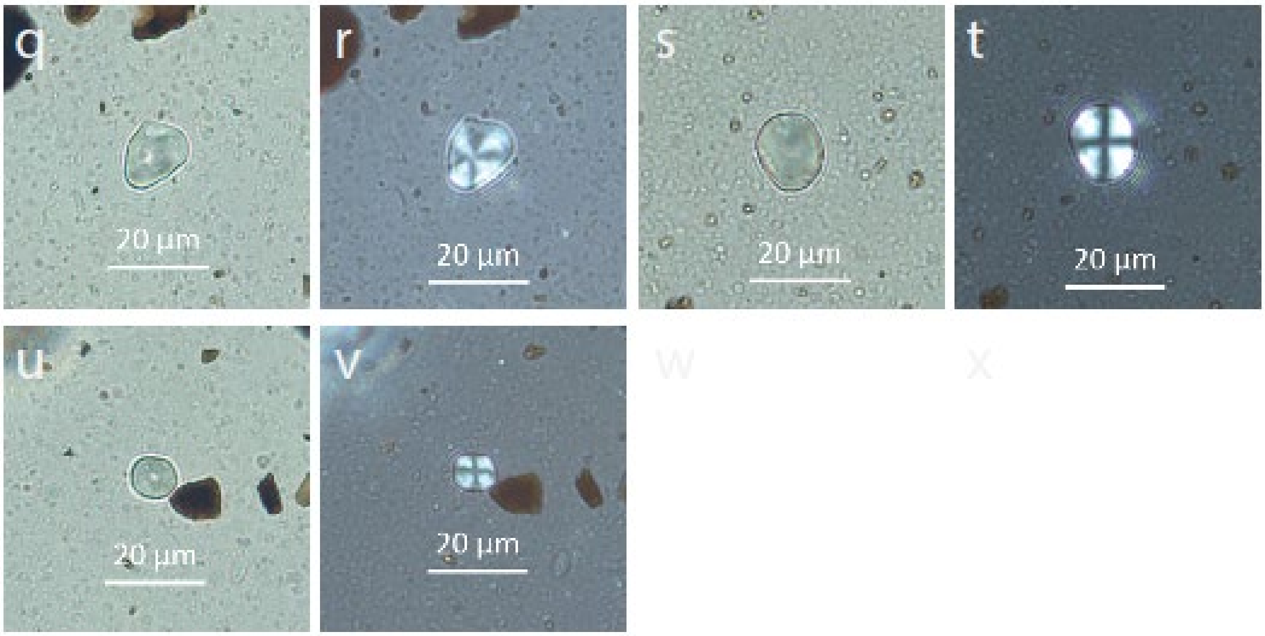


Figure 26 Unidentified Types pictured in transmitted light and polarized light. q,r.) Type 13l s,t.) Type 14; u,v.) Type 17.

