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TIME AND COMPLEXITY IN HISTORICAL ECOLOGY

STUDIES IN THE NEOTROPICAL LOWLANDS



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THE HISTORICAL ECOLOGY OF A COMPLEX LANDSCAPE IN BOLIVIA

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IDEAL STUDIES OF the interface between people and the environment involve collaboration among scholars from diverse backgrounds to understand how complex landscapes came to be over periods of hundreds, if not thousands, of years. Historical ecological research displays such interdisciplinary underpinnings because it is situated at the interface and overlap of the social sciences, natural sciences, and humanities in the programmatic study of how the typically complex interactions of nature and culture have become historical and cultural landscapes. Such diversity is in evidence with regard to the scholars who have contributed to this volume, from archaeology, ethnography, ethnobotany, genetics, geography, biology, and ecology.

The historical ecology applied in this chapter underscores how to read physical signatures and material patterning, including similarity, disjuncture, and anomaly, embedded in a cultural landscape in the Bolivian Amazon. On heterogeneous landscapes of considerable age, these signatures may form a complex palimpsest, a vertical or horizontal layering or stratigraphy of signatures and patterning etched on the surface of the earth, deep into the soil (Erickson, chapter 8, this volume; or, as in the case of Amazonian Dark Earth, Glaser and Woods 2004; Lehmann et al. 2003), or above the surface fixed in the layers of vegetation extending up through the emergent canopy (Balée 1989, 1994; Campbell et al., chapter 1, this volume). The multiple scales of study range from microorganisms and soil chemistry (in the case of Amazonian Dark Earth), stratigraphic profiles of anthropogenic soil horizons, to rearrangements of local hydrology, drainage, and water tables to the structure and physiognomy of the living forest and landscape more generally—that is, to the terrestrial and aquatic plants and animals living below, on, and above the earth's surface (chapters 2, 4, and 6, this volume).

This particular historical ecological study is of a relatively medium-scale cultural landscape of pre-Columbian earthworks that consists of mounds, causeways, canals, ponds, and the present vegetation growing on them in the Llanos de Mojos region of the Bolivian Amazon. The investigation involved an ethnobotanist/ethnographer (Balee), a team of archaeologists (Erickson, Bolivian coinvestigator Wilma Winkler, ethnographer Kay Candler, and then-students John Walker and Marcello Canuto), together with a group of indigenous Siriono. It soon became apparent to us that the ethnobotanist, archaeologist, and native person approach the same cultural landscape from different perspectives. In reading and interpreting an anthropogenic landscape, the ethnobotanist tends to look upward and then sees a cornucopia of plants and their myriad structures, together with plant parts: bole, branch, crown, bark, leaves, fruits, flowers, and seeds. In contrast, the archaeologist has a knack for staring at the ground, kicking leaf litter to expose bare ground, evaluating the topography of the surface, and rooting around under the roots of tree falls searching for pottery fragments, stone tool debris, charcoal, and any other signs of previous human activity. Although both are practicing science in the present, the archaeologist is thinking of the distant past and the ethnobotanist is contemplating the present and somewhat more recent past. When an ethnobotanist and archaeologist work together seeking to merge their interpretations of the same landscape into a holistic framework that will betoken an enriched and deeper, more complex notion of the past, sparks fly, debate ensues, and significant new insights gradually emerge as one scholar learns from the other. Their hosts, the Siriono, however, seem to be scanning the ground and sky in search of spoor left by the animals that they prize as game, traces of overgrown trails, and evidence of past campsites and farmsteads marking good agricultural soils and memories that link the anthropogenic past and present in a practical way into their remarkable landscape mosaic of forest, savanna, and wetland.

Erickson and Balee met on the streets of the tropical Bolivian city of Trinidad in 1994. Erickson and his Bolivian-U.S. team had been studying the cultural landscapes of earthworks and settlements since 1990 (Erickson, chapter 8, this volume). Balee had been investigating the economic plants, soils, languages, and management practices of Tupf-Cuaranf-speaking peoples in the Amazon basin for more than ten years (Balee 1994). After finding out that Erickson was an archaeologist, Balee invited Erickson and his team to meet authorities of the Siriono Indigenous Territory, where Balee had been collecting data on a plot deep under the canopy forest intermittently over the previous two years. What made this invitation interesting for Erickson the archaeologist was that the forest thrived on a *loma* or large, earthen, pre-Columbian settlement mound.¹ Balee, the ethnobotanist, needed long-term historical context in order to understand the human activities that structured the plant communities growing on the mound. A meeting was arranged with the Siriono community in Ibiato

(also located on a large pre-Columbian settlement mound). Some 80 people attended the meeting, and after four hours of public presentation, debate, and deliberation the Siriono gave them permission to map and study the mound. Aside from children and those not directly involved in the study, 10 adult Siriono worked with us at the Ibibate Mound Complex.

What makes the Ibibate Mound Complex an excellent case study in historical ecology and for collaboration between an archaeologist and ethnographer? The ethnobotanist is the medium-scale context of a heterogeneous cultural landscape well defined in time and space. We focus on comparing the biodiversity of two distinct environments (mound versus pampa) formed by different regimes of human activities. Differences in species composition and diversity demonstrate different degrees and scales of past human transformation and management of the Ibibate Mound Complex and surrounding anthropogenic landscape. Mapping and chronological dating provide high-definition spatial boundaries of the complex and heterogeneous topography of anthropogenic earthworks and natural geomorphological features of the landscape.

MOUNDS AND OTHER PRE-COLUMBIAN EARTHWORKS OF THE BOLIVIAN AMAZON

The Llanos de Mojos (Department of the Beni, Bolivia) is a prominent example of an anthropogenic landscape covered with earthworks such as raised fields, causeways, canals, reservoirs, fish weirs, and mounds (Erickson, chapter 8, this volume). Large artificial earthen mounds, locally referred to as *lomas*, are common in the Bolivian Amazon, especially near the city of Trinidad and along the Marnore, Ibare, and Apere rivers and their tributaries (Denevan 1966; Erickson 2000C). In addition, smaller mounds and related forest islands cover the savannas and gallery forests of the Llanos de Mojos (Department of the Beni) (Erickson 2000C; Langstroth 1996). Archaeological studies show that mounds were originally used as settlements and for the burial of the dead. Some may have had important ritual functions as ceremonial and political centers. Mounds are important motifs in indigenous mythology of the region (Riester 1976) and local public imagination (Pinto Parada 1987).² Although most are neglected and overgrown with vegetation, some mounds support modern ranches, homesteads, fields, and even entire communities and a military base. Mounds have been the traditional focus of archaeologists since the first excavations of Erland Nordenskiöld (1910, 1913, 1924) at the turn of the twentieth century. Since that time and until the present, numerous national and international projects have explored mounds through survey, mapping, and excavation. Stig Rydén (1941, 1964) and Wanda Hanke (1957) reported pottery found on mounds in the Casarabe area. Geographer William Denevan (1966, 2000) was the first to

provide a detailed inventory of mounds and other earthworks of the region. Research by local scholars such as Kenneth Lee (1979), Rodolfo Pinto Parada (1987), Mario Vilca, Ricardo Bottega, and others has raised public awareness of these features. The Argentinean-Bolivian team of Bernardo Dougherty, Horacio Calandra, Victor Bustos, and Juan Faldin surveyed, mapped, and excavated mounds in the Trinidad region during the late 1970s and 1980s (Bustos 1978a, 1978b, 1978c, 1978d; Dougherty and Calandra 1981, 1981-82, 1984, 1985; Faldin 1984), along with other scholars (Fernandez Distel 1987a; Pia 1983; Verjarano Carranza 1991). More recently, archaeologist Heiko Primers and his German-Bolivian team has mapped and meticulously excavated the Mendoza Mound near Casarabe (Primers 2000, 2001, 2002a, 2002b). Robert Langstroth's (1996) study of the vegetation, soils, and formation of mounds and forest islands is a landmark study. The U.S.-Bolivian team directed by Clark Erickson and Wilma Winkler has also reported mounds in addition to raised fields, fish weirs, causeways, and canals (Erickson 1980, 1995, 2000a, 2000b, 2000c, 2001, and chapter 8, this volume; Erickson et al. 1991; Erickson, Candler, Walker et al. 1993; Erickson, Candler, Winkler et al. 1993; Erickson, Winkler, and Candler 1997; Walker 2004).

ARCHAEOLOGICAL INVESTIGATIONS OF THE IBIBATE MOUND COMPLEX

The Ibibate Mound Complex is located in the Siriono Indigenous Territory (Territorio Indígena de los Siriono), Canton of San Javier, Cercado Province, Department of the Beni, Bolivia ($14^{\circ}48'14''.47''$ S/ $64^{\circ}24'30.53''$ W) (figure 7.1). The complex, made up of two large earthen mounds (lomas) referred to here as Mound 1 and Mound 2, are major anthropogenic topographic features on the local landscape. Today, the mounds are covered with old fallow forest. Community members have periodically used the mounds for swidden fields, gardens, temporary hunting camps, agroforestry, and ephemeral farmsteads over the past 60 years, although the evidence of these activities is subtle, and recent disturbance was minimal in the area of the vegetation studies, partly because certain long-lived, economic trees grow on the mound and only there, according to Siriono informants themselves, so that to practice slash and burn at such a locale would destroy the resource. Associated earthworks include barrow pits, ponds (*pozas*), causeways (*iteraplenes*, *calzadas*), and canals (*canales*, *zanjas*). Two impressive straight causeways with adjacent canals cross the savanna (pampa) and wetlands to the west of the forested mound complex. In the Siriono language, *ibi* means "earth" (*junto alpie, tierra, planta*) (Coimbra Sanz 1980:8) and *ebate* means "high" or "tall" (*alto*) (Monje Roca 1981:51), so that, combined, Ibibate translates as "high earth mound."³ Erickson's research

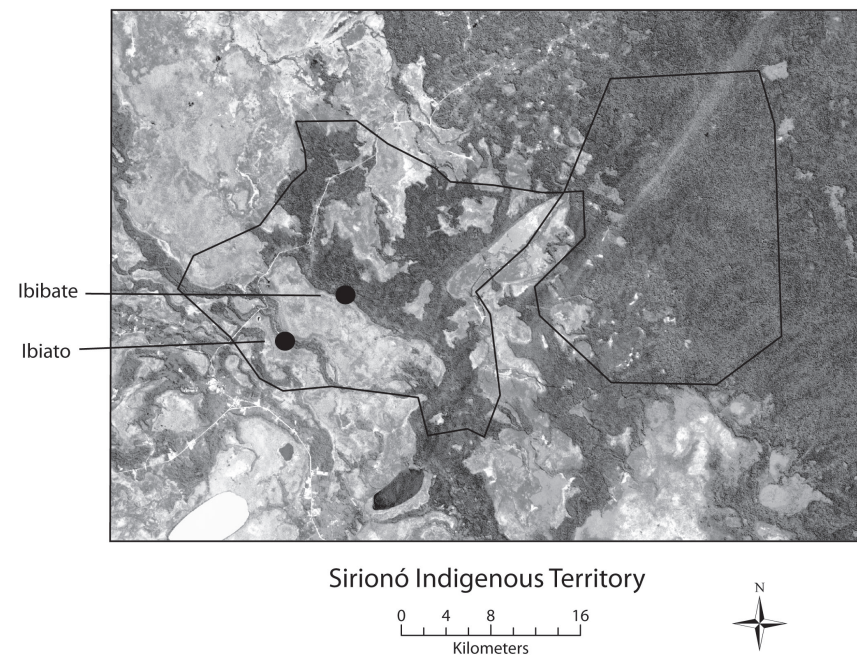


FIGURE 7.1 Location of the Ibibate Mound Complex, Bolivia.

team mapped the Mound Complex in July 1994,⁴ while ethnobotanist Balee continued his multiyear study of its anthropogenic vegetation, which began in 1993. Due to dense vegetation and time limitations, we were unable to make a detailed topographic map of the entire Ibibate Mound Complex.

Siriono informants identified more than 30 large mounds in the immediate area of the Ibibate Mound Complex and report many more within the nearby San Pablo Forest to the east. The mounds of the Siriono Indigenous Territory are related in size, shape, and general artifact types to the numerous large mounds of the Casarabe, Loreto, and Trinidad regions to the north, west, and south. This zone has the highest concentration of large and medium-size mounds in the Bolivian Amazon. The similar large mound, Loma Alta de Casarabe (16 meters tall and covering more than 10 hectares), is located less than 20 kilometers from the Ibibate Mound Complex (Dougherty and Calandra 1981-82; Rydén 1941).

