Climate Change and Cultural Dynamics: A Global Perspective on Mid-Holocene Transitions
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Chapter 4

Mid-Holocene climate and cultural dynamics in Brazil and the Guianas

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Abstract

It was assumed until recently that the climate and vegetation of the Neotropical lowlands were not significantly altered during the Pleistocene. This impression has been refuted by a variety of paleoclimatological evidence that indicates both Amazonia and the Brazilian coast were cooler and drier prior to ca. 7000 ^{14}C yr BP. In both regions, the forest was substantially reduced and the predominant vegetation was grass and shrubs. The similarity of the environment is reflected in the similarity of the subsistence remains and artifacts in rock shelters and open sites throughout both regions from the inception of human occupation ca. 13,000 ^{14}C yr BP until development of Holocene conditions. Simultaneously, culmination of sea level rise created new aquatic habitats along the coast and the floodplain of the Amazon with more concentrated protein resources. These ameliorations permitted larger and more sedentary communities, but inherent limitations to intensive agriculture and dependence on wild protein sources placed a ceiling on population concentration throughout the lowlands.

1. Introduction

The region considered here includes the largest extent of tropical rainforest on the planet, bounded on the south by a relatively arid coastal upland extending from tropical to temperate latitudes and on the north by lower and increasingly seasonal rainfall. At present, there is an abrupt ecological frontier between Amazonia and the Brazilian Coastal Strip, marked by the coincidence of three environmental features: (1) the boundary between the equatorial and transitional bioclimatic regions, (2) the southern margin of Amazonian rainforest vegetation, and (3) the limit of the northern physiographic zone. These differences are reflected in different types of modern land use (Fig. 4.1; Brochado et al., 1970). A similar, but less abrupt transition exists in the north, where rainforest becomes increasingly fragmented by more open vegetation culminating in the savannas of the Orinoco.

This pattern was considered to be ancient and unaffected by the climatic fluctuations that transformed temperate landscapes during the Pleistocene until the 1970s, when it was observed that the modern distributions of related species of Amazonian forest birds do not coincide with present environmental barriers to interbreeding. This suggested that the rainforest had been fragmented during the Pleistocene into "refugia" separated by more open types of vegetation that isolated ancestral populations

Figure 4.1. Present ecological boundary between the Coastal Strip and the Amazon Basin. A, Limit between the equatorial and transitional bioclimatic regions; B, Limit of Amazonian vegetation; C, Limit of the northern physiographic zone; D, Differences in land use (after Brochado et al., 1970, Fig. 1).

for sufficient time to permit their diversification (Haffer 1969, 1974; Prance, 1982; Hooghiemstra and van der Hammen, 1998). Although still disputed by some (e.g. Colinvaux and Oliveira, 2001; Cowling et al., 2001), the existence of fluctuations in the composition and distribution of the vegetation both in Amazonia and on the Coastal Strip during the late Pleistocene and early Holocene is increasingly supported by a variety of biogeographical, palynological, paleoecological, hydrological, geomorphological, sedimentological, and climatological data (Haffer and Prance, 2001).

Better understanding of the impact of atmospheric fluctuations such as the ENSO phenomenon and the Intertropical Convergence Zone (ITCZ), as well as identification of sea level changes and coastal dynamics, oceanic temperature variation, and marine sediment composition, increasingly supplement evidence for environmental changes based on terrestrial sources both in Amazonia and on the Coastal Strip. The geographical extent, frequency, intensity, and duration of these

environmental fluctuations must be taken into consideration in reconstructing and interpreting precolumbian cultural development.

In Amazonia, recognizing significant cultural changes prior to the adoption of pottery is hampered by the combination of poor preservation of perishable remains and impermanent settlement in open locations. However, lithic camp and workshop sites and a long series of ^{14}C dates attest to the presence of humans by ca. 13,000 ^{14}C yr BP (uncal.) and indirect evidence of prehistoric population movements is provided by the disjunct distributions of languages, genetic traits, and cultural elements among surviving indigenous groups. On the Brazilian Coastal Strip, shell middens and rock shelters preserve bone and shell artifacts, burials, and subsistence remains that amplify the record left by camp sites and rock art.

In the following discussion, I will summarize the evidence for paleoclimatological fluctuations and prehistoric cultural changes since ca. 13,000 ^{14}C yr BP (uncal.) separately for the Coastal Strip and the Amazon Basin. Both the climatological and cultural data indicate that these now distinct regions experienced long- and short-term environmental fluctuations during and since the Pleistocene that favored the emergence and perpetuation of similar general cultural configurations.

2. The coastal strip

This region, known geographically as the Brazilian highlands, is dominated by the Brazilian shield. Elevation rises to between 500 and 1500 m from southern Piauí across western Bahia, Goiás, Minas Gerais, São Paulo, Paraná, and Mato Grosso do Sul, with sporadic increases to 3000 m in Minas Gerais and São Paulo. Escarpments containing rock shelters are common, especially in Goiás and Minas Gerais. As elevation increases, annual rainfall decreases from above 1550 to 400–600 mm and changes from seasonal to intermittent. Present latitudinal variations in climate create three general vegetational zones. In the north, with 5–6 month dry season, cerrado (savanna and scrub woodland) predominates. In the center, with a 2–5 month dry season, semi-deciduous forest is characteristic. In the south, with no significant dry season, *Araucaria* forest is typical (Ledru et al., 1998b). A narrow strip of rainforest extends along the Atlantic coast as far south as Espírito Santo. The only major river is the São Francisco, which flows north before turning east to empty into the Atlantic. Between Bahia and Espírito Santo, a few small rivers flow east from the coastal highland, but drainage farther south is principally toward the west into the south-flowing Paraná. A specialized lacustrine habitat that developed along the shoreline from Espírito Santo to Rio Grande do Sul as sea level rose offered unique opportunities for human exploitation.

2.1. Paleoclimatic fluctuations

Evidence comes from two principal sources: terrestrial and marine pollen cores (Fig. 4.2) and sea-level changes.
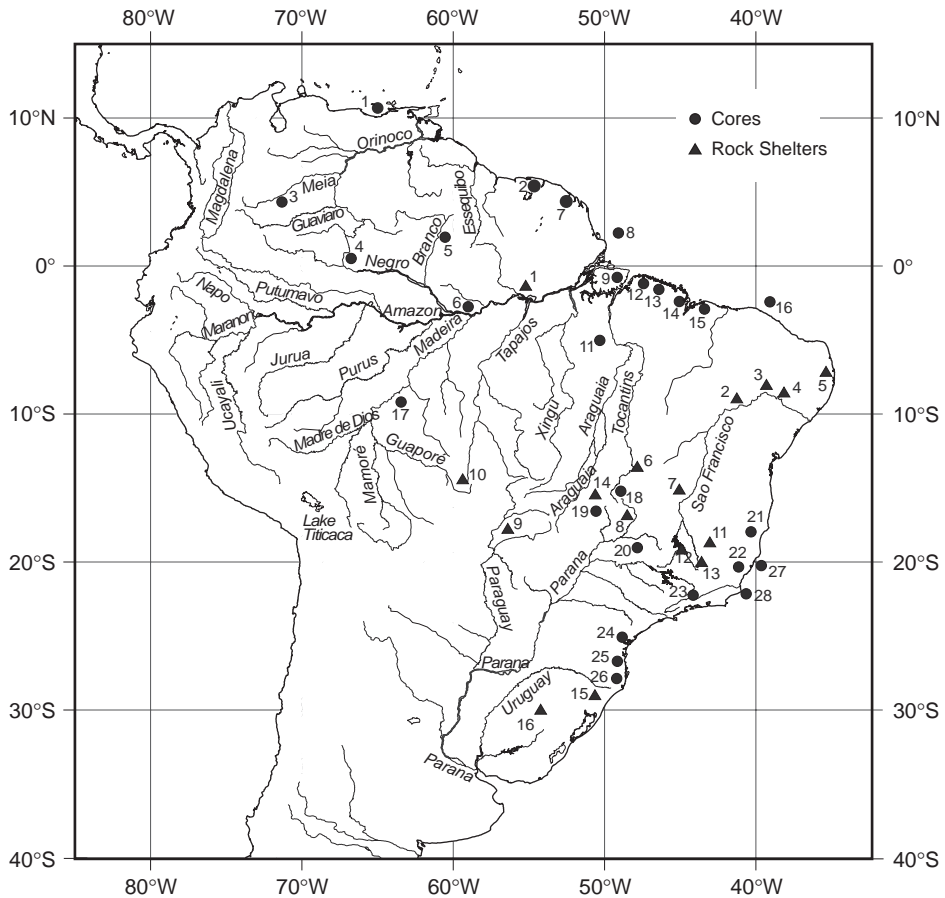
Figure 4.2. Locations of pollen cores and rock shelters mentioned in the text. Pollen cores: 1, Cariaco Basin; 2, Ogle Bridge; 3, Agua Sucia; 4, Pata; 5, Moriru; 6, Manaus; 7, Sinnamary; 8, Amazon Fan; 9, Ararí; 10, Curuá; 11, Carajás; 12, Curuça; 13, Crispim; 14, Bragança; 15, Caçó; 16, GeoB 3104-1; 17, Katira; 18, Aguas Emendadas; 19, Cromínia; 20, Salitre, Serra Negra; 21, Lago de Pires; 22, Catas Altas; 23, Itapeva; 24, Campos Gerais; 25, Poço Grande; 26, Boa Vista; 27, GeoB 3219-2; 28, GeoB 3202-1. Rock shelters: 1, Pedra Pintada; 2, Pedra Furada/Calderão do Rodriguez; 3, Sítio do Meio; 4, Gruta do Padre; 5, Pedra do Caboclo/ Bom Jardim; 6, Barreiro; 7, Boquête/Boqueirão Soberbo/Varal/Pequena; 8, Gentio/Foice; 9, Santa Elina; 10, Abrigo do Sol; 11, Santana do Riacho; 12, Lagoa Santa; 13, Lapa Vermelha; 14, Serranópolis; 15, Cerrito Dalpiaz; 16, RS-TQ-58.

2.1.1. Palynological evidence

The predominance of grass and other non-arboreal taxa throughout the coast during the Late Pleistocene implies markedly drier and 5–7°C cooler conditions (Behling et al., 2001, 2002; Ledru et al., 2001; Behling, 2002b). In the south, development of modern climatic conditions with warmer temperatures and brief or no dry periods

after ca. 4000 ^{14}C yr BP permitted the expansion of *Araucaria* and semi-deciduous forest (Behling, 1997; Ledru et al., 1998b). In the north, increasing seasonality, precipitation, and temperature allowed development of the heterogeneous vegetation of the cerrado (Ledru, 2002; Oliveira and Marquis, 2002). Regional diversity is implied, however, by the occurrence in Minas Gerais of landslides, peat deposits overlying erosional surfaces, and palm swamps indicative of episodes of torrential rain (Salgado-Labouriau et al., 1998), whereas drier conditions existed at Lago do Pires on the coast (Behling, 1998).