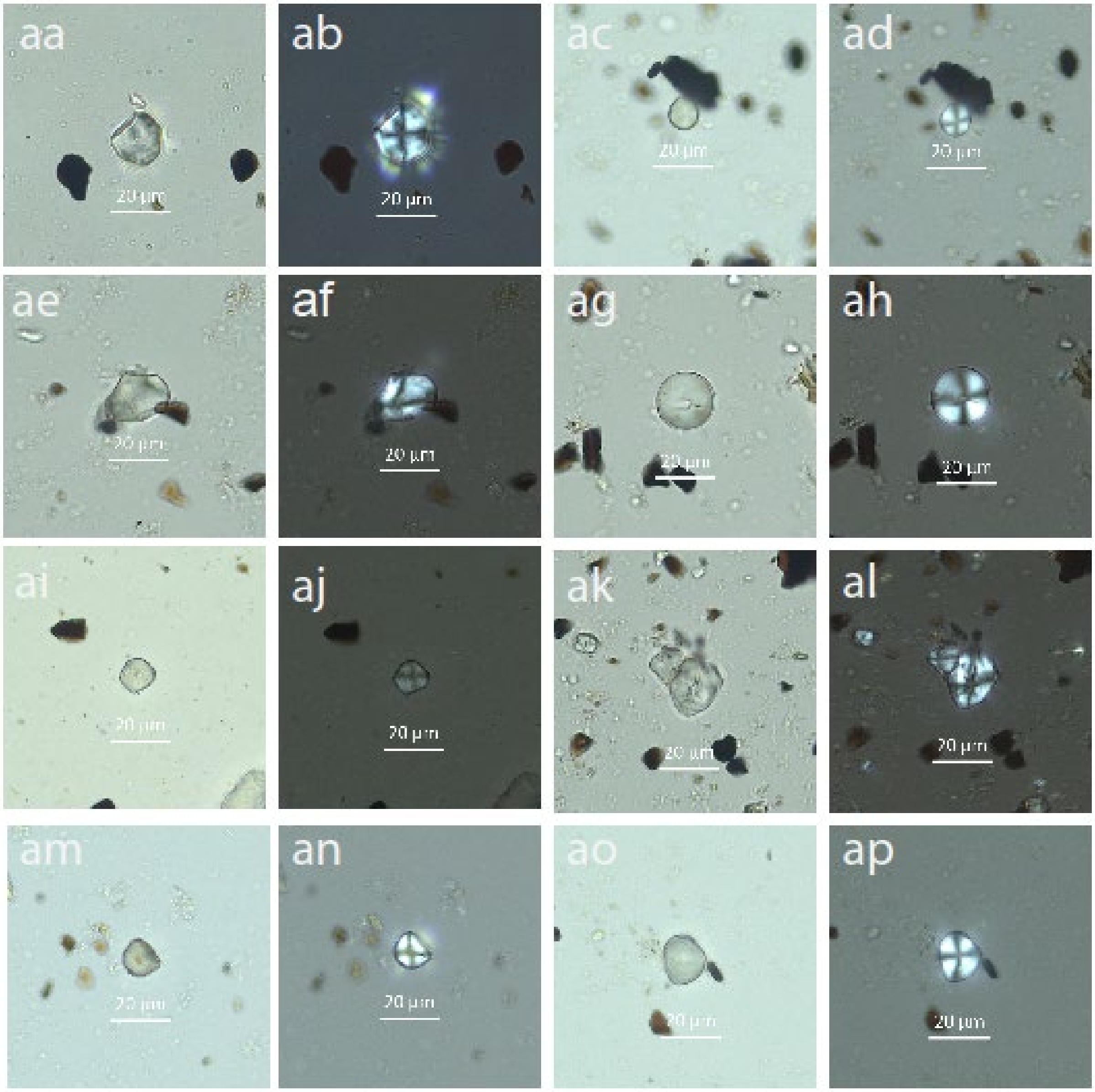


Figure 27 Unidentified types pictured in transmitted light and polarized light. aa,ab.) Type 19; ac,ad.) Type 20; ae,af.) Type 21; ag,ah.) Type 22; ai,aj.) Type 23; ak,al.) Type 24; am,an.) Type 25; ao,ap.) Type 26.