MOUND 1

Mound 1 is located in the northern half of the Ibibate Mound Complex (figures 7.2 and 7.3). The base of Mound 1 covers approximately 2.25 hectares and has a volume of 75,294 cubic meters (table 7.2). A large marsh

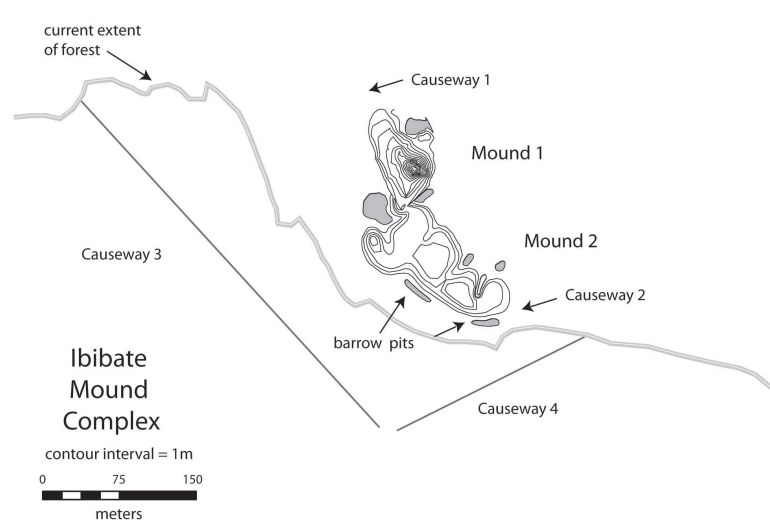


FIGURE 7.2 Earthworks of the Ibibate Mound Complex and surrounding cultural landscape: Mound 1, Mound 2, Causeway 1, Causeway/Canal 2, Causeway/Canal 3, Causeway/Canal 4, barrow pits, and ramps.

(*bajío*, or *curiche*) in the savanna to the west abuts the western edge of Mound 1. The orientation of the long axes of the Mound 1 and Mound 2 is northwest to southeast. Mound 1 has a gentle slope from the southeast to northwest and a steep slope on the northeast- and east-facing sides.

Mound 1 consists of at least two superimposed platforms. The 85- and 89-meter contours approximate the base and upper surface of the large lower platform. The footprint of the lower platform is "teardrop" in shape. The upper platform is located on the surface of the southeast end of the lower platform. The base of the upper platform is kidney bean shaped in footprint and follows roughly the 91-meter contour. The upper platform rises 9 meters above the surface of the lower platform. The highest point of the upper platform is 18 meters above the base of the barrow pits surrounding the mound, 15 meters above the present surface of the gallery forest, or 16 meters above the original surface of the gallery forest (based on posthole transects). Mound 1 has two "ramplike" features of earth (figure 7.2). The first begins at the northwest corner of the mound and ends at the highest point of the upper platform (figure 7.3). The other begins at Causeway 1 between Mound 1 and Mound 2 (described later) and ends at the highest point of the upper platform (figures 7.2 and 7.3).

A small extension of the lower platform (or possibly a separate mound that later merged with Mound 1) is located on the northeast side of Mound 1. This oval platform measures 30 meters long by 20 meters wide by 2.5 meters tall.

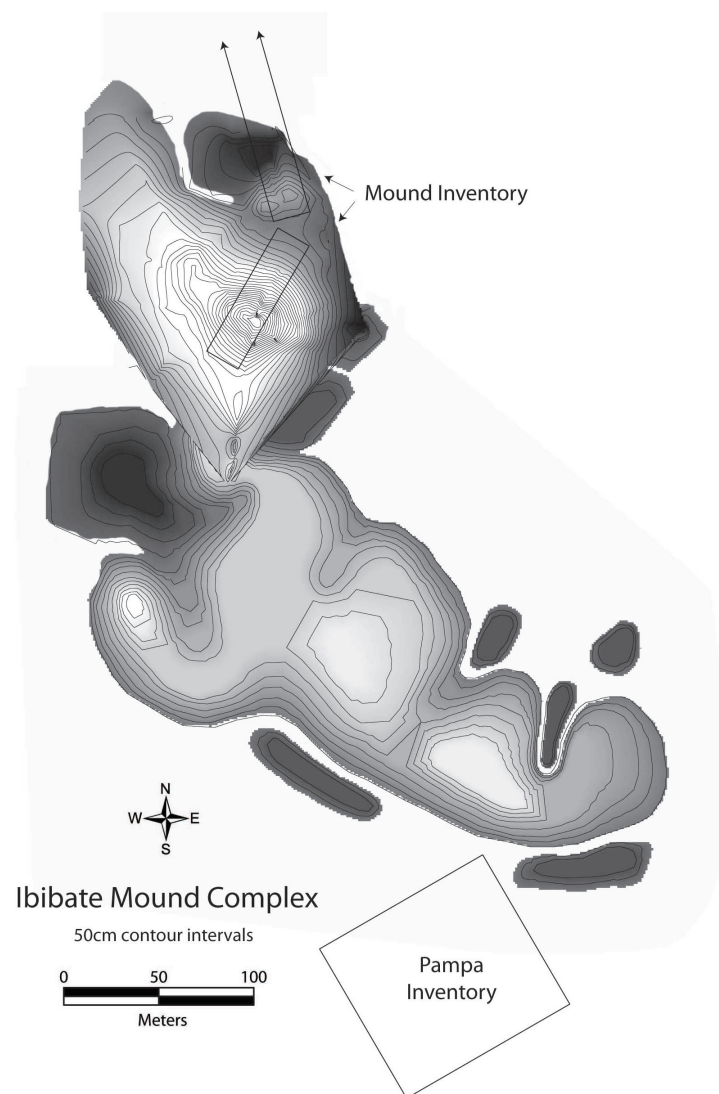


FIGURE 7.3 Topographic map and profiles of the Ibibate Mound Complex (Mound 1, Mound 2, and associated features). Mound 1 was accurately mapped with a Topcon EDM transit; thus, contour lines are precise. Mound 2 was mapped with compass and tape, and contour lines were estimated. Contour interval is 0.5 meter.

TABLE 7.1 Description of Soil from the Ibibate Mound Complex (0-20 Centimeters Below Surface)

| Inventory | pH | EC | Free Cations | | | Ca | Mg | Na | K | Sum Bases | CEC | Base Sat | Acidity | AI | P | O.M. | Total N | Sand | Silt | Clay | Texture |
|-----------|-----|-----|------------------------|-----|-----|---|------|------|----|-----------|------|----------|---------|--------------------------|----|------------------------|---------|------|------|------|---------|
| 1.05 | | | [MS cm ⁻¹] | | | ExchangableCations [emol kg ⁻¹] | | | | | | % | | [cmol kg ⁻¹] | | [mg kg ⁻¹] | | % | | % | |
| Mound | 6.3 | 195 | absent | 6.7 | 2.4 | 0.13 | 10.2 | 10.4 | 98 | 0.2 | 2.9 | 0.22 | 28 | 47 | 25 | | | | | | |
| Pampa | 4.5 | 144 | absent | 1.4 | 2 | 0.33 | 0.4 | 6.3 | 65 | 2.2 | 0.17 | 26 | 49 | 25 | | | | | | | |

MOUND 2

Mound 2 is located in the southern part of the Ibibate Mound Complex (figures 7.2 and 7.3). It was mapped with compass and tape, so the map is not as detailed or accurate as that of Mound 1. The long axis of Mound 2 is oriented northwest to southeast. Mound 2 is composed of two or more superimposed platforms covering an estimated 9.33 hectares and having an estimated volume of 177,357 cubic meters (table 7.2). The edge of the lower platform of Mound 2 is irregular, with many projecting ridges from the long northwest-southeast axis, some surrounded by ponds, remnants of the abandoned river channel and artificial barrow pits dug for earthen fill to construct the mound. The lower platform is approximately 3 meters tall (85-meter to 88-meter contours). The broad flat surface of the lower platform of Mound 2 would have been a better location for houses than the steeper and more irregular surface of Mound 1. The upper platform is found in two separate locations: a 2-meter-tall cone-shaped extension to the northeast and a 1-2 meter high ridgelike spin along the long axis of Mound 2. Both platforms grade steeply toward the forest and savanna to the east and west. The highest location on the northeast part of the mound was cleared for house site and garden approximately 20 years ago, but now is abandoned and overgrown. The Sirion6 regularly use a campsite (*pascana*) located at the southeastern tip of Mound 2 while hunting and gathering in the forest. The irregular surface and shape of Mound 2 may represent the aggregation of three to four individual mounds that grew into a single large mound over time.

BARROW PITS AND PONDS

Seven to eight water-filled depressions (*pozas, lagunas*) and the scars of one or two abandoned river channels or meander scars (*arroyos, canadas*) surround the Ibibate Mound Complex. Topographic survey suggests that for several weeks during the height of the rainy season, most of the terrain adjacent to the Ibibate Mound Complex would be inundated with shallow water or waterlogged. The deepest depressions are to the west, northeast, and east of Mound 1 and to the west and southwest of Mound 2. Several of these depressions are circular and cover 0.25 hectares in area. The majority of the smaller ponds are curvilinear or elliptical in form. The depths of these water bodies in July 1994 (the dry season) varied from 0.5 to 2 meters deep. These features are clearly the barrow pits for the soil used to construct the massive mound complex. These depressions were made in the base of the channel of a long-abandoned river that meanders around the northeast and east sides of Mound 1 and the east side of Mound 2. Traces of a second abandoned river channel are found on the west and southwest side of

Mound 1 and on the west side of Mound 2. Water originally may have flowed between Mound 1 and Mound 2 before Causeway 1 was constructed, which blocked the channel. The unmodified abandoned river channels and the modified barrow pits probably provided year-round sources of drinking and bathing water for the residents of the Ibibate Mound Complex, in addition to a web of water networks for canoe transportation during the rainy season and a source of fish and other aquatic resources. These artificial water bodies would have been connected to natural water bodies in the forest and savanna during typical annual flooding during the rainy season.

The barrow pits do not have sufficient volume to account for the volume of earth in the mounds of the Ibibate Mound Complex. They may have originally been much deeper. Over time, they became dumps for garbage generated by the mound's inhabitants and collected soil and detritus that eroded off the steep sides of the two mounds. After settlement abandonment, natural processes of erosion and sedimentation and use of the mounds for slash-and-burn fields may have also contributed to reducing the size of the barrow pits. Despite these factors, large quantities of earth fill for the construction of the mounds must have been brought in from beyond the barrow pits and other adjacent low spots (although not necessarily from long distances). Topsoil removed as mound fill from the now forested landscape around the complex may have increased risk of flooding of house sites, gardens, and fields during the rainy season and reduced fertility.

CAUSEWAYS AND CANALS

We documented four sets of pre-Columbian causeways (*iteraplones*, *calzadas*) and canals (*canales*, *zanjas*) at the Ibibate Mound Complex (figures 7.2 and 7.4). Earthen causeways in the Bolivian Amazon are usually accompanied by one or two parallel adjacent canals from which earth was removed to construct the raised platform (Erickson 2000b, 2001). Causeways were used for pedestrian traffic, and canals provided channels for canoes. In addition to use for transportation and communication, causeways may have also controlled and managed water as dikes, diversion dams, fish weirs, and reservoir walls; delineated family and community fields or territories; and served ritual and political functions.

A deep, steep-sided ditch oriented northeast-southwest and measuring approximately 15 meters wide and 4 meters deep separates Mound 1 and Mound 2 (figure 7.2). This depression may originally have been the channel of a river or stream. Although this gap between the mounds could easily have been filled in, the builders of the mounds intentionally maintained the division between the two mounds that tower above it. Causeway 1, an artificial earthen structure now used as a trail between the mounds, bridges this ditch. The causeway measures



FIGURE 7.4 Oblique aerial photograph of Causeway/Canal 4 in the savanna west of Mound 1 and Mound 2. Note the line of motacu palms growing on the causeway.

3 meters wide at the top and 6 meters wide at the base, 15 meters long, and 3 meters high. The causeway orientation is northwest-southeast (108°). Causeway 1 is linked directly to the summit of Mound 1 by a ramplike ridge (figure 7.2).

Causeway/Canal 2, a short segment of a large well-preserved causeway and canal, is located between the north edge of Mound 1 and the abandoned river channel to the northeast (figure 7.2). This causeway measures 4 meters wide and 0.5 meters high. The adjacent canal measures 4 meters wide and 0.5 meter deep. Because of dense vegetation cover, the length and destination of Causeway/Canal 2 is unknown. It is not oriented toward Mound 1.

Causeway/Canal 3 is located in the savanna (pampa) and roughly parallel to the savanna-forest boundary west of Mound 1 and Mound 2 (figure 7.2). This causeway/canal is approximately 300 meters long, intersects with Causeway/Canal 4, and disappears into a wetland to the southwest of the mound complex. Its azimuth (135° or 315°) is oriented toward the Santa Fe Mound to the south.

Causeway/Canal 4 is located in the savanna to the southwest of Mound 2 (figures 7.2, 7.4). This badly eroded causeway (3 meters wide and 0.3 meter tall) is clearly defined by vegetation-filled canals along both sides and supports a line of motacu palms (*Attalea phalerasa* Mart. ex. Spreng) and woody

shrubs. The causeway is straight and oriented 245°. The causeway/canal is visible in the savanna for a distance of 100 meters and disappears into a wet land. Causeway/Canals 4 is not aligned to the Ibibate Mound Complex and enters the gallery forest approximately 50 meters from the southwest edge of Mound 2, where it disappears. The east end of the causeway aligns with the Ibiato Mound 10 kilometers across the pampa. The pioneer ethnographer of the Siriono, Allan Holmberg, may have been referring to this causeway or to similar causeways when he mentioned that "rows of palm are sometimes encountered in the pampa" ([1950] 1985:7).