Regional variation in climate is also attested by a progressive decline in arboreal taxa between ca. 6500 and 4000 ^{14}C yr BP at Carajás. The abundance of pollen of pioneer vegetation is attributable to frequent droughts of short duration and associated fires that prevented the development of mature forest. By contrast, higher rainfall prevailed during this period in Santa Catarina (Martin et al., 1995a; Alexandre et al., 1999).

2.1.2. Sedimentological evidence

Hiatuses of 10,000 or more years in ^{14}C dates and abrupt changes in sedimentation rate and lithography in terrestrial and marine pollen cores at Salitre, Ipeva, Serra Negra, Cromínia, Aguas Emendadas, GeoB 3104-1, GeoB 3329-2, and GeoB 3202-1 also imply drought and colder temperatures during the Late Glacial Maximum (Fig. 4.3; Ledru et al., 1998a; Behling et al., 2000, 2002). Soil profiles from Paraná,
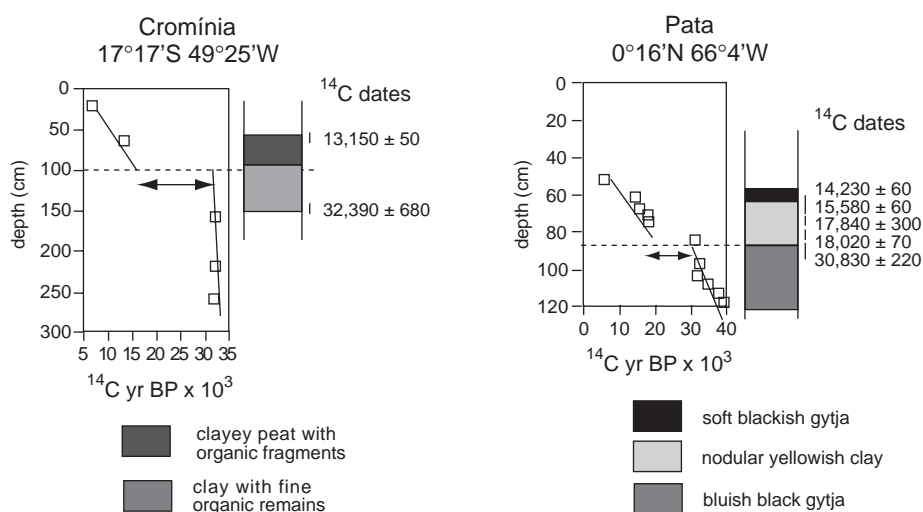

Figure 4.3. Correlation between gaps in ^{14}C dates and discontinuities in the stratigraphic records in cores from Cromínia (MG) and Pata (AM), implying a hiatus in sediment deposition lasting several millennia during the Late Glacial Maximum and accounting for the seeming continuity of forest vegetation (after Ledru et al., 1998a, Fig. 3).

São Paulo, and Minas Gerais show charcoal throughout, implying paleofires during the late Pleistocene/Holocene consistent with drier climate (Pessenda et al., 2004).

Parabolic compound dunes of eolian sand extend over an area ca. 7000 km^2 west of the middle São Francisco in Bahia, where the present climate is semi-arid and rainfall is sufficient to support caatinga vegetation. Twelve ^{14}C dates from different locations identify episodes of increased deposition ca. 4800, 3300, and 1700-850 ^{14}C yr BP (Barreto et al., 1996). This period is placed in larger temporal perspective by a pollen sequence from an adjacent peat bog, which shows a progressive decline in forest taxa from ca. 8910 to 6790 ^{14}C yr BP suggesting semi-arid conditions. Moisture increased between ca. 6230 and 4535 ^{14}C yr BP, followed by a marked decline thereafter and establishment of modern semi-arid conditions (Oliveira et al., 1999).

2.1.3. Sea level change

Systematic investigations along the Brazilian coast between Alagoas and Rio Grande do Sul have identified dead reefs, fossilized burrows of a marine arthropod, gastropod deposits, sea-urchin holes, and sandy beach deposits above present high-water level that provide the basis for detailed reconstruction of changes in sea level (Villwock et al., 1986; Suguio et al., 1988, 1991). More than 700 ^{14}C determinations permit correlating the local histories of the most recent transgression.

All of the regions sampled show a similar pattern, consisting of a rise ca. 7000 ^{14}C yr BP to ± 1 m above present mean sea level, a sudden spurt ca. 5100 ^{14}C yr BP to ± 4.8 m, followed by a rapid and then more gradual decline ca. 4100 ^{14}C yr BP to 0 or slightly below, a second rise between ca. 3800 and 3600 ^{14}C yr BP to ± 3.5 m, a brief drop, a third rise ca. 2500 ^{14}C yr BP to ± 2.5 m, followed by a slow decline to zero. Although the maximum elevation was achieved simultaneously throughout the coast, onset was delayed until ca. 6600 ^{14}C yr BP from São Paulo south. Elevation reached only ± 4 m on the coast of São Paulo and 2.5 m on the coast of Paraná (Fig. 4.4; Suguio et al., 1988 pp. 205–206; Angulo and Suguio, 1995). The substrates, locations on paleo-lagoons, and height above present sea level of selected sambaquis on the coast of São Paulo and the δ13C values of constituent molluscs are compatible with this paleoenvironmental reconstruction (Suguio et al., 1991). Stabilization of sea level allowed the formation of lagoons and marshes with varying saline composition, with resulting diversification of flora and fauna (Lorscheitter and Dillenburg, 1998; Ybert et al., 2003).

Another perspective on shoreline fluctuation is provided by beach ridges along the central coast, which record repeated reversals in the direction of transport of sand during the past 5100 years. Observation of a reversal produced by changes in ocean-swell patterns during the 1982–1983 ENSO event suggests that "the long periods of reversed long-shore transport are associated with long periods of blocking conditions of frontal systems related to El Niño-like conditions." The much higher volumes of sand accumulated during earlier reversals imply persistence of a low Southern Oscillation index during several decades and document climatic
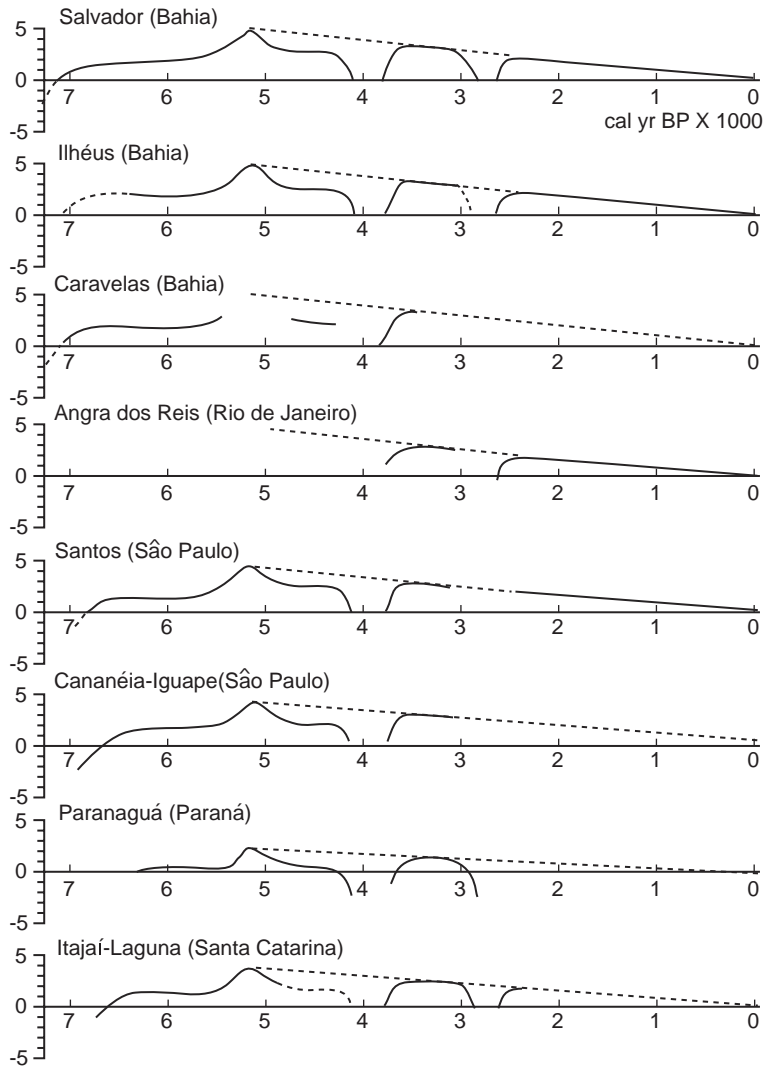
Figure 4.4. Changes in relative sea level along the Brazilian coast since ca. 7000 ^{14}C yr BP. All regions show a similar descending pattern and chronology from a maximum ca. 5100 ^{14}C yr BP. Vertical scale = meters above or below present mean sea level (after Suguio et al., 1988).

fluctuations too brief to be detectable in geological and palynological records, but sufficient to affect human populations inland as well as on the shore (McClone et al., 1992; Martin et al., 1993, p. 345, 1995a,b, 1996).

North of the mouth of the Amazon, the impact of sea level rise was minimized by the deposition of substantial amounts of Amazon sediment along the coast. About 20% of the annual discharge is carried northward along the Guianas, where it forms mud banks. Stable conditions were achieved by ca. 6000 ^{14}C yr BP and

subsequent changes in shoreline fauna and flora are attributable to increased salinity rather than to sea level fluctuations (Williams, 1992; Clapperton, 1993, pp. 570–571; Nittrouer et al., 1995, p. 181; Sommerfield et al., 1995, p. 353).

2.2. Archaeological evidence

2.2.1. Inland sites

In the north, the vast majority of the known preceramic sites are rock shelters, reflecting the abundance of these features in the landscape. Preceramic open sites have been encountered where survey has been conducted in Goiás and western Bahia, but information on their extent, composition, and antiquity is slight (Schmitz et al., 1996). Rock art, executed either by engraving or painting, is also most abundant here. Regional and chronological styles have been recognized, but their social context is unknown (Prous, 1994; Aguilar, 1996; Martin, 1996; Etch-evarne, 1999–2000; Martin and Asón, 2000). Open sites predominate in the south; several lithic traditions have been defined in both regions.