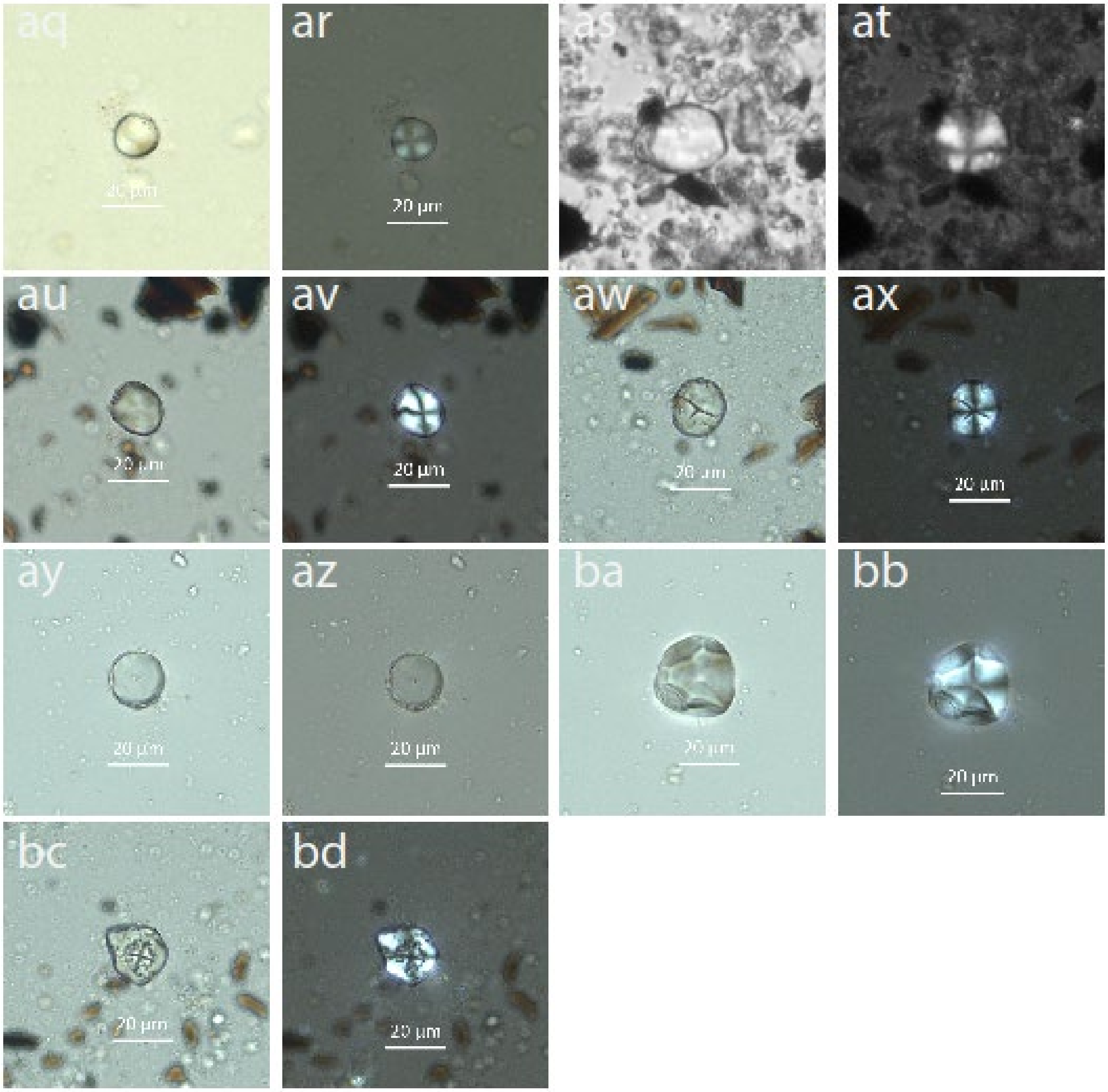


Figure 28 Unidentified types pictured in transmitted light and polarized light. aq,ar.) Type 27; as,at.) Type 29; au,av.) Type 30; aw,ax.) Type 31; ay,az.) Type 32; ba,bb.) Type 33; bc,bd.) Type 34.

APPENDIX F: ARTIFACT RESIDUE PROCESSING PROCEDURE

Paleoethnobotany and Environmental Archaeology Laboratory
Artifact Residue Processing Procedure

I. Deflocculation and Dispersion

Previously sonicated or scraped samples should be in 50 ml vials. If in water, fill vials with distilled H2O and centrifuge for 5 min at 3000 rpm. Decant supernatant, be carful not to disturb sample at the bottom of the tube.

To sample tubes, add ~15ml of 5% solution of sodium hexametaphospate. Replace caps on tubes and secure tightly. Vortex each tube for a few seconds.

Lay samples on the platform rotator. Set the machine to speed of 75, and timer for a minimum of two hours. Note: samples may sit longer, even overnight before continuing with following steps.

Rinse: Remove samples from platform shaker, fill tubes to full with dH2O. Centrifuge for 5 min at 3000 rpm. Decant. Repeat rinse.

II. Oxidation (optional)

If samples are particularly dirty, oxidation may help. Add 10 ml 6% H2O2 (hydrogen peroxide) solution to each sample. Let sit for 10 minutes. Then top off tubes with dH2O, vortex each sample for a few seconds. Rinse: Centrifuge for 5 minutes at 3000 rpm. Carefully decant. Repeat rinse 1 more times.