Causeway/Canal 4 also defines the straight southern boundary of a shallow wetland (*curiche* or *yomomo*) (figures 7.2, 7.4). The construction of the causeway may have intentionally or unintentionally impounded water and artificially created the wetland by blocking the natural flow of water from southeast to northwest in the savanna. Similar cases of water management have been documented in the Bolivian Amazon (Erickson 2000b, 2001, and chapter 8, this volume).

SURFACE COLLECTIONS OF ARTIFACTS

Cultural material, primarily fragments of pottery, is found on all exposed surfaces of Mound 1. Few potsherds are found on the vegetation-covered and less-disturbed surface of Mound 2. A number of potsherds were found on the foot trail across Mound 2 and at the edge of a small borrow pit on the east side of the mound. The densest concentration of surface remains was associated with the upper platform of Mound 1. The steep sides of the upper platform are conducive to soil erosion and slope wash. In addition, the upper platform is riddled with the burrows of armadillos, agoutis, and other animals that have made themselves at home in the well-drained areas of the mound. The spoil from this burrowing activity is filled with pottery, which over time has washed down the slope and collects on the surface. The pottery samples collected here are large fragments of vessels and, in one case, a complete vessel (figure 7-5), which suggests that the pottery is eroding from primary deposits within the upper platform of Mound 1 rather than from secondary fill taken from a previous midden filled with pottery and used to construct the mound. The high frequency of complete or near complete fine wares on the surface of the upper platform of Mound 1 suggests that the vessels were placed there as offerings in caches or burials.

The pottery is a mix of fine decorated wares and simple domestic wares.⁵ Most of the pottery collected from the surface is from decorated serving vessels. Forms include simple open-mouth bowls and complex incurving-mouth

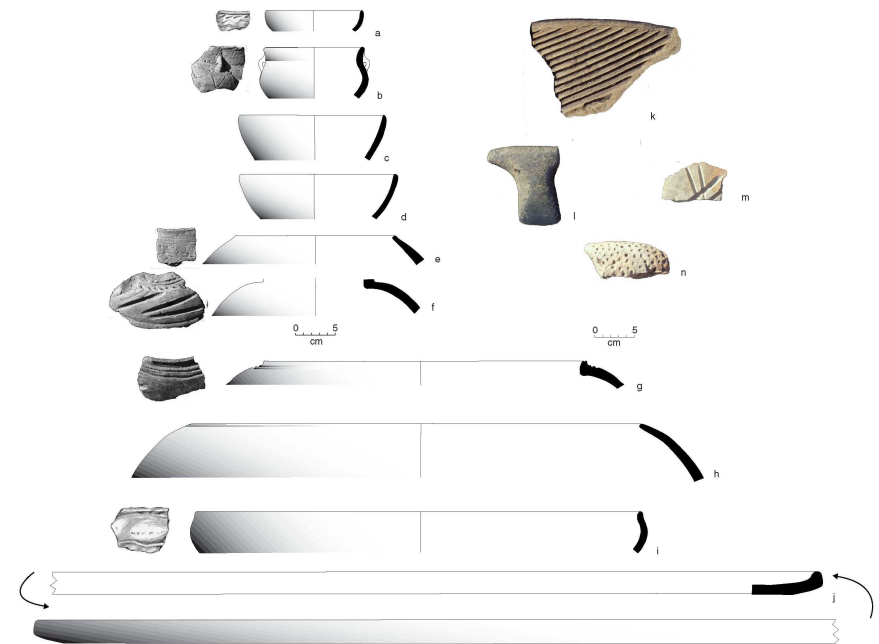


FIGURE 7.5 Examples of artifacts from surface collections at the Ibibate Mound Complex: (a-j) pottery vessels based on fragments, (d) a fragment of a ceramic hand-held grinder, (k) a fragment of a large ceramic "grater," (l) a broken ground stone ax of a T shape, (m) an arrow or spear shaft straightener or projectile point grinder.

bowls (figure 7.5). Based on ethnographic analogy with the lowland tropics, these vessels were probably used for serving and drinking of liquids, possibly a mild alcoholic beer (*chicba*) of manioc or maize. Decorations consist of fine and broad-line incision and geometric and curvilinear designs painted on slipped surfaces. Pottery "graters bowls" and hand "grinders," ubiquitous finds in pre-Columbian mounds of the Beni, are also present (figure 7.5). Archaeologists have described similar artifacts from mounds near Casarabe (Dougherty and Calandra 1981-82; Fernandez Distal 1987a; Pnimers 2000, 2001, 2002a; Rydén 1941, 1964). The functions attributed to graters and grinders include grating manioc for preparation of *chivé* (a toasted, lightly fermented coarse flour) (Nordenskiöld 1913; Rydén 1964), producing bark-cloth and distilling salt.

Fragments of eroded bone are common on the surface of Mound 1. The bones are of animals (species not yet determined) and of humans. Although some of the animal bones may be from animal burrows in the upper platform of the mound, the majority probably represents discarded food remains that

were incorporated into the artificial fill of the mound. The human bone is probably from primary context burials, possibly in urns, eroded out of the upper platform; thus, one use of the upper platform of Mound 1 was apparently as a cemetery.

Another common surface find at Ibibate Mound Complex are the remains of large apple snail (*turos*) (*Pomacea* sp. or *Ampularia* sp.). These molluscs are common in the fill of pre-Columbian mounds in the Beni, often forming thick stratigraphic layers (Erickson 2000; Pinto Parada 1987), and associated with fish weirs and artificial ponds in Baures (Erickson 2000a and chapter 8, this volume). Although rarely consumed by locals today, the highly productive snails are edible. Because of their low nutritional value and intact state, it is not clear if the molluscs in the mounds are food remains or served other purposes.

SOIL ANALYSES

Soil samples were taken from elevated areas of Mound I (Mound Inventory) and from the low-lying forest to the southwest of Mound I (Pampa Inventory; inventories are discussed in detail later) (figure 7.2). Each sample was based on 10 subsamples taken with a soil probe to depth of 20 centimeters at random locations within each inventory in July 1999. Subsamples were mixed thoroughly together, sun dried, and analyzed at Laboratorio del Centro de Investigación Agrícola Tropical, Santa Cruz, Bolivia (table 7.1).

The two samples have identical soil texture, reinforcing the idea that the mounds were constructed using local fill from nearby barrow pits. The soils from both inventories are relatively fertile by local standards, although the Mound Inventory obviously has better agricultural soil than the Pampa Inventory. The differences in pH, saturation of exchangeable bases, phosphorus, calcium, and total nitrogen are striking. The pH of the Mound Inventory is ideal for plant uptake of the cations of calcium, manganese, potassium, and phosphorus in contrast to the Pampa Inventory's low pH, which would limit nutrient availability for plants (Johannes Lehmann, personal communication, 2004). The phosphorus level is much higher in the Mound Inventory, sufficient for good yields of maize and other crops (Lehmann, personal communication, 2004). The low levels of organic matter in both samples is surprising due to the evidence of domestic activities or debris or both in the two inventories.

Although some of the differences in fertility may be due to the better drainage of the Mound Inventory, we believe that human activities best account for the soil characteristics. The Mound Inventory soils have maintained their fertility after 400 years since the settlement was densely occupied. With the exception of low levels of organic matter and charcoal, Johannes Lehmann (personal com-

munication, 2004) favorably compares the Mound Inventory sample to those of anthropogenic Amazonian Dark Earths found in Brazil (Glaser and Woods 2000; Lehmann et al. 2001, Neves and Peterson, chapter 9, this volume). We had expected the soils of the Pampa Inventory to have been more fertile due to the presence of domestic debris in the subsurface soil probe transects. The recovery of pottery, charcoal, and bone at depths of up to 85 centimeters below surface suggests that occupation was not limited to the well-drained mound surfaces or that domestic midden was regularly spread over adjacent landscape as an organic soil amendment.

COMPARATIVE DATING OF THE IBIBATE MOUND COMPLEX

Because no excavations were done and no radiocarbon samples were collected for dating, we have no absolute dates for the construction, use, and abandonment of the Ibibate Mound Complex. Comparison of pottery styles to that collected at better-dated mounds provides some chronological control. The pottery we collected is almost identical to that described from surface collections at the Ibiato Mound (Fernandez Distel 1987a) and the Santa Fe Mound (Hanke 1957), and from stratigraphic excavations at Loma Alta de Casarabe ("High Mound of Casarabe") (Dougherty and Calandra 1981-82, 1984:191 table z) and the Mendoza Mound (Primers 2000, 2001, 2002a, 2000b). The later mounds are located within easy walking distance (10 kilometers) of the Ibibate Mound Complex.⁶

Radiocarbon dates (a total of 14) obtained from excavations of the Loma Alta de Casarabe range from 735-145 BC (2685-145 BP) to AD 1050-70 (900-70 BP; all uncorrected dates) (Dougherty and Calandra 1984:191, table z). In a recent summary of the chronology of the Mendoza Mound, Primers (2002b) states that the initial mound construction and occupation began around AD 400, followed by additional construction phases in AD 700 and AD 1200, with occupation ending around AD 1400. Based on the geographic proximity and strong stylistic similarity between the pottery from these better-dated mounds and pottery that we recovered, we are confident that the chronology of construction, occupation, and abandonment for the Ibibate Mound complex is comparable (1,000 to 1,500 years of use ending 500 years ago with the arrival of Europeans).

MOUND-FORMATION PROCESSES

The Ibibate Mound Complex is unquestionably an artificial, human creation. Archaeological investigations since the initial excavations of Erland Nordenskiöld in 1910 have clearly demonstrated that mounds are anthropogenic (Denevan 1966;

Erickson 2000c; Kenneth Lee in Pinto Parada 1987; Nordenskiöld 1913), despite unsubstantiated claims that the mounds are accumulation of flood sediments and were periodically occupied by nomadic peoples (see, e.g., Dougherty and Calandra 1981-82, 1984; Faldin 1984). Pre-Columbian mounds are quite distinct from natural rock formations (upwelling of the Brazilian Shield known locally as *cerros* or *cerritos*) (Denevan 1966; Hanagarth 1993), the topography created by dynamic fluvial processes (the levees of active and inactive rivers) (Hanagarth 1993), and certain forest islands formed by natural processes (Langstroth 1996).

Mounds are clearly associated with active and abandoned river channels. Most mounds were established on river levees, natural elevations formed by accumulations of sediments dropped as floodwater velocity is slowed when rivers overflow their banks. Levees on active rivers are often continuous along both banks and covered with gallery forests (Hanagarth 1993). Older levees are often fragmented, and forest growing on them forms "islands" surrounded by savanna and wetlands (Langstroth 1996). The mound builders first colonized natural better-drained levees for settlement, gardens, and fields with direct access to drinking water, fish, and game attracted to the water; for protection from fire; and for open water for their canoes. The levees of smaller rivers and abandoned river channels as in the case of the Ibibate Mound Complex are low and narrow, probably less than 0.5 meters above the surrounding landscape. Thus, river geomorphology accounts for the location of mounds, but not for the processes that created them.

The colonization of levees may have occurred when the rivers were more active. As rivers meandered and changed courses over time, some mounds were left on abandoned river channels and bends (oxbox lakes, *cariadas*). Abandoned channels still provide access to active channels of the rivers during the rainy season when most of the flat landscape is covered with shallow floodwaters.

Once established as a settlement, the mounds grew through a variety of cultural formation processes that can be inferred from mapping, surface collections, road cuts, excavations of mounds, and observations of houses and settlements today (see Erickson 2000c for a summary of this literature). House floors were raised 20 centimeters or more by constructing a clay platform to prevent waterlogging. Garbage (food and food-processing debris, charcoal, and ash) was used to fill depressions around houses and to level activity-area surfaces. Traditional houses in the Bolivian Amazon had wattle-and-daub walls roofed with wooden poles and palm thatch (figure 7.6). The technique involves creating a basketry-like web of wood and cane between upright house posts and covering it with thick clay mixed with grass. Houses tended to last 5-10 years in the humid environment. When the house was



FIGURE 7.6 The present-day Siriono community on the Ibiato Mound. Similar, although more densely packed, thatched houses, work areas, plazas, and compact house gardens probably covered the Ibibate Mound Complex before it was abandoned.

abandoned, up to a ton of soil was added to the surface when its walls finally collapsed. These locations were leveled, and new houses were built on the raised surfaces. Thus, settlements surfaces were raised through a slow, but continuous, gradual accretion process as garbage was disposed and houses were abandoned and rebuilt by generations of inhabitants, which eventually resulted in the formation of a mound.

Stratigraphic profiles of some mounds often show wide strata of soil of uniform color and texture. In these cases, internal layers of some mounds were formed more rapidly through thick additions of construction fill over a short period of time, possibly a single episode. These construction layers are often associated with large pottery urns for human burials where the earth may have been added around a layer of urns or capped them to prevent damage. In other cases, layers of earth may have been added to mounds to increase their height and size or the area of flat surface for house and activities or to improve aesthetic appearance, or to achieve all three purposes. Clusters of large mounds such as those in the Siriono Indigenous Territory and Casarabe may have resulted from competition between communities for the most impressive monumental landscape feature.