Rock shelters

Pedra Furada in Piauí, Santana do Riacho and Boquête in Minas Gerais, and rock shelters in the Serranópolis region of Goiás have occupations beginning ca. 11,000 ^{14}C yr BP (Fig. 4.2; Schmitz, 1987a; Schmitz et al., 1989, 2004; Prous, 1991, 1994; Barbosa, 1992; Guidon et al., 1994; Kipnis, 1998; Prous and Fogaça, 1999). Faunal remains include deer, peccary, armadillo, rodents, marsupials, and birds, as well as terrestrial and freshwater molluscs. Plant remains represent a wide variety of edible seeds, nuts, fruits, and roots. Large, elongated, unifacial blades suitable for cutting and scraping, produced by percussion, are diagnostic of the widespread Itaparica Tradition; unformalized flakes, cores, and pounders are also character-istic. About 9000 ^{14}C yr BP, bifacial tools elaborated from flakes were added, along with bone points. Where sufficient radiocarbon dates have been obtained to provide reliable evidence, they show most of the rock shelters were abandoned between ca. 7000 and 4000 ^{14}C yr BP, when resumption of warmer and wetter conditions increased the abundance and variety of terrestrial and aquatic subsistence resources (Ab'Sáber, 1980). Although some were reoccupied after ca. 2500 ^{14}C yr BP, most were used later only for burial or rock art (Fig. 4.5; Dias, 1991, pp. 69–70; Mentz Ribeiro and Ribeiro, 1999; Araujo et al., 2005).

Open sites

Rare buried sites of the Ibucuí Phase dating ca. 12,700 ^{14}C yr BP have been encountered along the left bank of the Rio Uruguai on the western boundary of Rio Grande do Sul (Miller, 1987). The following Uruguai Phase, represented at numerous locations between ca. 11,000 and 8500 ^{14}C yr BP, is characterized by
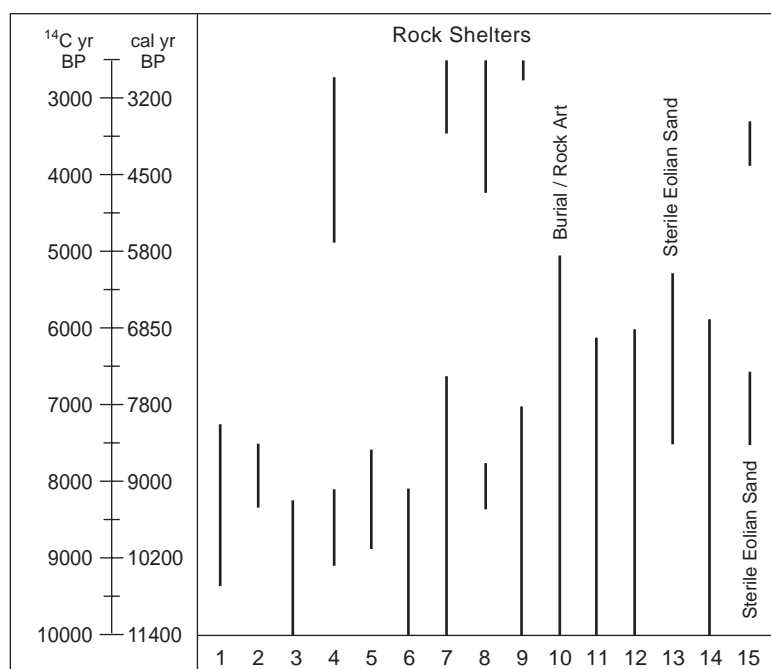
Figure 4.5. Rock shelters with sufficient ^{14}C dates to identify a hiatus between abandonment for habitation during the Pleistocene/Holocene transition and resumption of use for burial or art. 1, RS-TQ-58; 2, Lapa Pequena; 3, Lapa Varal; 4, Boqueirão Soberbo; 5, Barreiro; 6, Santana do Riacho; 7, Lapa do Gentio; 8, Lapa do Foice; 9, Boquête; 10, Lapa Vermelha; 11, Pedra Furada; 12, Calderão do Rodriguez; 13, Gruta do Padre; 14, Abrigo do Sol; 15, Pedra Pintada.

several kinds of stemmed projectile points, as well as scrapers, flakes, and expedient tools. Two contemporary traditions diverged about 7000 ^{14}C yr BP: Umbu characterized by bifacial-stemmed projectile points and Humaitá by large choppers and bifaces. Numerous habitation sites of both traditions have been recorded from Paraná to Rio Grande do Sul, those of the Humaitá Tradition associated with forested regions and those of the Umbu Tradition with more open vegetation (Schmitz, 1987b; Mentz Ribeiro, 1991; Rodríguez, 1992, Figs. 4–5).

Excavation of Cerrito Dalpiaz, a rock shelter in eastern Rio Grande do Sul occupied between ca. 5900 and 4200 ^{14}C yr BP by representatives of the Umbu Tradition, revealed a 50-cm thick stratum composed of thin lenses of ash and sand containing abundant postholes, faunal remains, artifacts, and lithic debitage. Animals of all sizes were hunted, but peccary, deer, tapir, and armadillo were most common. Fruit, snails, and molluscs were also consumed. Ovoid and pentagonal projectile points predominate initially, giving way gradually to a variety of stemmed forms with straight, convex, or concave bases. Bifacial knives, scrapers, and choppers, pitted anvil stones, small mortars with traces of red pigment, and hammer stones are also typical. Bone and horn artifacts include perforators,

spatulas, pressure flakers, and fishhooks. Circular shell beads, small gastropod shells, and animal teeth were used for personal adornment (Miller, 1969).

Projectile points rarely occur in sites of the contemporary Humaitá Tradition and the diagnostic artifact is a straight or boomerang-shaped, percussion-flaked tool. Large choppers, scrapers, and bifaces predominate and are often worked only along the margins.

Although regional and chronological variations in lithics and rock art existed prior to 4000 ^{14}C yr BP, the basic settlement behavior and material culture remained generally uniform and relatively stable (Bryan and Gruhn, 1993, p. 162; also Rodríguez, 1992; Schmitz et al., 1996). The appearance of domesticated cucurbits, peanuts, beans, and cotton in several rock shelters in Minas Gerais ca. 4000 ^{14}C yr BP correlates with a shift in settlement to open locations and increased abundance of bifacial projectile points and scrapers, and polished axes (Bird et al., 1991; Dias, 1993). Several regional pottery traditions appeared between ca. 2000 and 1500 ^{14}C yr BP, associated with different types of environment and contemporary with the widespread Tupiguarani Tradition. Social and settlement behavior are similar to those in Amazonia (Brochado et al., 1970; Oliveira and Viana, 1999–2000).

2.2.2. Shoreline sites

Two kinds of shoreline sites have been distinguished: (1) shell middens, known in Brazil as sambaquis and (2) habitation sites of the Itaipu Tradition, located on coastal dunes and containing minor amounts of shell.

Sambaqui Tradition

More than 1000 shell middens have been recorded along the margins of extinct and extant shallow bays and lagoons along the coast of Pará east of the mouth of the Amazon and in scattered locations between Maranhão and Bahia, but are most abundant in the south between Espírito Santo and Rio Grande do Sul. Most attention has been focused between Rio de Janeiro and Paraná, where mangrove borders canals, lagoons, bays, and estuaries that provide a wide range of diverse habitats for aquatic flora and fauna. Tabulation of 288 ^{14}C dates from 141 southern sites by 500-year intervals shows rare occurrences prior to 5500 ^{14}C yr BP, when sea level peaked, and a decline in density after 3000 ^{14}C yr BP, when sea level stabilized leading to desiccation of lagoons and decline in subsistence resources (Ybert et al., 2003). Dimensions range from ca. 15 m long and 1 m high to 300 m long and 32 m high (Schmitz, 1998). Where conditions were most favorable, density reached 23 or more in an area of 420 km^2. In this region, isolated between the ocean and the Serra do Mar, settlement appears to have been permanent, whereas the sambaquis of Rio Grande do Sul constitute seasonal occupations by inland preceramic and ceramic groups (Schmitz, 1998; Tenório, 1998).

Some 50 species of molluscs have been identified, but four sediment-dwelling and one mangrove species comprise the vast majority (Mello, 1999). Condition varies

from finely crushed to largely intact specimens. Bones of freshwater fish constitute up to 95% of the vertebrate remains in some sites; other aquatic resources include mammals (whale, dolfin), turtles, and crabs. Monkeys, armadillos, rodents, and other terrestrial fauna are abundant in some sites and absent in others. Analysis of the faunal remains at two sites along the coast of Rio de Janeiro indicated that permanent occupation could be sustained by intensive exploitation of the resources available within a radius of 2 km (Gaspar, 1995–1996; Kneip, 1998).

Cultural remains are exceeding rare in the large sambaquis on the coast of Rio Grande do Sul, the most striking objects being rare zooliths: geometric and zoomorphic ground-stone sculptures with a depression on one surface (Bryan, 1993; Gaspar, 1998; Kneip, 1998). Postholes, hearths, burials, and artifacts are often common in the smaller ones to the north. Postholes, sometimes associated with clay floors, suggest single circular or elliptical dwellings ranging from ca. 3×3 m to 14 m^2 (Gaspar, 1998, Table 2). Irregularly shaped picks, scrapers, blades, choppers, hammers, and projectile points were produced by percussion from quartz and andesite cores and flakes. Semi-polished artifacts include pestles, celts, and rubbing stones. Perforated fish vertebrae, drilled shark teeth, shell beads, and bone perforaters, spatulas, and projectile points also occur. The absence of fishhooks in sites along lagoons suggests that cast or stationary nets were used (Figuti, 1994–1995). Evidence of territoriality, contemporaneity, social inequality, and other aspects of social organization and demography remains equivocal (Blasis et al., 1998).

Whereas the southern shell middens are aceramic, several along the north coast of Brazil contain undecorated pottery. The Mina Tradition on the coast of Pará has an initial date of ca. 5000 ^{14}C yr BP, whereas the Periperi Tradition on the coast of Bahia is dated ca. 2800 ^{14}C yr BP (Calderon, 1969; Simões, 1981).

Itaipu Tradition

Populations of this tradition occupied fossil beaches or dunes accessible to forest, grassland, swamp, and lagoon habitats along the coasts of Rio de Janeiro and Espírito Santo between ca. 4500 and 1500 ^{14}C yr BP (Dias, 1992). Subsistence emphasized terrestrial resources and the faunal remains suggest the people ate anything that moved from mammals, reptiles, and birds to amphibians and insects, as well as fish and molluscs. High consumption of carbohydrates is implied by a frequency of caries exceeding that of agricultural groups and the associated unusual pattern of dental wear has been attributed to using the teeth to strip plant tissue. The high frequency of caries contrasts with their near absence among sambaqui populations (Machado, 1992). Lithic artifacts include pebble tools, grinding stones, and pitted anvil stones, as well as quartz flakes. Shell tools and ornaments are also common. Bone implements include projectile points and spatulas.