III. Dispersion part 2 (optional)

Equipment: 250 micron sieve, funnel stand

Samples can be sieved into fresh test tubes using a 250 micron sieve. After last rinse, add ~20 ml of dH2O to the sample. Vortex for a few second, then pour the sample through the sieve into a new tube. Reserve original tubes. Rinse original sample with distilled water through the sieve, and rinse the sieve, until new tube containing the sample is full. Be sure new tubes are also labelled with correct sample numbers

Centrifuge the samples for 5 min at 3000 rpm. Decant carefully.

III. Flotation

Samples should have as little supernatant as possible to avoid lowering the specific gravity of the heavy liquid. If necessary, centrifuge samples again to concentrate sample. Then very carefully pipette off the supernatant leaving as little water as possible, but without disturbing the sample at the bottom of the tube.

Prepare the heavy liquid as needed to 1.6 specific gravity:

LMT (lithium metatungstate) is in liquid solution at 2.95 sg. To make 100 ml of heavy liquid at 1.6 sg, combine 31 ml of LMT to 69 ml dH2O.

SPT (sodium polytungstate) Powdered. To make 1.6 sg, mix 74.1 g to 85.6 ml water.

Add ~10 ml of heavy liquid, 1.6 sg, to each sample. Cap and vortex. Centrifuge for 5 min at 3000 rpm. Decant supernatant containing floating starch grains into original labelled tubes. *This is the starch sample*. Append “ext” to tubes to indicate “extract.”

Rinsing samples of heavy liquid:

Adding water to sample reduces the specific gravity of the supernatant containing the starch. Fill the starch sample test tubes with dH2O until full. Cap and vortex for a few seconds. Centrifuge for 5 min at 3000 rpm.

Remove from centrifuge carefully and place in tube rack. 1) Carefully pipette off 15 ml of supernatant into beaker (we will save the diluted heavy liquid to recycle). Top off the tubes again with distilled water, vortex and centrifuge again, 5min/3000rpm. 2) Again in rack, pipette off approximately 30 ml supernatant, collect in beaker. Refill tubes with water, vortex and centrifuge again. 3) Again in rack, pipette off approximately 40 ml, be very careful not to disturb the pellet at the bottom of the tube. Refill with water, yet again, vortex and centrifuge. 4) Again with tubes in rack, pipette off 45 ml of supernatant. Top off again and vortex and centrifuge. 5) For the final time pipette off 45 ml being very careful not to disturb the sample.

Allow test tube to rest, capped and upright, for several hours, or, centrifuge for 2 min at 3000 rpm to settle the starches again at the be bottom of the tube. Samples are now ready for mounting.

APPENDIX G: BOTANICAL AND ETHNOBOTANICAL INDEX OF IDENTIFIED PLANTS

Apiaceae: the celery or carrot family

Arracacha (*Arracacia xanthorrhiza* Bancr.) was identified in this study, which belongs to Apiaceae. Arracacha is a stout perennial herb (NRC 1989:54) and a cultivated root native to South America. Its wild ancestor is unknown. It was once believed that arracacha needed short days and higher elevation to grow, but the crop can be grown from 600 meters to 3200 meters above sea level. Stems and leaves usually grow up to 1 meter in height, and roots can grow 5-25 centimeters long and 2-6 centimeters thick (NRC 1989:54). The growing season is typically 300-400 days from planting (NRC 1989:50). Arracacha gives off a similar aroma to its botanical relatives, carrots and celery, but is often eaten similarly to potato. It can be boiled, baked, fried, or added to stews. Two starch grains were identified as arracacha.

Arecaceae: the palm family

Palms are ubiquitous in Amazonia with over 150 species native to the region (Smith 2015:1). Their economic importance is illustrated by the high number of palm species that have at least one recorded use. Palm woods can be used for fabrication of houses or other structures, palm fronds for thatch roofing or material for weaving hammocks, and the fruits of various palm species are a major component of diet and cuisine in Amazonia. Several palm species are associated with Amazonian Dark Earth (ADE), an anthropogenic soil created by indigenous peoples hundreds or perhaps thousands of years ago (Woods and Denevan 2009).