Most mounds such as the Ibibate Mound Complex are surrounded by deep depressions that were created as construction fill was removed. Soil could be easily excavated from these barrow pits using simple digging sticks and carried in baskets or carrying cloths to the mounds. These depressions also served as a year-round source of drinking water for the mound's inhabitants. In the case of the Ibibate Mound Complex, sections of the old river channel were mined for soil, thus creating the ponds. At the height of the rainy season and flooding, these depressions formed a near continuous moat around the mounds. During the dry season, they provided the only source of water.

Primers (2000, 2001, 2002a, 2002b) has documented both slow accretion processes and mass additions of construction fill in the Mendoza Mound in Casarabe. Excavations in the exposed profile of a road cut through the center of the mound show that sections of the mound were built and abandoned as the settlement shifted horizontally over time. At various periods, thick layers of construction fill were added to raise and level the surface.

People have continued to return to these locations, once established, because of the dry surfaces and the rich soils they provide for settlement and gardens, even if humans occasionally abandoned them for short periods. Native peoples, ranchers, and colonists continue to seek out mounds for house sites and gardens. Mounds are permanent, valuable features on the local landscape.

Human activities are also a factor in the erosion and destruction of mounds. In the past, population densities were high on the mounds and surrounding landscape. Human disturbance such as deforestation, cultivation, burning, pathways, and hydraulic works would have impacted mounds. Mounds were eroding at the same time that they were being formed. The steep sides of the large mounds and barrow pits were easily eroded by the humans activities and heavy rains.

Our posthole testing transects demonstrated that buried pre-Columbian settlement debris (pottery sherds and charcoal) to a depth of 85 centimeters extended beyond the edges of Mound 1 and Mound 2 into the low ground to the north (the extension of the Mound Inventory to the northeast in figure 7.2). It is unlikely that these remains eroded from the mound located at a distance of 50-100 meters. Houses may have been established off mound, or garbage was tossed in this area for gardens and fields. As the mounds grew over time, flat space on the platforms and slopes for construction of houses would have been at a premium; thus, off-mound settlement may have been required. However, the low fertility of these soils suggests that anthropogenic activities were minimal.

The total amount of earth used in the construction of the Ibibate Mound Complex is impressive (table 7.2). Based on the topographic maps, an estimated 252,651 cubic meters of earth was moved to create the structures. Of course, the mounds grew through accretion, and this labor was spread out over many hundreds of years.

TABLE 7.2 Mound Descriptions and Labor Estimates

| | Planimetric Area ^a | Surface Area ^a | Volume m ³ | Labor minimum person-days ^b | Labor maximum person-days |
|---------|----------------------------------|------------------------------|--------------------------|---|------------------------------|
| Mound 1 | 2.21 | 2.25 | 75,294 | 30,117 | 65,473 |
| Mound 2 | 9.27 | 9.33 | 177,357 | 70,942 | 154,223 |
| Total | 11.48 | 11.58 | 252,651 | 101,060 | 219,697 |

^a Based on base at the 85-meter contour.

^b Based on experimental raised-field construction: 1.15 to 2.5 cubic meters of earth moved per day based on a 5-hour workday (Erickson 1994; Erickson et al. 1991).

Continuous occupation of the Ibibate Mound Complex probably ended with the arrival of the Spanish conquistadors, missionaries, and colonists in the Bolivian Amazon. Native populations collapsed as the people died from Old World diseases to which they had no resistance, were enslaved, or perished from civil and international wars. Forest gradually became established in what had been houses, communities, gardens, orchards, and fields.

SOME COMPARISONS TO OTHER MOUNDS IN THE BOLIVIAN AMAZON

At 16-18 meters tall, with a volume of 252,651 cubic meters and a combined base covering approximately 11.5 hectares, the Ibibate Mound Complex is one of the largest and probably the tallest recorded mound groups in the Bolivian Amazon (table 7.2). Based on manual earth moving to construct experimental raised fields, we estimate that between 101,000 and 220,000 person-days of labor were required to construct the Ibibate Mound Complex. Because the mounds were constructed piecemeal over hundreds of years, the labor costs would have been spread out. For example, 100 people working 30 days a year could have constructed the Mound Complex in 33.7 to 73.3 years. Accurate comparisons of size, volume of fill, and form of pre-Columbian mounds are difficult because few mounds have been adequately mapped. The Lama Alta of Casarabe may be the Ibibate Mound Complex's closest rival (discussed earlier).

Two structural principles reflected in the Ibibate Mound Complex are notable. First, the mounds are made up of two distinct structures—a large flattened platform covering several hectares, with a smaller cone- or pyramid-shaped earthen structure on top (figure 7.7). This form has also been recorded for the Ibiato Mound, Lama Alta de Casarabe, Mendoza Mound, Suarez Mound (Mamore River), Monte Sinai Mound (Apere River), and Cayalo Mound (Apere River). Mound 1 of the Ibibate Mound Complex, the Ibiato Mound, the Mendoza Mound, and Lama Alta de Casarabe are remarkably similar in form: all are

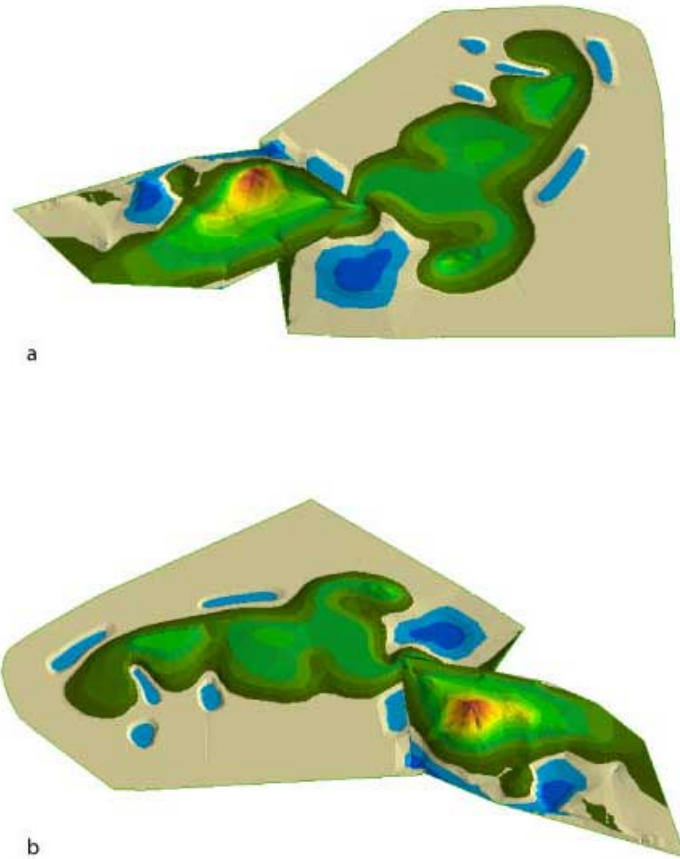


FIGURE 7.7 Perspectives of the Ibiate Mound Complex from different directions.

oriented northwest-southeast, and the highest elevation on the mounds is off center in the southeast of the lower platform (although the location is reversed in the case of Ibiato Mound) (compare figure 7.3 with Dougherty and Calandra 1981-82:17, lamina III; Priimers 2002a, figure 2; Stearman 1987:76, figure 3). The second characteristic is the pairing of mounds. In most cases, one mound is clearly larger or taller, or both, than the other. Dual mound groups have also been recorded for Dos Islas (Secure River), Cayalo Mound (Apere River), and Esperanza II Mound (Apere River). Concepts of duality embedded in settlement plans are often recorded in the ethnographic and historical Amazonian societies (Lévi-Strauss 1944). It is our central argument that these structures and the human intentionality that indisputably went into making them, perhaps principally for social and ritual purposes, have had a positive impact on the vegetation of this landscape.

Similar pre-Columbian networks of causeways and canals integrated with settlements and fields are common throughout the Bolivian Amazon (Denevan 1966; Erickson 2000b; Nordenskiöld 1916; Pinto Parada 1987).

FOREST INVENTORY METHODS

In order to understand similarities and differences of vegetation on the mounds and in the forest near the savanna (pampa) edge, two r-hectare inventories associated with Ibiate Mound Complex and its immediate environs were carried out. These inventories are referred to as the Mound Inventory and the Pampa Inventory. The methods employed in this study follow largely those explained in Boom 1986; Campbell and colleagues 1986 (and Campbell et al., chapter I, this volume); Gentry 1993; Mori and colleagues 1983; and Salomao, Silva, and Rosa 1988. The Mound Inventory was carried out in August 1993. Further collections and re-collections of trees in the Mound Inventory were made in July 1994 and September 1997. The Pampa Inventory began in September 1997. Revisits without plant collections being conducted were made to both inventory sites in July 1999 and August 2002, and soil samples were taken at both inventories in July 1999.

The Mound Inventory is a narrow rectangle, measuring 20 by 500 meters and includes the earthen pinnacle of Mound I located at $14^{\circ}48'25''$ S/ $64^{\circ}24'36''$ W. The inventory was divided into 40 subplots measuring 10 by 25 meters in order to calculate species' densities, ecological importance values (IV), species/area curves, and alpha diversity. The Mound Inventory is basically on *terra firme*, land that does not flood at any time of the year (as indicated in the term *libi-bate*, "true land" or "high ground," in the Siriono language).

The Pampa Inventory, at Subplot I, is located at $14^{\circ}48'23''$ S/ $64^{\circ}24'30''$ W. The Pampa Inventory measures 100 by 100 meters. It also consists of 40 subplots of 10 by 25 meters each. The Pampa Inventory is located southwest of Mound 2. The area between the depression and the open savanna is a narrow ecotone about 200 meters wide at its widest point. The ecotone of forest and savanna, called savanna edge (*orilla de fapampa* in Spanish, *ibera* in Siriono), is zigzag in shape. It was not feasible to layout a narrow rectangular inventory inside the single forest type in this area, but the roo-by-roo-meter inventory did cover and stay within the boundaries of this single forest type.

On both inventories, all trees in the size class greater than or equal to 10 centimeters diameter at breast height (DBH) were tagged, and, with a few exceptions—as when the field identification indicated that the same species had been already collected numerous times—each was collected. Also included were woody vines with diameters greater than or equal to 10 centimeters DBH. Trees were tagged with consecutively numbered aluminum tree tags starting

from the baseline of 10 meters in width at the zero point from each subplot. All inventory data were recorded in a large foldout notebook; a matrix was constructed whereby each row represented a numbered tree in the inventory, and these rows were listed consecutively in order of tree tag number, starting with number 1. Columns were (1) date of plant collection; (2) collection number (on Balee series); (3) subplot number (0-39); (4) location in relation to the transect (left or right of it when facing the heading of the inventory); (5) taxon (to genus and species, where possible); DBH; comments (for information such as the number of specimens made of each plant, whether it was fertile or not, whether it had leaves or was deciduous at the moment of collection, whether it had buttresses, sap, and other dendrological characteristics); (6) indigenous (Siriono) name; and (7) indigenous uses. Items 6 and 7 were also repeatedly recorded in a separate notebook of ethnobiological responses by individual Siriono consultants for the purposes of a different study. Vouchers of all specimens were deposited at the National Herbarium of Bolivia (Herbario Nacional de Bolivia) in La Paz.

Specimens that could not be determined to species, but were distinguished as being different species of the same genus, were treated as morphospecies and thus numbered differently; specimens that could not be identified to genus or, in rare cases, to family were treated likewise as undetermined (to genus or family) morphospecies and numbered accordingly. (The validity of morphospecies and their use in various aspects of understanding inventory data are discussed in Campbell 1989; Campbell et al. 1986; Campbell et al., chapter 1, this volume.) Identifications from the Mound Inventory are somewhat more reliable than those from the Pampa Inventory because (1) many trees at the time of the Pampa Inventory and collection were deciduous (in September 1997), so only dendrological collections in these cases could be made; (2) the plants were identified by more specialists; and (3) the vouchers were better distributed to determination specialists. Nevertheless, several of the individuals on the Pampa Inventory could be identified in the field with use of the keys given by Killeen, Garcia, and Beck (1993) and by Gentry (1993), as well as based on Balee's prior field experience and knowledge of species in the habitat, especially those shared at the Mound Inventory.

Two kinds of diversity, alpha and beta, are examined here. *Alpha diversity* is diversity of species in a restricted, given locale on the same substrate, as with the Mound Inventory or the Pampa Inventory. *Beta diversity* is the diversity of species sampled along an environmental gradient in a particular area across locales on different substrates; beta diversity in this case is a measure of change in species composition along the environmental gradient of slope (as one descends from the Mound Inventory, which is well drained, to the Pampa Inventory, which is flood prone).

The analysis of the inventory data was conducted using a program composed in DBASE Plus. Each raw tree database consists of the following structure

(per tree): family, species, subplot, tree tag number, DBH, basal area (calculated from the DBH by dividing the DBH by 2 to get the radius and then applying the formula for the area of a circle, as each tree is conceived mathematically, πr^2). Measure of similarity between the inventory sites was calculated based on the Jaccard coefficient (given later). The DBASE Plus© program calculated the number of individuals of each species; the number of subplots on which each species is found; the total basal area of each species; the relative density of each species (the number of subplots in which each species is found is divided by the total number of all such subplots for all species multiplied by 100); the relative frequency of each species (the number of individuals in a species divided by the total number of individuals in the inventory multiplied by 100); the relative dominance of each species (the total basal area of a species divided by the total basal area of all species multiplied by 100); and the ecological importance value, which is the sum of relative density, relative frequency, and relative dominance for each species.