Dwellings defined by postholes vary from 3–4 m^2 to more than 30 m^2, with the larger ones typically located on the inland side of the site. The floor was hard-packed silt. Superposition of occupation levels and the abundance of burials in some sites imply their use during several millennia. An average separation of ca. 6 km between

sites on the coast of Rio de Janeiro suggests they may have been central bases for macro-bands whose members dispersed periodically in family groups to exploit resources in the surrounding area and to interact with neighboring communities of the same tradition (Dias, 1992).

Excavations in the Corondó site on the coast of Rio de Janeiro produced remains of some 445 individuals. Single primary extended burials were most common, but multiple interments, secondary burials, and disarticulated bones were also encountered, the latter probably the result of disturbance by later burials. Orientation was preferably north–south. Grave goods, most often associated with adult females, included stone and shell artifacts, and bone, shell, and animal-tooth beads. Detailed analysis of the skeletal remains permitted reconstructing mortality and survivorship curves and observing a variety of fractures and degenerative conditions (Machado, 1992).

3. Amazonia

Compared to the Coastal Strip, Amazonia today is a homogeneous region topographically, climatically, and biotically. Except for protrusions of the Guayana and Brazilian shields in the northeast and southeast, elevation rarely exceeds 500 m. Rainfalls on 130 or more days per year, annual precipitation exceeds 1500 mm and reaches more than 3000 mm in the northeast, and relative humidity is normally above 80%. Daily temperature can fluctuate between 32 and 21°C, whereas annual variation averages only 3°C between the warmest and coldest month. Although a dozen major tributaries flow into the Amazon, their impact is mitigated by alternation of the influx from the northern and southern hemispheres, with the result that the normal difference between low and high water is only about 10 m. The clear and black water rivers draining the Guayana and Brazilian shields are deficient in nutrients whereas those descending from the Andes are rich in suspended sediments that are deposited on the varzea (flood plain), where they provide a diversified habitat for aquatic fauna and fertile soil for seasonal cultivation. By contrast, millennia of erosion have depleted the soil of the upland (terra firme) of soluble nutrients, creating "persisting ecological constraints on tropical agriculture" (Weischet and Caviedes, 1993).

3.1. Paleoclimatic fluctuations

Prior to the 1970s, the Amazon Basin was considered to have been unaffected by the glacial cycles that altered the flora and fauna elsewhere in the hemisphere. This assumption was called into question by Haffer's observation that the distributions of superspecies of forest-dwelling toucans do not coincide with existing disruptions of the forest, which would have prevented interbreeding (Haffer, 1969, 1974). Other biogeographers subsequently identified disjunct distributions in a variety of animals and plants that generally support the "refugia" model, whereas palynologists have

produced pollen profiles that do not show discontinuities in forest vegetation during and since the Pleistocene, leading them to argue that cooler temperatures, changes in river channels, sea level rise, and other variables, rather than periodic drought, are responsible for Amazonian biodiversity (see Hoogheimstra and van der Hammen, 1998, for a review and over 500 references). New types of evidence obtained since the late 1990s and greater understanding of global climatic processes increasingly support the existence of episodes of fragmentation of the rainforest of varying durations and magnitudes during and since the Pleistocene–Holocene transition (Haffer and Prance, 2001; Rossetti et al., 2004).

3.1.1. Palynological evidence

Although pollen analysis shows continuity in rainforest vegetation at Pata in northwest Amazonia, absence of sediment deposition between ca. 31,888 and 18,000 ^{14}C yr BP and between ca. 14,000 and 5800 ^{14}C yr BP implies a decline in precipitation. A similar hiatus has been identified in cores from Carajás on the southern periphery (Fig. 4.2; Suguio et al., 1996; Ledru et al., 1998a). A pollen profile from east-central Marajó at the mouth of the Amazon, now dominated by savanna, shows repeated fluctuations between forest and savanna during the past 7000 years (Fig. 4.6; Absy, 1985) and a profile from Katira on the southwestern margin of the lowlands also shows an arid interval (Absy and Van der Hammen, 1976).

On the eastern llanos of Colombia, where the present climate favors forest, grassland predominated between ca. 9700 and 5200 ^{14}C yr BP (Behling and Hooghiemstra, 1998, p. 265). Phytoliths and charcoal from cores at a site 90 km north of Manaus suggest forest vegetation prevailed during the past 5000 years, but identify major fires between 1795 and 550 ^{14}C yr BP (Piperno and Becker, 1996). Review of 32 cores north and south of the Amazon indicates that savannas expanded during glacial periods and that the early Holocene climate was drier prior to ca. 6000–5000 ^{14}C yr BP than earlier or later (Behling and Hooghiemstra, 2001).

Another type of botanical of evidence that "the tropical forest, thought to have remained stable since the last glacial event, has in fact undergone deep modifications" is charcoal in the soil (Sanford et al., 1985; Bassini and Becker, 1990; Fearnside, 1990; Lucas et al., 1993; Meggers, 1994a; Charles-Dominique et al., 1998, p. 296; Uhl and Nepstad, 1990, p. 85). Profiles exposed along the Transamazonian Highway between Santarem and Cuiabá show sporadic pockets of charcoal dating between 6000 and 3000 ^{14}C yr BP implying, drier conditions than at present. This history of disturbance is reflected in disharmony between the present rainfall and vegetation (Soubiès, 1980). A similar inference has been drawn from the existence of enclaves of savanna in the forest of southern Venezuela, where drainage, relief, soil conditions, and climate are equivalent to those in the surrounding forest, and from the disjunct distributions of many plant species in widely separated savanna enclaves across the tropical lowlands (Eden, 1974; Harley, 1988, p. 113).
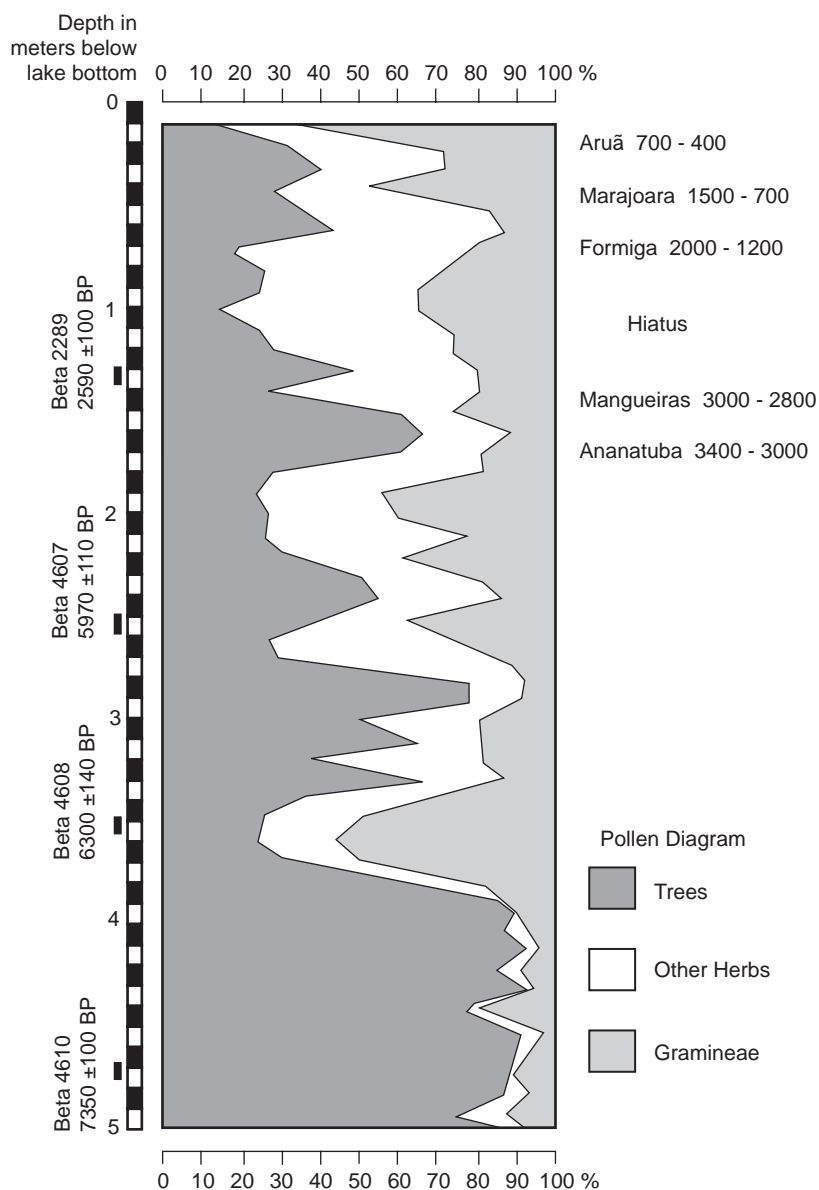
Figure 4.6. Pollen profile from Lago Ararí in east-central Marajó showing fluctuations in the extent of forest during the past 7000 years. The ^{14}C and TL dates for replacements of the archaeological phases correlate with declines in forest vegetation ca. 2800-2000, 1500, and 700 cal yr BP (after Absy, 1985, Fig. 4.9; Meggers and Danon, 1988, Fig. 2).

3.1.2. Paleoecological evidence

A detailed reconstruction of local climatic fluctuations during the past 10,000 years has been produced by a decade-long multidisciplinary investigation conducted in an

undisturbed tract of rainforest 100 km inland from the coast of French Guiana, where present annual rainfall exceeds 3000 mm (Charles-Dominique et al., 1998, 2001; Ledru, 2001). The trees in primary forest and four other formations in the study area were inventoried; core samples and sediments along streams were processed for seeds, pollen, and charcoal; alluvial terraces were identified, soil profiles were analyzed for evidence of erosion, and the impact of heavy rain on the forest floor and on small agricultural clearings was observed. The geological, ecological, palynological, and climatological evidence from all sources, combined with a large set of ^{14}C dates, provide the following sequence of events:

- Major droughts between ca. 8000–7000 and 6000–4000 ^{14}C yr BP, implied by the lower diversity of primary forest species during these periods.
- More humid conditions between ca. 3000 and 2000 ^{14}C yr BP, reflected in increased taxonomic diversity.
- Drought between ca. 1800 and 1200 ^{14}C yr BP, implied by the dominance of pioneer species over large areas; an intense episode of erosion occurred ca. 1390 ^{14}C yr BP.
- More humid conditions between ca. 1200 and 900 ^{14}C yr BP, marked by expansion of the forest;
- New disturbances between 900 and 600 ^{14}C yr BP, indicated by re-emergence of pioneer assemblages.
- An episode of intense erosion ca. 530 ^{14}C yr BP.
- Consolidation of present-day vegetation ca. 300 ^{14}C yr BP.