Bixaceae: the achiote family

Bixa Orellana L. Also called *achiote*, *annatto*, or *urucu.* Urucu is a cultivated shrub often used for its colorful seeds that produce a strong red pigment. This pigment is added to color

foods and for bodily decoration. The foliage can also be used for skin problems and to treat hepatitis (Duke and Vasquez 1994:31). The Chácobo Indians cook the seeds in butter (Boom 1996). Kayapo people massage the stomachs of women in labor with the leaves (Duke and Vasquez 1994). It is also thought that the pigment from this plant is an insect repellant (Cardenas 1969:289). Five starch grains were identified as urucu.

Cannaceae: the achira family

Achira (*Canna edulis* Ker. Grawl.) can grow well in a variety of climates. The edible rhizomes of achira can be harvested starting about six months after planting, although most plants are harvested 8-10 months after planting. It was likely one of the first plant domesticated in the Andean region (NRC 1989:27). Some achira is cooked and eaten, but it is mostly used for starch (NRC1989:27). Achira starch is made by shredding and grating the rhizome, then the grated pulp is dumped in water and separated from the heavy starch by decanting. The starch is easily digestible, which is an important feature for infants and elderly individuals (NRC 1989:28). Two starch grains were identified as achira.

Convolvulaceae: the bindweed or morning glory family

Convolvulaceae is a large family that includes 60 genera and 1700 species (Mabberley 1987). Several of these species are of economic importance, especially *Ipomoea batatas* (L.) Lam, or sweet potato. In Latin America it is also called *camote, apichu* (Quechua), or *batata dulce.* Sweet potato is an edible, cultivated tuber. While its main role is as a food source, sweet potato has several uses, including as an aphrodisiac, bactericide, fungicide, and laxative (Duke and Vasquez 1994:94). Plant stems typically grow about 9 inches tall but vines spread between

8-10 feet wide. Sweet potato is low maintenance, but needs full sun and prefers sandy soils. Sweet potatoes can be harvested 3 to 5 months after planting (Cardenas 1989). Six starch grains were tentatively identified as sweet potato.

Cucurbitaceae: the squash family

The Cucurbitaceae family is a large plant family composed of economically valuable plants mainly utilized as food or medicine (Baloglu 2018:413). Most cucurbits are herbaceous vines adapted to warm climates (Schaffer and Paris 2016). Cucurbits, of the genus *Cucurbita* include many plants of economic importance. These include: figleaf gourd (*Curbita ficifolia* Bouché), pumpkin (*Cucurbita maxima* Duchesne), butternut squash (*Cucurbita moschata* Duchesne), and the bottle gourd (*Lageneria siceraria* Molina Standl.). These squashes are typically eaten raw or roasted. All have edible seeds. Bottle gourd is not usually eaten, but is important for its use as a serving vessel. Métraux (1942:74) reports that *chicha* was often served in gourds. Three starch grains tentatively identified to Cucurbitaceae were recorded on samples from Santa Maria and San Francisco, but they could not be identified to species-level.

Cyperaceae: the sedge family

Cyperaceae consists of monocotyledonous plants that typically grow near water. Sedges would be plentiful during the summer months in Bolivia when the savannas flood and along riverbanks and arroyos. Phytoliths identified to the Cyperaceae family were commonly encountered throughout the assemblage, and are environmental indicators. Several species of *Cyperus* have edible rhizomes that could have been used as a food source (Van Den Eynden et al. 2003).

Dioscoreaceae: the yam family

Dioscoreaceae includes over 600 species of tropical rhizomatous or tuberous perennials (Huber 1998). Cultivated species in Bolivia include: *Dioscorea alata* L. (chami papa), *Dioscorea bulbifera* L. (huayra papa), *Dioscorea decorticans* Presl. (Macaquiño), and *Dioscorea trifida* L. (Sacha papa). Several of these species are also called air potatoes or wild potatoes. The tubers of *Dioscorea spp.* are consumed in lowland Bolivia, several parts of the plant are also used for medicinal purposes. The raw tubers are often crushed into a poultice that can be applied to boils or inflammations, but are also used to heal cancer, dysentery, fever, goiter, hernias, piles, sores, syphilis, gonorrhea, and leprosy (Duke and Vasquez 1994:66). *Dioscorea decorticans* is cultivated as an ornamental plant (Duke and Vasquez 1994:67). One starch grain was tentatively identified to *Dioscorea spp.*