ANTHROPOGENIC FOREST

The total number of trees on the Mound Inventory was 448, and the total basal area was 27.730 square meters (appendix 7.1). The total number of trees on the Pampa Inventory was 425, and the total basal area was 26.158 square meters (appendix 7.2). These figures are similar both in tree numbers and basal areas and suggest maturity, possibly even great age, of both forests on these sites. That is because these basal areas, which are indirect measures or proxies for biomass, are higher than open forests (with or without palms) and vine forests (which are usually between 18 and 24 square meters [Pires and Prance 1985:112, 119]), though somewhat lower than or classical, mature forests of equatorial Amazonia (which can reach 40 square meters and greater [Pires and Prance 1985:112]). The basal areas of these forests, which are heavily represented by palms, especially *Astrocaryum murumuru* var. *murumuru* and *Attalea phalerata*, are roughly comparable to a set of four old-fallow forest (anthropogenic forest) inventories Balee conducted in Maranhao, Brazil (extreme eastern Amazonia), which had an average basal area, using essentially the same sampling techniques as here, of 26.25 square meters (Balee 1994:124-129). The forests of the Mound Inventory and adjoining Pampa Inventory seem slightly higher in biomass than two anthropogenic liana forests (with many palms present also) sampled in the middle Xingu River basin at 22.10 square meters and 21.90 square meters, respectively (Balee and Campbell 1990:47).

The two inventories are similar in terms of their respective alpha diversities, with 55 species in the Mound Inventory and 53 species in the Pampa Inventory (appendixes 7.1 and 7.2). They share 24 species (table 7.3), meaning that the

TABLE 7.3 Shared Species Between Mound Inventory and Pampa Inventory with Ecological Importance Values (IV) Shown at Each Site

| Species | IV at Mound | IV at Pampa |
|---|-------------|-------------|
| <i>Spondias mombin</i> L. | 3.93 | 3.04 |
| <i>Aspidosperma</i> sp. 1 | 1.30 | 3.88 |
| <i>Dendropanax arboreus</i> (L.) Decne. & Planchon | 3.86 | 0.71 |
| <i>Astrocaryum murumuru</i> Mart. var. <i>murumuru</i> | 46.21 | 9.21 |
| <i>Attalea phalerata</i> Mart. ex Spreng (= <i>Scheelea princeps</i>) | 41.70 | 83.27 |
| <i>Syagrus sancona</i> H. Karst | 4.50 | 18.10 |
| <i>Clatostoma ulegnum</i> Kanzlin | 2.80 | 0.72 |
| <i>Ceiba pentandra</i> Gaertn. | 5.61 | 4.43 |
| <i>Cecropia concolor</i> Willd. | 2.08 | 1.15 |
| <i>Calophyllum brasiliense</i> Camb. | 6.38 | 2.82 |
| <i>Terminalia</i> sp. 1 | 6.93 | 5.32 |
| <i>Hura crepitans</i> L. | 15.38 | 12.10 |
| <i>Sapium glandulosum</i> (L.) Morang | 5.51 | 5.32 |
| <i>Swartzia jororoi</i> Harms | 2.44 | 2.24 |
| <i>Caesaria gossypiosperma</i> Briq. | 1.90 | 15.78 |
| Lauraceae sp. 1 | 3.52 | 0.72 |
| <i>Acacia</i> sp. 1 | 0.64 | 0.70 |
| <i>Gallesia integrifolia</i> (Spreng.) Harms | 23.47 | 23.15 |
| <i>Triplaris Americana</i> Fisch & Meyer ex C. Meyer | 4.47 | 4.34 |
| <i>Calycophyllum</i> sp. 1 | 0.79 | 4.23 |
| <i>Genipa americana</i> L. | 0.94 | 1.45 |
| <i>Sapindus saponaria</i> L. | 0.97 | 0.72 |
| <i>Talisia hexaphylla</i> M. Vahl. | 3.93 | 6.24 |
| <i>Ampelocera ruizii</i> Klotzsch | 22.43 | 10.88 |

total number of species in both inventories is 84 ($55 + 53 = 108$; $108 - 24 = 84$). The current alpha diversity at the Mound Inventory would not exist without human intervention, specifically the making of the built environment in prehistory. Langstroth (1996) has referred to the Ibibate Mound Complex and other forested mounds like it as "ceramic" forests because of the vast quantity of potsherds found inside them. The forest of the Pampa Inventory is anthropogenic as well, but for different reasons.

The analysis of shared species (table 7.3) yields significant circumstantial evidence as to anthropogenic origins of the forests on these two inventories. Both forests are, in a strictly vegetative sense, palm forests. They are also oligarchic, being heavily dominated by just a few species (Campbell et al., chapter 1, this volume; Peters et al. 1989). In terms of ecological importance values, the top 10 species in the Mound Inventory account for 65.4 percent of all importance values of all trees summed together ($196.2/300 = 0.654$). The top 10 species at Pampa Inventory account for 70.9 percent of all importance values of all trees summed together ($212.7/300 = 0.709$). The two ecologically most important species on each inventory account for 23.12 percent of the Mound Inventory's total importance value and 41.65 percent of the Pampa Inventory's total importance value. However similar as oligarchies, though, the two forests are *different* types of oligarchic forests.

Many palm forests in Amazonia are anthropogenic (Balee 1988; Balee and Campbell 1990). In referring to forests in six 0.1-hectare sampled subplots in a vegetation study south of the Ibibate Mound Complex, Wendy Townsend noted, "Palm trees predominate in much of the forest area. The mounds and the canals of this landscape were built by humans before the arrival of the Spanish. The high proportion of palm trees in the forest is another indication of past human occupancy" (1995:26, see also 1996:16-19). Specifically, the motacu palm (*Attalea phalerata* Mart. ex. Spreng) accounted for *at least* 50 percent of trees on four of six plots (Townsend 1995:21); on one of these six subplots, the spiny chonta palm (*Astrocaryum murumuru* Mart. var. *murumuru*) also accounted for more than 50 percent of the total frequencies. Townsend indicated that Siri-ono informants recognize three forest types (Ibibate, Kiarochu, and Ibera). Because these forest types are not "detectable on aerial photographs" (Townsend 1995:20), field research is necessary to understand the variety and subtlety of human disturbance and molding of landscapes.

In terms of palms, the relative frequency (number of individuals of a species divided by all individuals multiplied by 100) is less in the Mound and Pampa inventories than in the plots sampled by Townsend. At the Mound Inventory, *A. phalerata* at 53 individuals is only 8.8 percent relative frequency (53 divided by 448 multiplied by 100) of the total number of trees in the size class greater than or equal to 10 centimeters DBH. This palm is much more frequent in the

Pampa Inventory, at 36 percent (153 divided by 425 times 100), though this is somewhat less than half the total—that is, slightly dissimilar from Townsend's results; her plots appear to have been located in a slightly less well-drained area than the Pampa Inventory. *A. phalerata* is the ecologically most important species in the Pampa Inventory and the second ecologically most important species in the Mound Inventory (table 7.4). In contrast, the spiny chonta palm with its highly desirable heart of palm, *A. murumuru* var. *murumuru*, accounts for exactly 25 percent of all individual trees in the Mound Inventory, and it is the ecologically most important species there. Although this palm is less frequent (at 3.5 percent) in the Pampa Inventory, it still has a relatively high importance value (rank eighth among 53 species).

The two forests are similar, yet different enough to be categorized by different names and concepts, as they are in Siriono language and culture. The solitary palm, *A. phalerata*, which has high importance values on both inventories, being somewhat more important in the Pampa Inventory, is facultative in this sense (it can occur in more than one biome, defined in terms of environmental gradients and immediate, local features such as slope, light penetration, and water tolerance), tolerating some flooding and also appearing on the better-drained terra firme of the Mound Inventory. On sedimentary soils to the west of the Brazilian Shield, this species appears to replace the babacu palm (*Attalea speciosa* Mart. ex Spreng.) in an allopatric manner (Henderson 1995:151); babacu palms are associated with anthropogenic forests in eastern Amazonia and elsewhere south of the Amazon River. The palm has a multitude of uses, and its fruits traditionally were gathered as food by the Siriono in every month of the year, fronds used as thatch, and cooked fruit employed as a laxative (Fernandez Distel 1987b:n8; Holmberg [1950] 1985:48-5°). *A. murumuru* var. *murumuru* is likewise facultative, being found "in periodically inundated areas or tidally inundated areas near the sea, along river margins, or occasionally in lowland rain forest on terra firme. Since the fruits are edible, it is likely that its range has been extended by humans" (Henderson 1995:246). Indeed, the heart of palm of juvenile *A. murumuru* var. *murumuru* is a delicacy and an important, nutritious food item of the Siriono in every month of the year (Holmberg [1950] 1985:48-5°; he calls it "palm cabbage"). The sumuque palm, *Syagrus sancona* H. Karst, with an edible fruit, is common in the Pampa Inventory and somewhat less important on the Mound Inventory. According to Henderson, this palm is a rare and threatened species in Amazonia, and its distribution may be due to humans (1995:135).

In terms of dicotyledonous plants collected in the inventories, several indicate the possibility of anthropogenic patterns of distribution. Hog plum or yellow mombin (*Spondias mombin* L.), a tree with a juicy, tart, vitamin C-rich edible fruit that occurs on both inventories, is well known from both anthropogenic forests and riparian (i.e., floodable) forests elsewhere (Balee, 1994:132;

Clement, chapter 6, this volume). Sometimes it is cultivated in Amazonian dooryard gardens (Paz Rivera 2003:30; Smith et al. 1995:215) and is facultative, as are many species of old-forest fallows. Hog plum may have migrated from gardens, orchards, or fields on the mounds down the slope into the floodplain of the Pampa Inventory.

A number of wind-dispersed species are present on both sites. Anemochory is an efficient dispersal mechanism of pioneer species, some of which are long lived and grow to display significant height and high biomass. Although no single species of *Tabebuia* appears to be shared between the Pampa and Mound inventories, the genus itself has winged seeds, which facilitate dispersal into areas cleared or disturbed by humans (Gentry 1993:268). All *Tabebuia* species (rajibo or pau d'arco) are valuable timber. *Tabebuia serratifolia* (M. Vahl) Nicholson (known as yellow tabs in the horticultural landscaping market of southern California), which occurs on the Mound Inventory (appendix 7.1), is a well-known species found in secondary forests throughout Amazonia and much of South America (Balee 1994:277; Killeen, Garcia, and Beck 1993:149). Likewise, although no one species of *Cordia* (Boraginaceae) appears on both inventories, *Cordia alliodora* (Rufz and Pavon) Oken, which occurs on the Mound Inventory, possesses dry and expanded corolla lobes that contribute to its wind dispersal (Gentry 1993:296), as with *Tabebuia*. The kapok tree (*Ceiba pentandra* Gaertn.), a pan-tropical species, is frequently associated with disturbed sites (as a pioneer species) or with riparian habitats (Whitmore 1990:104), possibly because its small seeds occur inside the kapok, accounting for dispersal by wind (cf Gentry 1993:288; van Roosmalen 1985:56). The Guarayo, Tupf-Guaranf people to the south of the Siriono, evidently planted *C. pentandra* and considered it to be a sacred tree, as did the Maya (Paz Rivera 2003:8). The moraceous *Cecropia concolor* Willd., which is shared on both inventories, is a common member of fallow forests in eastern Amazonia (Balee 1994:281). Another dicot with winged seeds is the combretaceous *Terminalia* sp. 1, which not only is shared between the two inventories (table 7.3), but is also the tenth ecologically most important species in the Mound Inventory (table 7.4). *Terminalia* sp. is tied for twelfth place with *Sapium glandulosum* (L.) Morong in the Pampa Inventory (appendix 7.2).

The euphorbiaceous *S. glandulosum*, an ancient species, is found in numerous habitats of eastern Bolivia, including secondary forest (Killeen, Garcia, and Beck 1993:12). The related and poisonous ochoo tree (*Hura crepitans* L.) is a taxon probably dating from the beginning of the formation of the Amazon floodplain forests millions of years ago (Bush 1994; Colinvaux et al. 1996); it is physiologically plastic, having coexisted with cold-indicator taxa in the Pleistocene period (Bush 1994:14; Bush et al. 1990; Killeen, Garcia, and Beck 1993:303; Piperno, Bush, and Colinvaux 1990). Ochoo (called *assacu* in Brazilian Portuguese) is commonly found in poorly drained Amazonian forests, but it is also present in secondary forest on terra firme (Killeen, Garcia, and Beck 1993:303).