The authors argue that "the apparitions of pioneer species during several consecutive centuries suggest that, during each of these periods, brief disturbances must have occurred every 10–30 years, impeding the establishment of mature forest species and maintaining a widespread secondary vegetation" (Charles-Dominique et al., 1998, p. 299).

3.1.3. Sedimentological evidence

A variety of geoscientific evidence supports episodes of drought and forest fragmentation during the late Pleistocene (Haffer, 1997, pp. 465–466; Haffer and Prance, 2001, pp. 582–583). Extensive deposits of eolian sand have been reported on the llanos of the Orinoco (Clapperton, 1993, pp. 199–200) and in the Negro basin (Santos et al., 1993). The Pantanal do Norte, which covers several thousand square kilometers between the Branco and Negro in north-central Amazonia, and the Parintins Formation, which extends some 400 km along the left bank of the Amazon eastward from the mouth of the Negro, have similar characteristics (Santos et al., 1993; Iriondo and Latrubesse, 1994). Four periods of eolian activity have been identified by 14 TL dates, the two most recent spanning 17,200–12,700 and 10,400–7800 BP (Filho et al., 2002). The latter interval is documented in the stratigraphy in Pedra Pintada, a rockshelter near Monte Alegre on the left bank of the lower Amazon, where the

earliest human occupation ca. 10,000 ^{14}C yr BP is separated from a later occupation beginning ca. 7600 ^{14}C yr BP by an irregular deposit of wind-blown sand some 30 cm thick (Roosevelt et al., 1996). It is also represented in the earliest major period of aridity in the sequence from French Guiana and falls within the more recent hiatus in the dates from the Pata pollen core.

3.1.4. Hydrology

Eustatic changes in sea level during and since the Pleistocene have had a significant impact on the extent and composition of the Amazonian flood plain. As a consequence of the increased gradient caused by the decline of ca. 120 m in sea level during the Late Glacial Maximum, the rivers cut deeply into their beds and sediments were deposited on the Amazon fan rather than the riverbed. The conclusion that absence of an increase in grass pollen in these sediments shows "unequivocally that the Amazon lowlands were forested in glacial times as they are now" (Colinvaux, 1996, p. 389) is contradicted by hydrological research in various forested and desert landscapes in the tropics indicating that the small-scale observations of runoff relied on in climate models can be misleading. "Significantly, as the scale is increased, redistribution of overland flow becomes more dominant and takes place in the form of spatially, discontinuous surface flow … the redistribution mechanism causes the runoff term to be virtually zero at this scale" (Bonell, 1998, p. 104). These conditions, added to the relatively small contribution (under 20%) of the eastern tributaries to the present sediment load of the Amazon (Clapperton, 1993, p. 181; Sommerfield et al., 1995, p. 353) and the massive input from increased rainfall in the eastern Andes, which produced the second and third highest water levels recorded during this century at Manaus (Molion, 1990), also discredit the reliability of pollen profiles from the Amazon fan as indicators of rainforest vegetation.

3.1.5. Specialized studies

Further support for the refugia model is provided by several kinds of specialized studies. Isotopic data suggest that reductions in atmospheric CO_2 during the Late Glacial Maximum contributed to a reduction in terrestrial biomass (Street-Perrott et al., 1997). Stable isotope ratios of soil organic carbon identify Holocene fluctuations in the forest-savanna boundary (Desjardins et al., 1996). Changes in the oxygen composition of foraminifera in Amazon fan sediments indicate a 60% reduction in Amazon flow during the Younger Dryas, implying a 40% reduction in rainfall (Maslin and Burns, 2000). In the Cariaco Basin off the east coast of Venezuela, a similar shift in foraminifera provides "a broad regional signal of water balance over tropical South America not previously identified in terrestrial records" (Peterson et al., 2000). Amazon cone isotopic stratigraphy (Showers and Beavis, 1988), sediment deposition on the Amazon continental shelf (Nittrouer et al., 1995),

and carbon isotope ratios in porewaters from Amazon fan sediments (Burns, 1998) also support aridity during the Pleistocene/Holocene transition.

Fluctuations in glacial moraines and the thickness of layers in Andean ice cores provide additional evidence, since highland rainfall originates from the eastern lowlands (Heine, 2000).

Observations of the impact of recent displacements of the ITCZ and fluctuations in Sea Surface Temperature (SST) on Amazonian precipitation provide another explanation for past episodes of aridity (Peterson et al., 2000; Haug et al., 2001).

Integration of the various forms of direct and indirect evidence has led to "a majority view" that a 25–50% reduction in rainfall occurred during the Late Glacial Maximum (Heine, 2000; Thomas, 2000) and that Van der Hammen's model "appears to be more consistent with the available pollen evidence" (Haberle and Maslin, 1999, p. 36). This model is based on the current climatic and vegetational associations in northern South America, which indicate that closed forest dominates when annual rainfall exceeds 2000 mm, more deciduous forest prevails between 2000 and 1500 mm, savanna woodland or cerrado develops between 1500 and 1000 mm, and savanna/cerrado or semidesert occurs below 1000 mm. Imposing a 40% diminution on the present-day rainfall map reduces the current 1500 mm isohyet to 1000 mm, placing Carajás, Pata, and the dune fields on the upper Negro in savanna/cerrado or semidesert environments (Fig. 4.7; Van der
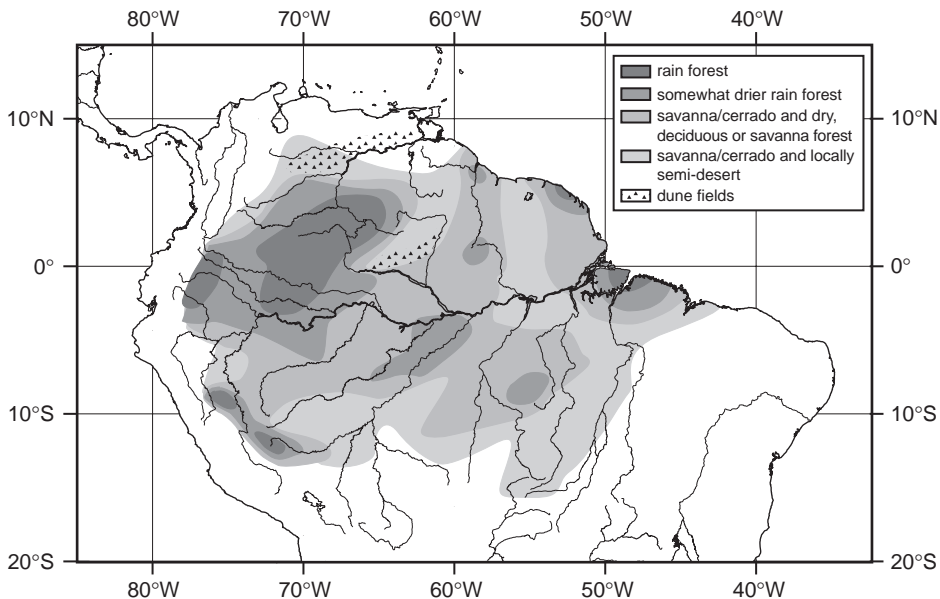
Figure 4.7. Postulated distribution of rainforest with a reduction of 40% in annual rainfall, based on the present-day isohyets and correlation of savanna and savanna woodland vegetation with rainfall below 1500 mm. A large refugium would have existed in the northwest and smaller refugia in central and eastern Amazonia (after Van der Hammen and Hooghiemstra 2000, Fig. 3).

Hammen and Hooghiemstra, 2000). Rainforest persists in a large refugium in the northwest and several smaller refugia elsewhere in the lowlands. Although, the locations of the rainfall isohyets may have been somewhat different in the past and regional variations in precipitation certainly existed, at least a 10% reduction in input from the Atlantic has been predicted by a general circulation model of atmospheric and oceanic interactions (Bush and Philander, 1998).

3.2. Holocene conditions

Geomorphological, sedimentological, and hydrological studies conducted along the Amazon above and below the Negro indicate that the varzea (floodplain) reached its present extent after stabilization of sea level and has a maximum age of 5000–6000 years (Irion et al., 1997; Behling, 2002a). The same conclusion emerged from detailed examination of the morphology of the riverbed at the mouth of the Amazon (Irion, 1984; Junk, 1984; Irion et al., 1997; Vital et al., 1998). Comparison of the configuration of the flood plain during the past two decades documents continuous cutting and depositing, shifting the locations, shapes, and magnitudes of the islands, creating and obliterating auxiliary channels, and causing minor changes in the course of the main river (Mertes et al., 1996), all of which would have affected human exploitation.

The principal source of rainfall variability during the past five millennia is the ENSO phenomenon. During the brief 1982–1983 episode, weather stations throughout Brazilian Amazonia registered precipitation 70% below normal (Nobre and Renno, 1985). During one day in February, the discharge of the Trombetas, a left-bank tributary of the lower Amazon, declined to $47\,m^3$ compared with a long-term average of $2100\,m^3$ (Molion and de Moraes, 1987). The fact that 50% or more of local rainfall originates from evapotranspiration suggests that the reduced input of moisture from the ocean would have been amplified during prolonged episodes as rainforest trees gave way to the more drought-resistant vegetation registered in pollen profiles ca. 1500, 1000, 700, and 500 ^{14}C yr BP (Absy, 1982; Salati, 1985, p. 39; Goldammer and Price, 1998, p. 278). These vegetational fluctuations are also reflected in the nitrate concentrations in late Holocene ice cores in the southern Andes (Thompson, 1995) and the fluctuating discharges in the Magdalena, Cauca, and San Jorge rivers in Colombia (Van der Hammen and Cleef, 1992).