Euphorbiaceae: the spurge family

Manioc (*Manihot esculenta* Crantz.), a root crop of significant importance since its domestication. Also called *cassava, yuca, mandioca, aypi,* and *huacamote*, manioc is a cultivated root and a major source of carbohydrates for people in the Neotropics. Manioc is a woody shrub that grows between 1 to 4 meters (Isendahl 2011). The roots of manioc plants can be harvested within 8 to 10 months after planting, although it can be left in the ground up to 24 months. Manioc roots vary in size but can grow up to 1 meter in length and weigh about 2 kilograms (Isendahl 2011). Sweet and bitter varieties of manioc exist. Bitter varieties contain concentrations of cyanogenic glucosides that are poisonous, and must be prepared by grinding, sieving, or pressing the cyanic juice out of the root (Ugent et al. 1986:78). Sweet varieties require no further processing other than common cooking practices such as boiling or roasting.

Eleven starch grains were identified as manioc. Current genomic evidence indicates that manioc was domesticated in the Southwestern Amazon, in northern Matto Grasso, Rondônia and Acre states, adjacent to northern Bolivia (Clement et al. 2010:77).

Fabaceae: the bean family

Fabaceae is a large plant family, that includes beans and legumes. Common bean, or "frijol," (*Phaseolus vulgaris* L.) was identified in the assemblage. Beans are cultivated legumes. Several species of bean are found in the Amazon, including: common bean (*Phaseolus vulgaris)*, jackbean (*Canavalia ensiformis* L.*)*, ice cream bean *(Inga spp.)*, and others. Beans were grown along the riverbanks in Mojos (Métraux 1942). Although beans were commonly eaten in the past, they are rarely consumed in Bolivia today (Cardenas 1969). Two starch grains were identified as common bean, and one starch grains identified to Fabaceae.

Marantaceae: the arrowroot family

Marantaceae is a rhizomatous family that includes over 550 species, about 300 of which belong to the genera *Calathea,* and about 30 of which belong to the genera *Maranta* (Pearsall 2014:205). Marantaceae includes several crops of economic importance, including the edible rhizome arrowroot (*Maranta arundinacea* L.). It is also called "shimi pampana," or "jamachipeke." Arrowroot is a cultivated rhizome that is edible. Can be used to make starch and love potions (Duke and Vasquez 1994). Although detailed genomic information about its domestication is lacking, it is believed that arrowroot was likely one of the first rhizomes domesticated in South America (Pearsall 2014). Cardenas (1969:79) reports the rhizomes in the Yungas of La Paz are small, only measuring 2 to 5 centimeters in length, although they can grow

up to 10 centimeters. Today arrowroot is rarely eaten, but remains economically important as a flour, which is exported globally. Arrowroot starch is useful for feeding infants, the elderly, and those with ailments because it is easy to digest (Cardenas 1969:79). Leren (*Calathea allouia* (Aubl.) Lindl.) is an herbaceous perennial that can grow between 0.75 and 1.5 meters tall, and small edible tubers that reach lengths between 3.5 centimeters to 6 centimeters (Pearsall 2014). Currently, leren flowers and leaves are commonly found in markets in Guatemala; the flowers are cooked and eaten, and the leaves are used to wrap foods (Pearsall 2014:210). Both arrowroot and leren have a long history in Central and South America, and archaeological evidence indicates that these two root/tuber crops may have been domesticated before other root crops which later overshadowed them in importance (Pearsall 2014:204). Five starch grains were identified as arrowroot, and one starch grain was identified as Maranta/Calathea.

Poaceae: the grass family

Poaceae includes over 10,000 species, including several important economic crops (GPWG 2001). *Zea mays* L., also known as *maize*, *maíz*, or *corn*, is one of the most important economic crops in the New World. In Mojos, maize kernels were ground and boiled, fermenting into beer, called *chicha.* Block (1994:23) indicates that maize was eaten on special occasions, but does not specify how it was eaten. Duke and Vasquez (1994) note that besides its uses as a food source, maize can be added to a poultice for fever. Both Poaceae and maize were abundant and ubiquitous throughout the assemblage. Seventy-three starch grains were identified as maize, and 30 starch grains were identified to Poaceae. Three starch grains identified as *Setaria spp.* were also recovered. *Setaria spp.* is considered a forage grass today (Duke and Vasquez 1994).

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