TABLE 7.4 Ten Species from Mound and Pampa Inventories with Highest Importance Values (IVs) in Order of Importance

| Rank | Mound Inventory | IV | Pampa Inventory | IV |
|------|--|-------|--|-------|
| | <i>Astrocaryum murumuru</i> Mart. var. <i>murumuru</i> | 46.21 | <i>Attaleaphalerata</i> Mart. ex Spreng. | 83.27 |
| 2 | <i>Attaleaphalerata</i> Mart. ex Spreng | 23.15 | <i>Gallesia integrifolia</i> (Spreng.) Harms | 41.70 |
| 3 | <i>Hirtella triandra</i> Sw. ssp. <i>triandra</i> | 25.47 | <i>Ficus</i> sp. 1 | 21.66 |
| 4 | <i>Gallesia integrifolia</i> (Spreng.) Harms | 23.47 | <i>Syagrus sancona</i> H. Karst | 18.10 |
| 5 | <i>Ampelocera ruizii</i> Klotzch | 22.43 | <i>Caesaria gossypiosperma</i> Briq. | 15.78 |
| 6 | <i>Hura crepitans</i> L. | 15.38 | <i>Hura crepitans</i> L. | 12.10 |
| 7 | <i>Dendropanax cuneatus</i> (DC) Decne & Planch. | 13.73 | <i>Ampelocera ruizii</i> Klotzsch | 10.88 |
| 8 | <i>Sorocea guilleminiana</i> Gaudich. | 12.25 | <i>Astrocaryum murumuru</i> Mart. var. <i>murumuru</i> | 9.21 |
| 9 | <i>Ficus pertusa</i> L.f. | 7.18 | <i>Tabebuia</i> sp. 1 | 7.15 |
| 10 | <i>Terminalia</i> sp. 1 | 6.93 | <i>Jacaranda</i> sp. 1 | 7.01 |

Ochoo is mostly confined to the floodplain or riparian habitats in a natural state; thus, its appearance on the mound inventory makes up 5.12 percent of the total importance value there (i.e., 15.38/300 times IOO), with a frequency of 29.09 percent (i.e., 15 individuals/55 total individuals times IOO) suggests human interference (appendix 7.1; table 7.4). The sap of the ochoo tree is used as a fish poison by the Sirlono. The tree is also important on the Pampa Inventory (with 4.03 percent of the total importance value and a frequency of 9.43 percent; appendix 7.2, tables 7.3 and 7.4) and is the sixth ecologically most important species on both inventories (table 7.4).

The Widespread *Genipa americana* L., bi or genipapo, which has an edible fruit that is also used in native body painting, is frequently cultivated and occurs in a wide variety of habitats in Amazonia (van Roosmalen 1985:379). The plant is present on both inventories. *Sapindus saponaria* L., shared on both inventories, has many indigenous uses in lowland South America and its range may have been increased by humans (Paz Rivera 20°3:38-39, citing Briichner 1989).

The shared species with different degrees of ecological importance suggest exchange of germplasm between the two forest types. In some cases, species with high ecological importance values on the terra firme of the Mound Inventory have more recently migrated downslope and thus have lower ecological

importance in the Pampa Inventory (as with *A. murumuru* var. *murumuru*). In other cases, species with high ecological importance values in the Pampa Inventory may have migrated to the terra firme of the Mound Inventory and thus display much lower ecological importance values (as with *S. sancona*).

The human impact on the vegetation of the Mound Inventory becomes clear when noting species that occur only on terra firme. One of the most ecologically important of terra firme species is the moraceous *Sorocea guilleminiana* Gaudich, known as *turumburi* in Siriono. This culturally and ritually important tree produces a bright red fruit in bunches, from which the Siriono make a highly appreciated fermented beverage September through December. Siriono informants say it occurs only on mounds, and thus for the Sirlono it is the indicator species par excellence of anthropogenic mounds. Although it is not planted by humans per se (birds appear to be the zoochorous dispersal agents [Robert Langstroth, personal communication, 1999]), *Sorocea* sp. is present only because its typical habitat of permanent terra firme was created by humans in the remote past.

Both forests inventories contain many useful trees in a variety of categories, including food, fuel, construction material, medicine, stimulant, condiment, fish poison, and body adornment. The Mound Inventory has a somewhat higher proportion of useful species in all categories. Considering only the attribute of edibility (table 7.5), wild plant foods collected by the Siriono occurring within the Mound Inventory include the fruits of *turumburi* (*S. guilleminiana*), motacu (*A. phalerata*, fruits and heart of palm), sumuque (*S. sancona*, fruits), chonta palm (*Astrocaryum murumuru* Mart. var. *murumuru*, heart of palm), hog plum (*S. mombin*, fruits), pacay (*Inga* spp., fruits), murure (*Brosimum acutifolium* C. C. Berg, fruit and seeds), genipapo (*G. americana*, fruits), coquino (*Pouteria* sp. 1, which is quite possibly *Pouteria macrophylla*, a common denizen of old-forest fallows in eastern Amazonia, fruits), and aguai (*Pouteria* sp. 2, fruits). The highly prized, large, sweet, pulpy fruits of the sapotaceous species are considered important food items in the traditional Siriono diet in February, March, and April (Holmberg [1950] 1985:48-49). The frequency of fruit trees is 202 individual trees within 448 total trees, or 44.86 percent of the total. The introduced feral orange tree (*Citrus maxima* [Burman E] Merr.), which does not tolerate flooding, but has thrived in the anthropogenic conditions of the mounds, may have been spread by the Jesuits.

The Pampa and Mound inventories share five trees having edible fruits or seeds: *S. mombin*, *A. murumuru*, *A. phalerata*, *S. sancona*, and *G. americana* (table 7.5). The Pampa Inventory also has a few unidentified economic species as well as the well-known sterculiaceae (cacao family) *Guazuma ulmifolia* Lam., which has fruits considered to be edible throughout much of Amazonia. Fruit trees on the Pampa Inventory account for 41.86 percent of the ecological importance value of the inventory and a frequency of 5°58 percent. The figures

TABLE 7.5 Trees with Edible Fruits or Seeds in Sirion6 Culture Measured on the Mound Inventory and the Pampa Inventory

| Species at Mound | Relative Frequency | <i>N</i> | Species at Pampa | Relative Frequency | <i>N</i> |
|--|--------------------|----------|--|--------------------|----------|
| <i>Spondias mombin</i> L. | 0.446% | 3.93 | <i>Spondias mombin</i> L. | 0.705% | 3.04 |
| <i>Astrocaryum murumuru</i> Matt. vat. <i>murumuru</i> | 25.00% | 46.21 | <i>Astrocaryum murumuru</i> Mart. vat. <i>murumuru</i> | 3.52% | 9.21 |
| <i>Attalea phalerata</i> Mart ex. Spreng | 11.83% | 41.70 | <i>Attalea phalerata</i> Mart ex. Spreng. | 34.15% | 83.27 |
| <i>Syagrus sancona</i> H. Karst | 1.56% | 4.50 | <i>Syagrus sancona</i> H. Karst | 7.52% | 18.10 |
| <i>Inga quaternata</i> Poeppig. & Endl. | 0.446% | 1.29 | <i>Inga</i> sp. 17 | 0.705% | 1.78 |
| <i>Inga</i> sp. 1 | 0.223% | 0.67 | <i>Genipa americana</i> L. | 0.470% | 1.45 |
| <i>Brosimum acutifolium</i> C. C. Berg | 0.223% | 0.75 | <i>Pouteria</i> sp. 16 | 0.235% | 0.80 |
| <i>Sorocea guilleminiana</i> | 4.464% | 12.25 | <i>Pouteria</i> sp. 17 | 0.235% | 3.22 |
| <i>Genipa americana</i> L. Gaudich. | 0.223% | 0.94 | Sapotaceae sp. 11 | 0.235% | 1.65 |
| <i>Pouteria</i> sp. 1 (coquino) | 0.446% | 1.32 | Sapotaceae sp. 12 | 0.235% | 0.72 |
| <i>Pouteria</i> sp. 2 (aguai) | 0.223% | 0.62 | <i>Guazuma ulmifolia</i> Lam. | 0.705% | 2.42 |
| Totals | 45.08% | 113.82 | | 50.58% | 125.66 |
| (202 individual trees/448 = 44.86) | | | (215/425 = 50.58) | | |

are therefore comparable with the Mound Inventory: both inventories are heavily rich in fruit trees. In summary, the forests of the Mound and Pampa inventories may not have been planted and cultivated by humans, but these orchards of fruit trees are genuine and present because of, not in spite of, human influence, intentionality, and management, specifically in the building of the mound and its associated structures and attributes.

Finally, the alpha diversity, especially the turumburi tree (*S. guilleminiana*) in the Mound Inventory, can only be understood as caused by humans, given that species on the mounds normally occur only on terra firme (which, given the periodic geomorphological reworking of the floodplain, flooding, and high

water table, are rare in this part of the Bolivian Amazon). The alpha diversity of the Pampa Inventory is high for the region as a whole, given that it is surrounded by savannas characterized by fewer than 20 species regardless of DBH (Townsend 1995:22). The beta diversity is also high in both inventories (when we consider the Mound and Pampa inventories to be different habitat types, defined principally by slope differentiation, itself an artifact of human disturbance), given that they share only 22.22 percent of their species. In other words, species diversity of both inventories is lower than the classic high-canopy forests in Amazonia, yet the adjacent inventories share only about 23 percent of their species. The analysis suggests that long-term human activities are important for understanding alpha and beta diversity at the Ibiate Mound Complex and vicinity.

Although both forests are anthropogenic, the formative processes that created the Mound and Pampa inventories differ in specifics. The forest of the Mound Inventory is a direct artifact of past human activities on the mounds (dwellings, garbage accumulation, gardens, fields, and orchards). When the mounds were occupied, there was less vegetation due to dense housing and activity areas. The historical (anthropogenic) processes that shaped the vegetation in the Pampa Inventory may have been different. When the Ibiate Mound Complex was occupied, the low-lying area around the mounds was maintained as open savanna and managed as gardens, fields, and orchards. Despite being prone to annual flooding, the domestic debris found in soil probes to the northwest of Mound 1 suggests that the area supported dispersed houses. Some of this debris may have been intentionally mixed into the soils to enhance fertility. The presence of forest in the Pampa Inventory is probably due to the cessation of annual burning and farming, which occurred with the removal of native peoples from the landscape. The forests on both inventories were managed in pre-Columbian times, as they are today.

HISTORICAL ECOLOGY OF THE IBIBATE MOUND COMPLEX

The Ibiate Mound Complex is an excellent example of the complex temporal and biological dynamics of the landscape and the importance of humans with their associated cultural technologies in the shaping of that landscape. When the mounds were occupied, they and probably much of the surrounding landscape were relatively treeless. The presently occupied Ibiate Mound is a good analogy for what the Ibiate Mound Complex may have looked like as a low-density settlement (figure 7.7). Based on the density of artifact debris and information from archaeological excavations the Mendoza and Loma Alta de Casarabe mounds, we believe that the population density would have been higher in the pre-Columbian period. The number and density of inhabitants

living on the Ibibate Mound Complex and in the immediate vicinity would have had a massive effect on the local ecology. Hunting, burning, gathering, fuel collecting, garbage and human waste disposal, and earthwork construction were potent anthropogenic processes. The removal of humans from the mound and the surrounding landscape during the Colonial period, with the exception of small surviving groups of trekking and foraging bands, would have had a dramatic effect on the development of the vegetation assemblage and ecological complexity. After the mounds were abandoned as a settlement (which means cessation of house building, hearth use, pottery firing, garbage and fill accumulation, weed clearance, and other domestic activities), long-lived, woody vegetation colonized the mound, encouraged by the artificially organically enriched and well-drained soils. Many of these species survived and thrived because they were originally established on the mounds in gardens and fields. The deep water-filled barrow pits around the mounds protected the tree vegetation from sporadic fires that trekking and hunting peoples set on the savannas. Over time, a dense gallery forest became established on the mounds and along the old river levee. What appears to be a pristine canopy forest is actually a product of anthropogenic formation over a considerable period of time. During the period of intensive occupation of the Ibibate Mound Complex and other mounds of the area, gallery forests and forest islands were probably greatly reduced by cultivated fields and gardens, settlements, paths, and roads. Tree coverage was probably limited to small patches of forest along the old river levees, orchards, and fields in the fallow cycle (figure 7.8). Any forest that did exist was probably anthropogenic within gardens, orchards, forest fallow, and secondary growth in old fields and settlements.

Aerial photographs and satellite imagery show that much of the presently forested areas were once savanna grassland. This is particularly the case for the low-lying areas of seasonally inundated forest immediately to the east of the Ibibate Mound Complex (figure 7.1). In addition, much of the San Pablo Forest was once open savanna. Strips of original gallery forest along old river-channel levees can be distinguished from areas of old savanna that are now covered with a lower canopy of trees (figure 7.1). This landscape is clearly the product of less-intense human management in recent times, in particular a reduction in annual burning of the savanna, since the massive demographic collapse caused after the arrival of Europeans.