Additional environmental uncertainty is created by the magnitude of unpredictable fluctuations in maximum and minimum water level. Records at Manaus since 1902 show the maximum to be least variable, typically ranging between 26 and 29 m above mean sea level (Fig. 4.8). Two exceptionally low crests of 25.5 and 21.5 m coincide with the 1912 and 1926 episodes of El Niño. Minimum water levels are far more erratic, ranging between 21 and 15 m, with differences of 5 m often occurring in successive years. A low of 21 m leaves the lower varzea flooded, whereas a low of 15 m drains pools and leaves fish stranded in cutoff channels. The coincidence of a low maximum and a low minimum during the 1926 episode of El Niño had a devastating impact on the aquatic fauna.
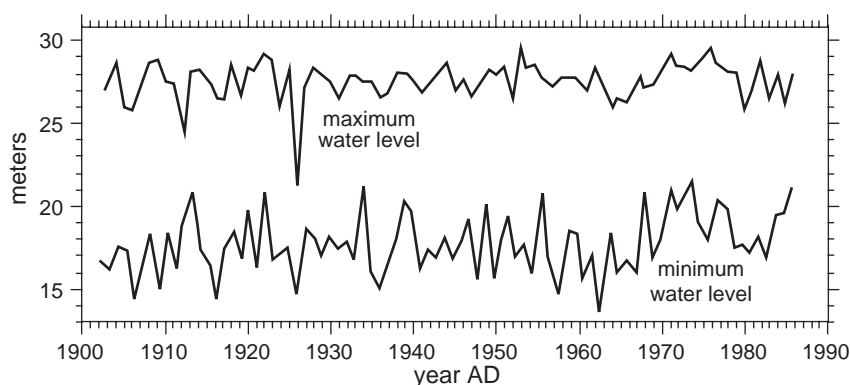
Figure 4.8. Maximum and minimum water level of the Amazon at Manaus between 1902 and 1985 (meters above mean sea level). Whereas fluctuations in maximum water level typically do not exceed 3 m, minimum water level fluctuates more than 5 m, with extremes often occurring in consecutive years. The coincidence of a low maximum and low minimum during the 1926 episode of El Niño caused high mortality of aquatic fauna (after Junk, 1989, Fig. 2).

The impact of even brief drought on the rainforest vegetation is illustrated by changes in the composition of a 50 ha plot on Barro Colorado Island in Panama as a consequence of the 1983 episode of El Niño and subsequent fluctuations in rainfall periodicity (Condit, 1998, p. 419):

> There were 37 species … defined as moisture-demanding … and 33 of these declined in abundance between 1982 and 1995 … One of these moisture-specialists … is a large, prominent canopy species that has undergone a striking crash, from 3426 stems in 1982 to 1777 stems in 1995. But it was small-stature moisture-specialists (shrubs and treelets) that were most affected: 17 of 81 declined in abundance, one went extinct … and their total abundance fell by 35% over 13 years … If drying trends continue, it seems likely that most of these 37 will be lost within 25 years.

The failure of many plants to flower or fruit during an abnormal weather cycle on Barro Colorado Island in 1970–1971 and the resultant famine and death among frugivores testify to the subsistence stress longer episodes would have inflicted on humans (Foster, 1982).

3.3. Archaeological evidence

The rarity of stone tools and of habitable rock shelters limits evidence of humans prior to the adoption of pottery, but camp sites and workshops encountered during environmental impact surveys document their existence throughout the lowlands by 13,000 ^{14}C yr BP at the latest.

3.3.1. Rock shelters

Although rock shelters occur in the Guayana Shield, most are too small for habitation and were used mainly for burial or temporary camps. The only known exception is Pedra Pintada near the left bank of the lower Amazon, where the earliest occupation during the 10th millennium BP is separated from two later occupations beginning ca. 7500 ^{14}C yr BP by a layer of windblown sand 20–40 cm thick containing fragments of charcoal (Roosevelt et al., 1996). The lower levels produced rare unifacial scrapers and blades, expedient tools, and abundant flakes. Subsistence remains included a variety of seeds, nuts, and palm fruits, as well as fish, mammal, reptile, and amphibian bones. Pictographs on the rear wall of the shelter have been assigned to this occupation. The similarity between this complex and the early levels at Boquête in Minas Gerais supports the existence of environmental continuity during the Pleistocene/Holocene transition (Kipnis, 1998). Two rock shelters on the southern margin of Amazonia, Abrigo do Sol and Santa Elina, attest to human presence by ca. 15,000 ^{14}C yr BP and possibly earlier (Fig. 4.2; Miller, 1987; Vilhena Vialou and Vialou, 1989; Vilhena Vialou et al., 1999).

3.3.2. Shell middens

Shell middens of the preceramic Alaka Phase appear on the northwest coast of Guyana ca. 6800 ^{14}C yr BP and were abandoned ca. 4000 ^{14}C yr BP. Area ranges from 12×12 to 80×30 m; maximum height is 1–15 m. Mammal, bird, and fish bones and crab fragments are mixed among the shells. Stone artifacts were rudimentarily shaped by percussion for use as choppers, hammerstones, picks, knives, and scrapers. Burials often occur (Evans and Meggers, 1960, pp. 38–54; Williams, 1992).

A shell midden 6 m high has been reported at Taperinha on the right bank of the Amazon below the mouth of the Tapajós. Twelve ^{14}C dates from the lower preceramic levels extend from 7090 to 5700 ^{14}C yr BP. A sterile layer separates this occupation from the upper levels, which are undated, but the presence of pottery related to the Barlovento Phase on the north coast of Colombia implies a reoccupation after ca. 3500 ^{14}C yr BP (Roosevelt et al., 1991; Meggers, 1998).

Two swampy locations on the southern margin of the rainforest were exploited for intensive shellfish gathering. Nearly 200 small middens have been documented along the Rio Paraguai and associated lakes in the pantanal of Mato Grosso do Sul. Thirteen ^{14}C dates bracket the preceramic Corumbá Phase between ca. 8300 and 2700 ^{14}C yr BP. Pottery was introduced ca. 2000 ^{14}C yr BP (Schmitz et al., 1998). Large shell middens of the Sinimbu Phase are scattered across the pantanal of the middle Guaporé. Area ranges from 25×20 to 210×130 m and height is up to 6 m. During the rainy season, they are now surrounded by water up to 1.7 m deep. Layers of crushed and calcined shell, postholes, occupation floors, and artifacts of stone, bone, and shell occur throughout, as well as lumps of clay with twig, fiber or mat impressions. Ten ^{14}C dates extend from ca. 6316 to 4300 ^{14}C yr BP, when the

region was abandoned for several centuries as a consequence of drought (Miller, 1999 and n.d.).

3.3.3. Open sites

Finely chipped bifacial-stemmed projectile points resembling those from early contexts elsewhere in South America have been encountered sporadically throughout the central lowlands (Fig. 4.9; Meggers and Miller, 2003), but the only Amazonian example
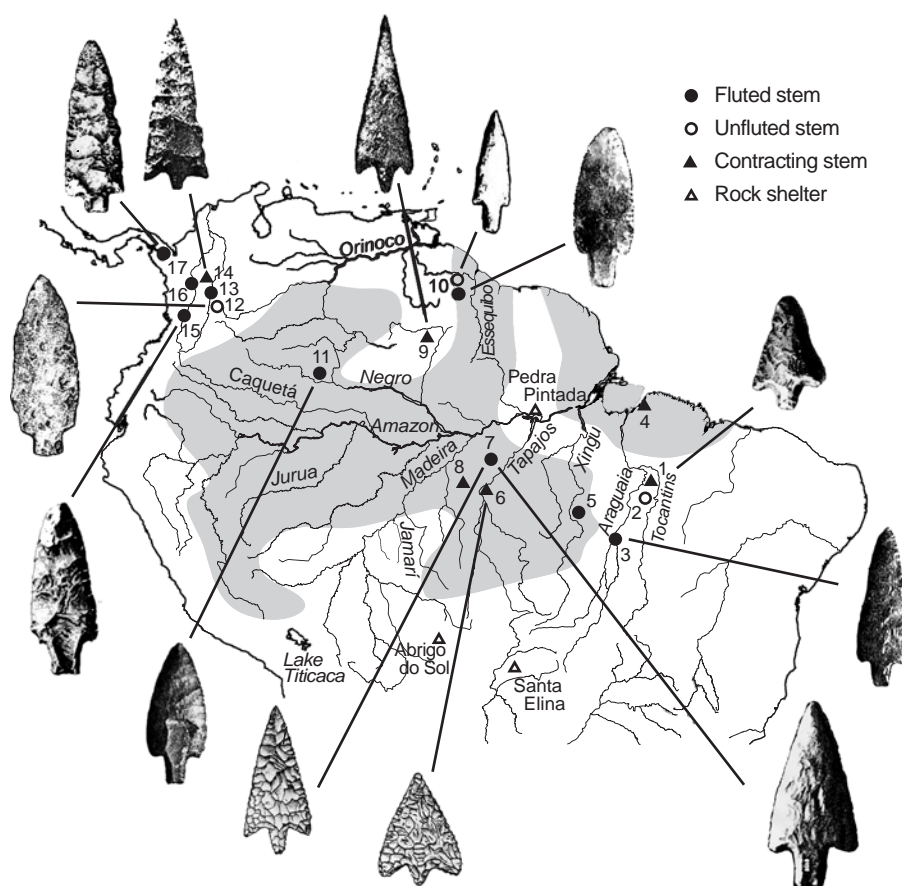

Figure 4.9. Locations of rock shelters and isolated projectile points in relation to the distribution of forest vegetation during the Late Pleistocene, assuming a 25% reduction in precipitation and a similar distribution (after Van der Hammen and Absy, 1994). 1, Itaguatins TO; 2, Darcinópolis TO; 3, Upper Araguaia TO/MT; 4, Ilha Cotijuba PA; 5, Middle Xingu PA; 6, Middle Tapajós PA; 7, Cara Preta AM; 8, Apuí AM; 9, Igarapé Murupu RR; 10, Mazaruni District, Guyana; 11, Upper Negro AM; 12, Sabana de Bogotá; 13, Middle Magdalena valley; 14, Puerto Berrio; 15, Restrepo; 16, Niquía; 17, Golfo de Urubá (after Meggers and Miller, 2003, Fig. 10.2).

from a documented context was encountered during salvage excavations along a powerline transect between the Tocantins and Araguaia, where it was associated with a variety of expedient tools and debitage. Lithics and debitage were encountered at 299 locations along this transect and 230 locations along a similar transect in northern Roraima, as well as in transects near the coast of Amapá, between the Tocantins and Tapajós, and in Rondônia between the Ji-Paraná and Rolim de Moura. Initial dates in each region range between 13,720 and 11,300 ^{14}C yr BP and many sites remained in use until 1100 ^{14}C yr BP (Meggers and Miller, 2003). A date of 14,990 ^{14}C yr BP was obtained from a site on the lower Sinnamary on the central coast of French Guiana, where rainforest would have persisted (Vacher et al., 1998).

Stratigraphic excavations in open sites along the Jamarí, a right-bank tributary of the upper Madeira in southwest Amazonia, identify three successive preceramic components: (1) the Itapipoca Phase, with dates extending from ca. 8000 to 6900 ^{14}C yr BP; (2) the Pacatuba Phase, extending from ca. 6000 to 5000 ^{14}C yr BP; and (3) the Massangana Phase, extending between ca. 4800 and 2600 ^{14}C yr BP. Artifacts of the Itapipoca Phase consist mainly of large percussion-flaked bifaces, end and side scrapers, flakes with and without retouch, and hammerstones. The succeeding Pacatuba Phase is characterized by the addition of rare small scrapers, cores, flakes, and micro-flakes, some showing micro-retouch from use (Miller et al., 1992, pp. 36–37).