In summary, ethnographers, botanists, archaeologists, and foresters have recently begun collaborative research to document the long-term history of human use of the Amazon basin and of human impact on the environment. The collaborative effort herein derives its sustenance and guiding theoretical organization ultimately from our own diverse backgrounds—in this case, archaeology and ethnography/ethnobotany. The Ibibate Mound Complex provides an excellent case of massive pre-Hispanic human disturbance of a local

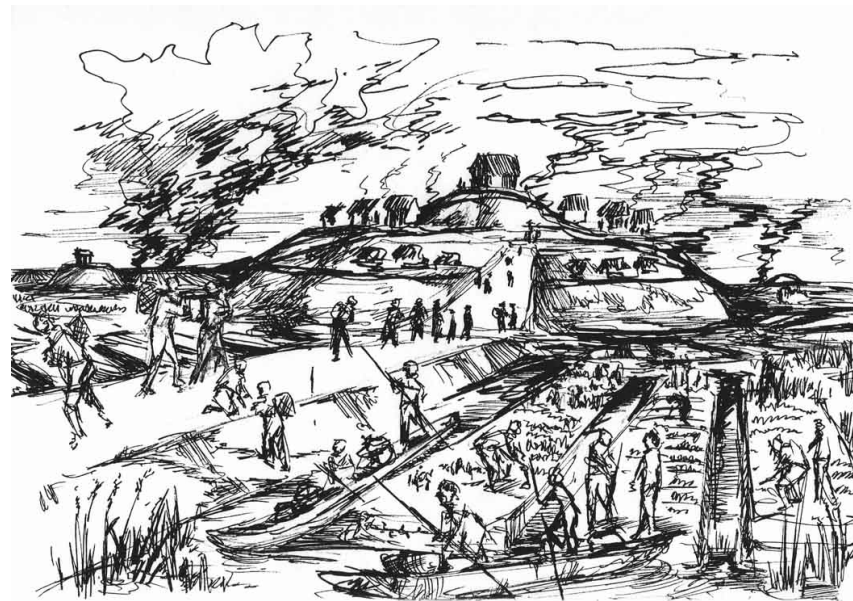


FIGURE 7.8 Reconstruction of a typical mound and cultural landscape in the Bolivian Amazon. (Artwork by Daniel Brinkmeier)

context through the construction of a large mound complex, excavation of large moatlike barrow pits, and generations of settlement, gardening, and slash-and-burn farming on the site. The mound complex is still used by the Siriono for collecting, hunting, and farming limited swidden fields (*chaco*). Balée created a detailed inventory of vegetation on and around the mound complex. Erickson's archaeological research provided context for these vegetation inventories. Specific results included mapping of the mounds and other earthworks; making surface collections of artifacts; and conducting subsurface testing to determine the age and use period of the mounds, the cultures associated, and the functions of the mounds. Limited archaeological survey was also conducted in the forest surrounding the mounds and in the savanna toward the Ibibate Mound Complex.

The massive effects of the long history of human transformation and creation of the environment can be seen in the landscape today. The sharp boundaries of forest-savanna and forest island-savanna are products of systematic anthropogenic burning. Many forest islands are artificial elevations created by human occupation and earthwork construction. Straight lines of trees on the savanna, some kilometers in length, grow on earthen causeways originally built for transportation, communication, and possibly water management. Many ponds (*pozas*) used for drinking water and fishing were created during construction of the large mounds for settlement and burial. The effect on transforming the soil

horizons-improving soil drainage and fertility through earthwork construction and incorporation of pottery, burned clay, charcoal, ash, and other organic matter-was profound. In some cases, it can be demonstrated that the natural hydrology of the region was altered through the construction of canals and causeways. The presence and distribution of fauna-in particular, the game animals prized by the Sirionó hunters-was greatly determined by anthropogenic processes. The long history of human disturbance and transformation of the landscape expanded and enhanced the habitats for these animals. Through disturbance and management, humans produced the ecotones where game is most abundant, in particular the thick stands of palms within the forests and along the forest-savanna edge, artificial sources of drinking water, forest-fallow fields with stands of economically important species, and soils amenable to agriculture and settlement. We conclude, therefore, that the landscape of the Ibibate Mound Complex and the Sirionó Indigenous Territory in general is not a pristine forest-savanna environment, but rather a record of a long history of human manipulation embedded in the land that can be read as a palimpsest.

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NOTES

1. See chapter 3, note 1, for a distinction between the use of *loma* in that chapter and the use in this chapter.
2. Alicia Duran Coirolo and Roberto Bracco Boksar (2000) provide an excellent survey of pre-Columbian mounds in the Americas.
3. Ibibare should not be confused with another name used frequently in this chapter, Ibiato (also spelled Iviato, Eviaro), the location of the main Sirionó community and also a pre-Columbian mound with an elevation of 9.5 meters.
4. Mound 1 was mapped using a Topcon 302 © EDM Surveying Instrument. Mound 2 was mapped using Brunton © compass and tape. The maps and perspectives (figures 7.2, 7.3, and 7.7) were created using SURFER 3.2 © and ArcView GIS 8.2 © mapping and geographical information system software.
5. Detailed descriptions and illustrations of the artifacts will be presented in future reports.
6. Our surface collections also show general similarities to pottery styles in the Hernmarck, Velarde, and Masquito mounds excavated by Nordenskiöld (1910, 1913, 1924). These mounds are located 30-40 kilometers to the south and southwest of the Ibibare Mound Complex.
7. Although we did not study the faunal biodiversity at the Ibibate Mound Complex, the mounds provide a dry habitat for burrowing animals that thrive in the highest elevations of the mounds. The Sirionó state that the mounds are excellent hunting

APPENDIX 7.1 Analysis of Woody Plant Species ³ 10-Centimeters DBH on One Hectare of Forest in the Mound Inventory at the Ibibare Mound Complex, Bolivia

| Family | Species | Number of Individuals | Number of Subplots of Occurrence | Basal Area (m ²) | Relative Density | Relative Frequency | Relative Dominance | Importance Value (IV) |
|-----------------|---|--------------------------|--|---------------------------------|---------------------|-----------------------|-----------------------|--------------------------|
| Achatocarpaceae | <i>Achatocarpus praecox</i> Griseb. | 1 | 1 | 0.037 | 0.37 | 0.22 | 0.13 | 0.72 |
| Anacardiaceae | <i>Spondias mombin</i> L. | 2 | 2 | 0.758 | 0.75 | 0.45 | 2.73 | 3.93 |
| Annonaceae | Annonaceae sp. 1 | 1 | 1 | 0.010 | 0.37 | 0.22 | 0.04 | 0.63 |
| Annonaceae | <i>Xylopia ligustrifolia</i> Humb. & Bonp. ex Dunal | 1 | 1 | 0.017 | 0.37 | 0.22 | 0.06 | 0.65 |
| Apocynaceae | <i>Aspidosperma</i> sp. 1 | 2 | 2 | 0.029 | 0.75 | 0.45 | 0.10 | 1.3 |
| Araceae | Indt.04 | 1 | 1 | 0.014 | 0.37 | 0.22 | 0.05 | 0.64 |
| Araliaceae | <i>Dendropanax arboreus</i> (L.) Decne. & Planchon | 3 | 3 | 0.573 | 1.12 | 0.67 | 2.07 | 3.86 |
| Araliaceae | <i>Dendropanax cuneatus</i> (DC.) Decne. & Planchon | 21 | 16 | 0.850 | 5.97 | 4.69 | 3.07 | 13.73 |
| Arecaceae | <i>Astrocaryum murumuru</i> Mart. var. <i>murumuru</i> (= <i>Astrocaryum chonta</i>) | 112 | 32 | 2.571 | 11.94 | 25.00 | 9.27 | 46.21 |
| Arecaceae | <i>Attalea phalerata</i> Mart. ex Spreng. (= <i>Scheelea princeps</i>) | 53 | 31 | 5.074 | 11.57 | 11.83 | 18.30 | 41.70 |

APPENDIX 7.1 (continued)

| Family | Species | Number of Individuals | Number of Subplots of Occurrence | Basal Area (m ²) | Relative Density | Relative Frequency | Relative Dominance | Importance Value (IV) |
|------------------|--|--------------------------|--|---------------------------------|---------------------|-----------------------|-----------------------|--------------------------|
| Arecaceae | <i>Syagrus sancona</i> H. Karst. | 7 | 6 | 0.195 | 2.24 | 1.56 | 0.70 | 4.50 |
| Bignoniaceae | Bignoniaceae sp. 14 | 4 | 3 | 0.039 | 1.12 | 0.89 | 0.14 | 2.15 |
| Bignoniaceae | <i>Clytostoma ulegnum</i> Kanzlin | 5 | 4 | 0.052 | 1.49 | 1.12 | 0.19 | 2.80 |
| Bignoniaceae | <i>Tabebuia capitata</i> (Bur. & K. Schum.) Sandw. | 2 | 2 | 0.038 | 0.75 | 0.45 | 0.14 | 1.34 |
| Bignoniaceae | <i>Tabebuia serratifolia</i> (M. Vahl) Nicholson | 2 | 2 | 0.028 | 0.75 | 0.45 | 0.10 | 1.30 |
| Bombacaceae | <i>Ceiba pentandra</i> Gaerrn. | 7 | 6 | 0.502 | 2.24 | 1.56 | 1.81 | 5.61 |
| Boraginaceae | <i>Cordia alliodora</i> (Ruiz & Pavon) Oken | 2 | 2 | 0.044 | 0.75 | 0.45 | 0.16 | 1.36 |
| Cecropiaceae | <i>Cecropia concolor</i> Willd. | 3 | 2 | 0.182 | 0.75 | 0.67 | 0.66 | 2.08 |
| Celastraceae | <i>Salacia impressifolia</i> (Miers) A.C. Smith | 2 | 2 | 0.023 | 0.75 | 0.45 | 0.08 | 1.28 |
| Chrysobalanaceae | <i>Hirtella triandra</i> Sw. subsp. <i>triandra</i> | 56 | 27 | 0.804 | 10.07 | 12.50 | 2.90 | 25.47 |
| Clusiaceae | <i>Calophyllum brasiliense</i> Cambess. | 5 | 5 | 0.939 | 1.87 | 1.12 | 3.39 | 6.38 |
| Combretaceae | <i>Terminalia</i> sp. 1 | 7 | 7 | 0.766 | 2.61 | 1.56 | 2.76 | 6.93 |

APPENDIX 7.1 (continued)

| Family | Species | Number of Individuals | Number of Subplots of Occurrence | Basal Area (m ²) | Relative Density | Relative Frequency | Relative Dominance | Importance Value (IV) |
|----------------|---|--------------------------|--|---------------------------------|---------------------|-----------------------|-----------------------|--------------------------|
| Euphorbiaceae | <i>Hura crepitans</i> 1. | 16 | 11 | 2.139 | 4.10 | 3.57 | 7.71 | 15.38 |
| Euphorbiaceae | <i>Sapium glandulosum</i> (1.) Morong | 7 | 6 | 0.473 | 2.24 | 1.56 | 1.71 | 5.51 |
| Fabaceae | <i>Fabaceae</i> sp. 1 | | | 0.050 | 0.37 | 0.22 | 0.18 | 0.77 |
| Fabaceae | <i>Machaerium</i> sp. 1 | | | 0.021 | 0.37 | 0.22 | 0.08 | 0.67 |
| Fabaceae | <i>Ormosianobilis</i> Tul. | | | 0.125 | 0.37 | 0.22 | 0.45 | 1.04 |
| Fabaceae | <i>Swartziajororii</i> Harms | 4 | 3 | 0.118 | 1.12 | 0.89 | 0.43 | 2.44 |
| Flacourtiaceae | <i>Casearia gossypiosperma</i> Briq. | 3 | 3 | 0.030 | 1.12 | 0.67 | 0.11 | 1.90 |
| INDT | Indt.02 | 3 | | 0.034 | 0.37 | 0.67 | 0.12 | 1.16 |
| Lauraceae | <i>Lauraceae</i> sp. 1 | 5 | 5 | 0.147 | 1.87 | 1.12 | 0.53 | 3.52 |
| Lauraceae | <i>Lauraceae</i> sp. 2 | | | 0.021 | 0.37 | 0.22 | 0.08 | 0.67 |
| Lauraceae | <i>Lauraceae</i> sp. 3 | | | 0.048 | 0.37 | 0.22 | 0.17 | 0.76 |
| Lauraceae | <i>Lauraceae</i> sp. 4 | | | 0.009 | 0.37 | 0.22 | 0.03 | 0.62 |
| Mimosaceae | <i>Acacia</i> sp. 1 | | | 0.015 | 0.37 | 0.22 | 0.05 | 0.64 |
| Mimosaceae | <i>Inga quatemata</i> Poeppig. & Endl. | 2 | 2 | 0.026 | 0.75 | 0.45 | 0.09 | 1.29 |
| Mimosaceae | <i>Inga</i> sp. 1 | | | 0.021 | 0.37 | 0.22 | 0.08 | 0.67 |
| Moraceae | <i>Brosimum acutifolium</i> C. C.Berg | | | 0.045 | 0.37 | 0.22 | 0.16 | 0.75 |

APPENDIX 7.1 (continued)

| Family | Species | Number of Individuals | Number of Subplots of Occurrence | Basal Area (m ²) | Relative Density | Relative Frequency | Relative Dominance | Importance Value (IV) |
|----------------|--|--------------------------|--|---------------------------------|---------------------|-----------------------|-----------------------|--------------------------|
| Moraceae | <i>Ficus insipida</i> Willd. | 2 | 2 | 0.111 | 0.75 | 0.45 | 0.40 | 1.60 |
| Moraceae | <i>Ficus pertusa</i> L.f | 6 | 5 | 1.102 | 1.87 | 1.34 | 3.97 | 7.18 |
| Moraceae | <i>Moraceae</i> sp. 2 | | | 0.015 | 0.37 | 0.22 | 0.05 | 0.64 |
| Moraceae | <i>Sorocea guilleminiana</i> Gaudich. | 20 | 12 | 0.919 | 4.48 | 4.46 | 3.31 | 12.25 |
| Olacaceae | <i>Heisteria nitida</i> Spruce ex Engler | | | 0.042 | 0.37 | 0.22 | 0.15 | 0.74 |
| Phyrolaccaceae | <i>Gallesia integrifolia</i> (Spreng.) Harms | 18 | 11 | 4.256 | 4.10 | 4.02 | 15.35 | 23.47 |
| Polygonaceae | <i>Coccoloba cujabensis</i> Weddell | | | 0.022 | 0.037 | 0.22 | 0.08 | 0.67 |
| Polygonaceae | <i>Triplaris americana</i> Fisch. & Meyer ex C. Meyer | 7 | 7 | 0.084 | 2.61 | 1.56 | 0.30 | 4.47 |
| Rubiaceae | <i>Calycophyllum</i> sp. 1 | | | 0.056 | 0.37 | 0.22 | 0.20 | 0.79 |
| Rubiaceae | <i>Genipa americana</i> 1. | | | 0.096 | 0.37 | 0.22 | 0.35 | 0.94 |
| Sapindaceae | <i>Sapindus saponaria</i> 1. | | | 0.106 | 0.37 | 0.22 | 0.38 | 0.97 |
| Sapindaceae | <i>Talisia hexaphylla</i> M. Vahl. | 6 | 6 | 0.096 | 2.24 | 1.34 | 0.35 | 3.93 |
| Saporaceae | <i>Pouteria</i> sp. 1 | 2 | 2 | 0.032 | 0.75 | 0.45 | 0.12 | 1.32 |
| Sapotaceae | <i>Pouteria</i> sp. 2 | | | 0.009 | 0.37 | 0.22 | 0.03 | 0.62 |
| Sapotaceae | <i>Sapotaceae</i> sp. 12 | 2 | 2 | 0.110 | 0.75 | 0.45 | 0.40 | 1.60 |
| Ulmaceae | <i>Ampelocera ruizii</i> Klotzsch | 28 | 14 | 3.039 | 5.22 | 6.25 | 10.96 | 22.43 |
| Verbenaceae | <i>Vitex cymosa</i> | 2 | 2 | 0.768 | 0.75 | 0.45 | 2.77 | 3.97 |
| TOTALS | | 448 | 268 | 27.730 | | | | 300.0 |

APPENDIX 7.2 Analysis of Woody Plant Species 3 to-Centimeters DBH on One Hectare of Forest in the Pampa Inventory at the Ibibate Mound Complex, Bolivia

| Family | Species | Number of Individuals | Number of Subplots of Occurrence | Basal Area (m ²) | Relative Density | Relative Frequency | Relative Dominance | Importance Value (IV) |
|---------------|--|--------------------------|--|---------------------------------|---------------------|-----------------------|-----------------------|--------------------------|
| Anacardiaceae | <i>Spondias mombin</i> L. | 3 | 3 | 0.275 | 1.29 | 0.71 | 1.04 | 3.04 |
| Apocynaceae | <i>Aspidosperma</i> sp. 1 | 5 | 5 | 0.142 | 2.16 | 1.18 | 0.54 | 3.88 |
| Apocynaceae | <i>Aspidosperma</i> sp. 5 | 2 | 0.026 | 0.026 | 0.86 | 0.47 | 0.10 | 1.43 |
| Araliaceae | <i>Dendropanax arboreus</i> Decne & Planchon | 1 | 1 | 0.010 | 0.43 | 0.24 | 0.04 | 0.71 |
| Araliaceae | <i>Schefflera</i> <i>morotoni</i> (Aubl.) M.S.F. | 1 | 1 | 0.016 | 0.43 | 0.24 | 0.06 | 0.73 |
| Arecaceae | <i>Astrocaryum</i> <i>murumuru</i> Mart. var. <i>murumuru</i> | 15 | 11 | 0.249 | 4.74 | 3.53 | 0.94 | 9.21 |
| Arecaceae | <i>Attalea phalerata</i> Mart. ex Spreng. (= <i>Scheelea princeps</i>) | 153 | 34 | 8.619 | 14.66 | 36.00 | 32.61 | 83.27 |
| Arecaceae | <i>Syagrus sancona</i> H. Karst | 32 | 18 | 0.742 | 7.76 | 7.53 | 2.81 | 18.10 |
| Bignoniaceae | <i>Clytostoma ulegnum</i> Kanzlin | 1 | 1 | 0.013 | 0.43 | 0.24 | 0.05 | 0.72 |
| Bignoniaceae | <i>Jacaranda</i> sp. 1 | 9 | 8 | 0.381 | 3.45 | 2.12 | 1.44 | 7.01 |
| Bignoniaceae | <i>Tabebuia</i> sp. 1 | 9 | 9 | 0.303 | 3.88 | 2.12 | 1.15 | 7.15 |

APPENDIX 7.2 (continued)

| Family | Species | Number of Individuals | Number of Subplots of Occurrence | Basal Area (m ²) | Relative Density | Relative Frequency | Relative Dominance | Importance Value (IV) |
|----------------|---|--------------------------|--|---------------------------------|---------------------|-----------------------|-----------------------|--------------------------|
| Bignoniaceae | Bignoniaceae sp. 22 | 2 | 1 | 0.021 | 0.43 | 0.47 | 0.08 | 0.98 |
| Bignoniaceae | Bignoniaceae sp. 38 | 1 | 1 | 0.009 | 0.43 | 0.2403 | 0.03 | 0.70 |
| Bombacaceae | <i>Ceiba pentandra</i> Gaern. | 5 | 5 | 0.287 | 2.16 | 1.18 | 1.09 | 4.43 |
| Boraginaceae | <i>Cordia</i> sp. 1 | 3 | 3 | 0.075 | 1.29 | 0.71 | 0.28 | 2.28 |
| Cecropiaceae | <i>Cecropia concolor</i> Willd. | 2 | 1 | 0.066 | 0.43 | 0.47 | 0.25 | 1.15 |
| Clusiaceae | <i>Calophyllum</i> <i>brasiliense</i> Camb. | 2 | 2 | 0.393 | 0.86 | 0.47 | 1.49 | 2.82 |
| Combretaceae | <i>Terminalia</i> sp. 1 | 5 | 5 | 0.157 | 2.16 | 1.18 | 1.98 | 5.32 |
| Euphorbiaceae | <i>Hura crepitans</i> L. | 10 | 6 | 1.893 | 2.59 | 2.35 | 7.16 | 12.10 |
| Euphorbiaceae | <i>Sapium</i> <i>glandulosum</i> (L.) Morong | 5 | 5 | 0.524 | 2.16 | 1.18 | 1.98 | 5.32 |
| Fabaceae | <i>Swartzia gregorii</i> Harms | 4 | 2 | 0.116 | 0.86 | 0.94 | 0.44 | 2.24 |
| Flacourtiaceae | <i>Casearia</i> <i>gossypiosperma</i> Briq. | 30 | 15 | 0.594 | 6.47 | 7.06 | 2.25 | 15.78 |
| INDET 32 | indt. 16 | 5 | 4 | 0.056 | 1.72 | 1.18 | 0.21 | 3.11 |
| INDET 33 | indt. 17 | 4 | 4 | 0.125 | 1.72 | 0.94 | 0.47 | 3.13 |
| INDET 35 | indt. 19 | 2 | 1 | 0.020 | 0.43 | 0.47 | 0.08 | 0.98 |

APPENDIX 7.2 (continued)

| Family | Species | Number of Individuals | Number of Subplots of Occurrence | Basal Area (m ²) | Relative Density | Relative Frequency | Relative Dominance | Importance Value (IV) |
|----------------|--|--------------------------|--|---------------------------------|---------------------|-----------------------|-----------------------|--------------------------|
| INDET36 | indt.20 | 5 | 4 | 0.153 | 1.72 | 1.18 | 0.58 | 3.48 |
| INDET38 | indt.22 | 2 | 1 | 0.021 | 0.43 | 0.47 | 0.08 | 0.98 |
| INDET 40 | indt.24 | 1 | 1 | 0.008 | 0.43 | 0.24 | 0.03 | 0.79 |
| INDET41 | indt.25 | 1 | 1 | 0.010 | 0.43 | 0.24 | 0.04 | 0.71 |
| INDET42 | indt.26 | 1 | 1 | 0.016 | 0.43 | 0.24 | 0.06 | 0.73 |
| INDET43 | indt.29 | 4 | 3 | 0.149 | 1.29 | 0.94 | 0.56 | 2.779 |
| Lauraceae | Lauraceaes. 1 | 1 | 1 | 0.012 | 0.43 | 0.24 | 0.05 | |
| Lauraceae | Lauraceaes. 26 | 3 | 2 | 0.054 | 0.86 | 0.71 | 0.20 | 1.77 |
| Mimosaceae | <i>Acacia</i> sp. 1 | 1 | 1 | 0.008 | 0.43 | 0.24 | 0.03 | 0.70 |
| Mimosaceae | <i>Anadenanthera colubrina</i> (Yell. Conc.) Benth. | 2 | 2 | 0.407 | 0.86 | 0.47 | 1.54 | 2.87 |
| Mimosaceae | <i>Ingas</i> sp. 17 | 3 | 2 | 0.055 | 0.86 | 0.71 | 0.21 | 1.78 |
| Mimosaceae | Mimosaceaes. 25 | 1 | 1 | 0.029 | 0.43 | 0.24 | 0.11 | 0.78 |
| Mimosaceae | Mimosaceaes. 28 | 2 | 2 | 0.103 | 0.86 | 0.47 | 0.39 | 1.72 |
| Moraceae | <i>Ficus</i> sp. 1 | 6 | 5 | 4.782 | 2.16 | 1.41 | 18.09 | 21.66 |
| Phytolaccaceae | <i>Galleia integrifolia</i> (Spreng.) Harms | 31 | 19 | 2.026 | 8.19 | 7.29 | 7.67 | 23.15 |

APPENDIX 7.2 (continued)

| Family | Species | Number of Individuals | Number of Subplots of Occurrence | Basal Area (m ²) | Relative Density | Relative Frequency | Relative Dominance | Importance Value (IV) |
|---------------|--|--------------------------|--|---------------------------------|---------------------|-----------------------|-----------------------|--------------------------|
| Polygonaceae | <i>Muehlenbeckia</i> sp. 2 | 1 | 0.013 | 0.43 | 0.24 | 0.05 | 0.72 | |
| Polygonaceae | <i>Triplaris americana</i> Fisch. & Meyer ex C. Meyer | 6 | 6 | 0.090 | 2.59 | 1.41 | 0.34 | 4.34 |
| Rubiaceae | <i>Calycophyllum</i> sp. 1 | 6 | 3 | 0.404 | 1.29 | 1.41 | 1.53 | 4.23 |
| Rubiaceae | <i>Genipa americana</i> L. | 2 | 1 | 0.145 | 0.43 | 0.47 | 0.55 | 1.45 |
| Sapindaceae | <i>Sapindus saponaria</i> L. | 1 | 1 | 0.012 | 0.43 | 0.24 | 0.05 | 0.72 |
| Sapindaceae | Sapindaceae indt. 10 | 1 | 1 | 0.011 | 0.43 | 0.24 | 0.04 | 0.71 |
| Sapindaceae | <i>Talisia hexaphylla</i> M. Vahl. | 8 | 8 | 0.240 | 3.45 | 1.88 | 0.91 | 6.24 |
| Sapotaceae | <i>Pouteria</i> sp. 16 | 1 | 1 | 0.035 | 0.43 | 0.24 | 0.13 | 0.80 |
| Sapotaceae | <i>Pouteria</i> sp. 17 | 1 | 1 | 0.673 | 0.43 | 0.24 | 2.55 | 3.22 |
| Sapotaceae | Sapotaceaes. 11 | 1 | 1 | 0.259 | 0.43 | 0.24 | 0.98 | 1.65 |
| Sapotaceae | Sapotaceaes. 12 | 1 | 1 | 0.012 | 0.43 | 0.24 | 0.05 | 0.72 |
| Sterculiaceae | <i>Guazuma ulmifolia</i> Lam. | 3 | 3 | 0.110 | 1.29 | 0.71 | 0.42 | 2.42 |
| Ulmaceae | <i>Ampelocera Ruizii</i> Klorzsch | 14 | 8 | 1.093 | 3.45 | 3.29 | 4.14 | 10.88 |
| TOTAL | | 425 | 232 | 26.158 | | | | 299.1 |

locations for the game they prize, probably attracted to the fruiting trees. The complex microtopography of the earthwork complex provides numerous artificially created ecotones between terrestrial and aquatic environments. The water-filled barrow pits or ponds provide stable habitats for fish and other aquatic species and year-round drinking water for terrestrial animals (also see Townsend 1995, 1996).

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