In contrast to the sites of the two earlier phases, Massangana Phase occupations are associated with black soil (*terra preta*). Since black soil is characteristic of the shifting habitation sites of ceramic phases, both along the Jamarí and elsewhere in Amazonia, this situation suggests that slash-and-burn agriculture and semi-permanent settlement behavior were adopted here prior to the acquisition of pottery. This inference is supported by the addition to the lithic inventory of axes, anvil stones, small mortars and pestles, and grinding stones impregnated with hematite pigment. Cores, flakes, and micro-flakes persist from the previous phase (Miller, 1992; Miller et al., 1992, pp. 37–38). It is also compatible with genetic evidence for manioc domestication in the region (Olsen and Schaal, 2001).

Palm starch (sago) is the primary source of carbohydrate throughout southeast Asia and various kinds of evidence indicate that prehistoric Amazonian hunter-gatherers depended on the burití palm (*Mauritia flexuosa*) for starch, fruit, and grubs (Jones, 1955; Meggers, 2001b). Access to this resource increased substantially after ca. 8000 ^{14}C yr BP, when rising sea level expanded the extent of swampy habitats throughout the lowlands (Behling, 2002a). It remains a staple among several marginal groups, among them the Warao of the Orinoco delta (Heinen and Ruddle, 1994). On the western coast of Guyana, where depletion of palms and molluscs as a consequence of sea-level rise and increased aridity provoked abandonment of the shell middens for inland locations ca. 5000 ^{14}C yr BP, more intensive exploitation of terrestrial resources is reflected in the addition of axes, choppers, adzes, pitted anvil stones, and scrapers to the lithic inventory. It has been suggested that the procedures employed for processing palm starch would have

preadapted the inhabitants for eliminating the toxic content of bitter manioc (Williams, 1992, pp. 238–240).

The earliest well-documented ceramic complexes are Ananatuba on Marajó, with an initial TL date of 3400 BP (Meggers and Danon, 1988), and Bacabal on the upper Guaporé, with an initial ^{14}C date ca. 3900 ^{14}C yr BP (Miller, 1999 and ms). Pottery became widespread throughout the lowlands after ca. 2000 ^{14}C yr BP, permitting construction of detailed local relative chronologies. Correlation of archaeological sequences from lowland Bolivia, the central Amazon, Marajó, northern Colombia, and Venezuela shows simultaneous discontinuities ca. 1500, 1000, 700, and 400 ^{14}C yr BP implying the dispersal and replacement of an earlier community of shifting agriculturalists by a later one as a consequence of subsistence stress inflicted by the impact of mega-Niño droughts on the biota (Fig. 4.10; Absy, 1982; Meggers, 1994a, 1996b). The extensive habitation sites along the major tributaries and sectors of the middle Amazon have been interpreted as large permanent settlements, but all those that have been investigated archaeologically are the product of multiple re-occupation by small villages during hundreds of years (Miller et al., 1992; Meggers, 2001a; Meggers and Miller, 2006).

Although it has been suggested that population pressure on the varzea was relieved by expansion up the tributaries, archaeological evidence indicates that the first rapid was a permanent ecological barrier to movement in either direction (Meggers et al., 1988). The implication that adaptations suitable for sustained exploitation of one region are not equally effective in the other is confirmed by detailed analysis of the behavior of contemporary riverine and hinterland Achuar communities in southeastern Ecuador (Descola, 1994).

3.4. Biogeographical evidence

The paucity of archaeological evidence for reconstructing indigenous movements prior to the adoption of pottery is partly compensated by the geographical distributions of languages, genetic features, and cultural traits (Meggers, 1987).

3.4.1. Linguistic distributions

The principal Amazonian language families have been assigned to two major phyla: Ge-Pano-Carib and Equatorial-Tucanoan (Greenberg, 1987). The lexicostatistical estimates for the primary separation of Ge, Pano, and Carib languages and their present isolation in non-forest habitats in eastern Brazil, eastern Peru, and the Guianas are consistent with displacement of the speakers of the proto-language from the central lowlands during consolidation of the rainforest ca. 5000 ^{14}C yr BP (Fig. 4.11; Meggers, 1994b). Similarly, the present predominance of speakers of Equatorial languages (Arawak and Tupí) in the rainforest suggests that they
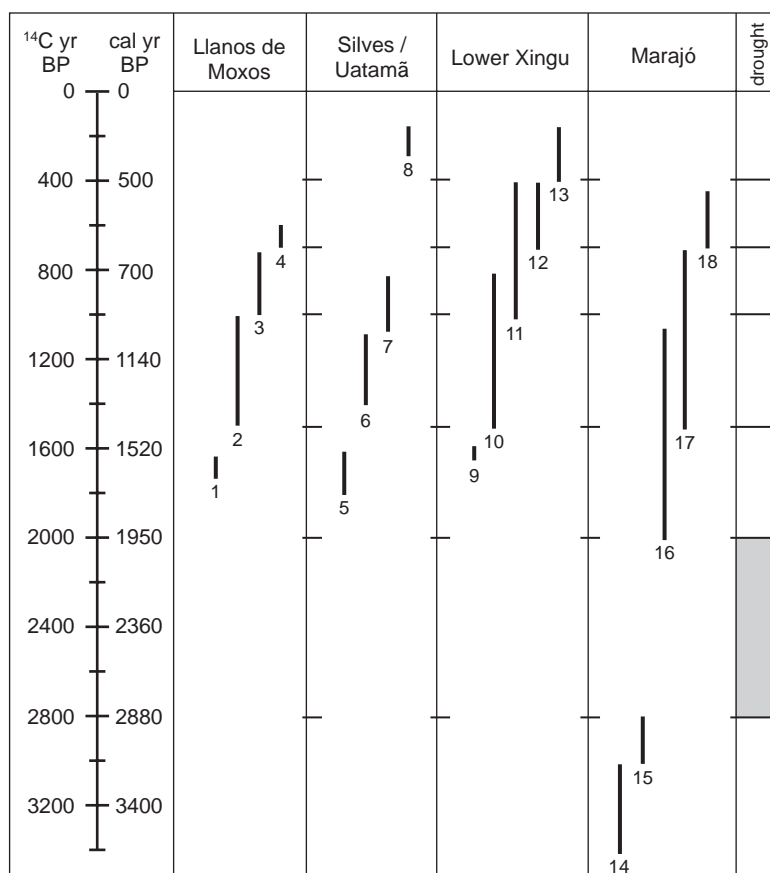
Figure 4.10. Discontinuities in well-dated ceramic sequences from lowland Bolivia (Llanos de Mojos), the central Amazon (Silves/Uatumã and Lower Xingu), and the mouth of the Amazon (Marajó), implying substitution of an earlier population by a later one ca. 1500, 1000, 700, and 400 ^{14}C yr BP. These dates coincide with severe droughts induced by mega-Niño events, which diminished the productivity of subsistence resources. 1, Casarabe Tradition; 2, Mamoré Tradition; 3, Kiusiu Tradition; 4, Ibare Tradition; 5, Polychrome Tradition, Manacapuru Subtradition; 6, Polychrome Tradition, Saracá Subtradition; 7, Incised and Punctate Tradition; 8, Uatumã Phase; 9, Macapá Phase; 10, Guará Phase; 11, Polychrome Tradition, Cacarapí Phase; 12, Pacajá Phase; 13, Curuá Phase; 14, Ananatuba Phase; 15, Mangueiras Phase; 16, Formiga Phase; 17, Polychrome Tradition, Marajoara Phase; 18, Aruã Phase (after Meggers, 1994a, Fig. 4).

expanded from a homeland in the refugium east of the Andes as the forest coalesced. The coincidence between the estimates for the subsequent diversification within Arawak and Tupí ca. 1500, 1000, and 500 ^{14}C yr BP and the mega-Niño episodes of aridity provides an explanation for the present heterogeneous linguistic, cultural element, and genetic distributions throughout Amazonia (Migliazza, 1982; Black et al., 1983).
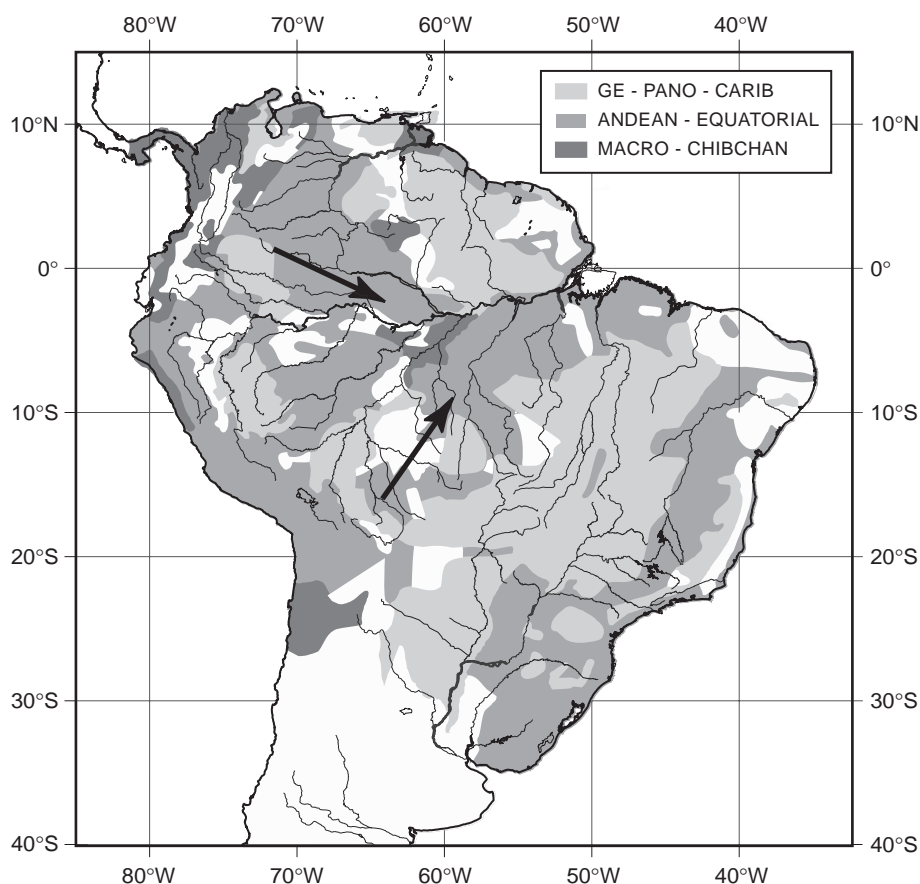
Figure 4.11. Present distributions of the principal lowland language phyla, suggesting replacement the savanna/cerrado-adapted proto-Ge-Pano-Carib speakers from the central lowlands by intrusion of forest-adapted Equatorial-Tucanoan speakers from the west. This inference is supported by the coincidence between the lexicostatistical dates for completion of primary differentiation within each phylum ca. 5000 ^{14}C yr BP and ^{14}C estimates for coalescence of the rainforest about that time, and the present-day association of Ge, Pano, and Carib speakers with open environments on the northeastern, southeastern, and western margins of the rainforest (after Meggers, 1994b, Fig. 3; Greenberg, 1987).

3.4.2. Cultural element distributions

Although the deculturation and disappearance of many indigenous Amazonian groups leaves large geographical blanks, some cultural traits free of adaptive constraints have concentric distributions compatible with the displacement of earlier by later populations in the central lowlands. Among two types of racks for roasting meat, the tripod is restricted to Amazonia whereas the tetrapod occurs in the surrounding regions, implying its greater antiquity (Fig. 4.12; Nordenskiold, 1924). Three types of finger positions for arrow releases also have circum-Amazonian
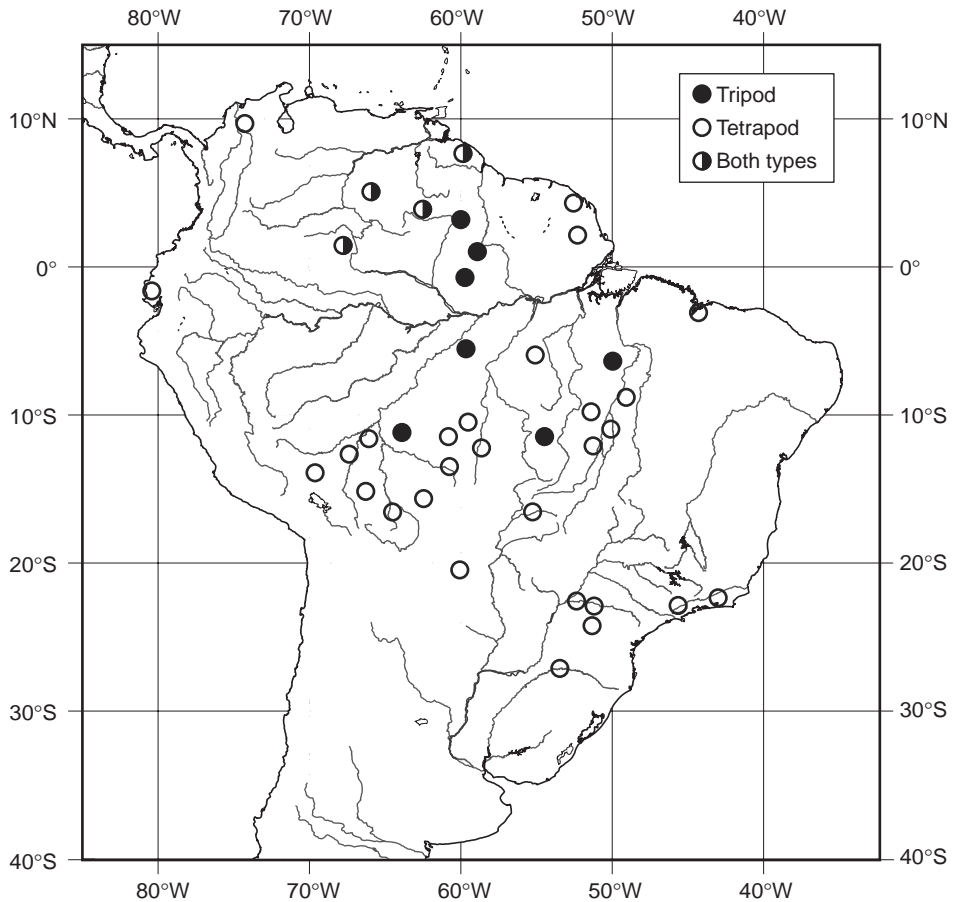
Figure 4.12. South American distributions of tripod and tetrapod racks for roasting meat. The concentric pattern is compatible with the linguistic evidence for displacement of Ge-Pano-Carib speakers by Equatorial-Tucanoan speakers in the central lowlands. Bisected circles indicate the presence of both varieties (after Nordenskiold, 1924, Map 15).

distributions, whereas the secondary position is restricted to the intervening region (Heath and Chiara, 1977, Map 5), and pole snares are more widespread than simple nooses for capturing small mammals (Ryden, 1950). Among various mythical explanations of the dark patches on the surface of the moon, that interpreting them as the face of a man is restricted to Amazonian groups (Blixen, 1992).

3.4.3. Genetic distributions

Most blood group alleles, mtDNA, and other genetic traits considered immune to natural selection have heterogeneous distributions among contemporary indigenous Amazonians. As in the case of languages, this pattern is "dramatically different from the regular clinal distributions found for North America" (O'Rourke and

Suarez, 1985, p. 24) and is attributable to the repeated fractionations and dispersals of indigenous communities triggered by mega-Niño episodes during recent millennia (Ward et al., 1975, p. 18).

An exception to this general pattern was revealed by multivariate analysis of 13 alleles among 21 indigenous populations, which produced distributions in the first three principal components suggesting dispersal from the central lowlands (Rothhammer and Silva, 1992). Examining the linguistic affiliations of the groups sampled shows 10 to be Ge-Pano-Carib speakers and 7 to be Equatorial speakers. The former are distributed peripherally to the latter with two exceptions in the eastern Guianas, which represent post-contact migrants from south of the Amazon.

3.4.4. Historical evidence

The impact on the biota and human populations in northern Amazonia of the short-term droughts associated with 20th century episodes of El Niño is proxy evidence for the situation confronted by the precolumbian inhabitants. During the 1912 event, fires burned continuously for several months on the lower Branco, the river was not navigable, and thousands of rubber gatherers are reported to have died. Between the upper Ventuari and upper Uraricuara in southern Venezuela, massive destruction of the forest by fire was followed by toppling of semi-burned vegetation. During the 1926 event, extensive fires lasting more than a month affected the entire lower Negro region, causing massive mortality among the fauna, especially large birds. The heat was sufficiently intense in some streams to kill the fish (Koch-Grünberg, 1979–1982, p. 234; Carvalho, 1952, p. 16).

The impact of the 1972–1973 drought on a Yanomami community on the Alto Siapa is illuminating:

> The Indians, accustomed to burning the dried vegetation in their fields to expand the cultivated area or remove plant residue, were careless and the flames consumed the producing plants. What happened next was inconceivable under normal conditions: the fires spread via the undergrowth and flared up on hilltops where the stony soil made vegetation sparse. Few gardens escaped the catastrophe, creating a shortage of cultivated foods. Forest resources, however, remained available. Consequently, the majority of the population abandoned their dwellings and assumed a nomadic existence, exploiting zones of forest successively. Working harder than normal, they remained constantly hungry but survived. The state of health … testified that the food shortage they had experienced was not dramatic … Nevertheless, the palmito that had replaced the plantain as their primary food was becoming increasingly scarce" (Lizot, 1974, p. 7; Meggers, 1994a, p. 332).

Recent efforts to exploit the more fertile soils of the varzea for intensive agriculture have been frustrated by the unpredictable regime of the rivers. On the Ucayali in eastern Peru, "floods annually threaten crops grown in fertile low-lying areas [and] even crops grown in all but the very highest parts of restinga are destroyed by floods once or twice every decade" (Chubnik, 1994, p. 221). The 100-year history of a

varzea community on the Solimões reveals a decline in the number of settlements because of subsistence uncertainties induced by riverine fluctuations and an increase in population density on the adjacent *terra firma*, where conditions are more stable (Lima-Ayres and Alencar, 1994). The disastrous impact of the erratic flood cycle on jute production has been documented on an island near Santarem (Santos, 1982). On the middle Caquetá in eastern Colombia, where periodic losses occur as a result of untimely or excessive flooding, both indigenous groups and colonists grow commercial crops on the floodplain, but raise subsistence crops on the *terra firma* where they are less susceptible to loss (Eden, 1990, p. 124). High vulnerability to pathogens constitutes an additional hazard (Bahri et al., 1990).

4. Conclusion

The first humans arriving in lowland South America ca. 15,000 years ago would have encountered cooler and drier conditions than exist today. A 25–50% decrease in rainfall is reflected in the formation of extensive eolian sand deposits in the upper Orinoco and Negro regions, reduction of the rainforest to enclaves separated by savanna and cerrado vegetation in central Amazonia, and downcutting of the bed of the Amazon and its tributaries (Fig. 4.7). The climate on the Coastal Strip was also drier and 5–7°C cooler prior to ca. 4000 ^{14}C yr BP, reducing the availability of perennial streams and favoring development of xerophytic vegetation (Araujo et al., 2005).

The absence of an ecological barrier between Amazonia and the Coastal Strip during the Pleistocene–Holocene transition is implied by the existence of the same flora and fauna, domestic features, artifacts, and art in the early occupations at Pedra Pintada in east-central Amazonia and Boquête in Minas Gerais. Although there are local differences in lithic traditions, the characteristics of the habitation sites, subsistence remains, and artifacts throughout the lowlands prior to ca. 5000 ^{14}C yr BP imply the existence of small bands of foragers that, like surviving indigenous hunter–gatherers, moved as local resources were depleted or seasonal ones became available (Dias, 1991, 1993; Barbosa, 1992, pp. 155–159; Schmitz et al., 1996, pp. 180–184; Politis et al., 1997; Kipnis, 1998).

The achievement of Holocene climatic conditions and stabilization of sea level ca. 5000 ^{14}C yr BP had two major environmental consequences: (1) it created an ecological barrier between Amazonia and the Coastal Strip and (2) it divided each region into a narrow aquatic zone and a large hinterland. On the Coastal Strip, stabilization of sea level opened a new niche for specialized exploitation of marine resources and higher temperature and rainfall inland favored expansion of forest vegetation, the development of perennial streams, and the diversification of terrestrial and aquatic fauna. The abandonment of many rock shelters between ca. 7000 and 4000 ^{14}C yr BP reflects increased diversity and abundances of wild subsistence resources as well as the adoption of domesticated maize, cucurbits, beans, and manioc. Although communities became more sedentary and somewhat larger, a ceiling was set by dependence on wild sources of protein.

In Amazonia, consolidation of the rainforest permitted groups adapted to its exploitation to expand eastward and replace those adapted to more open environments. Simultaneously, the culmination of sea level rise allowed sediments formerly deposited on the fan to accumulate on the flood plain, creating habitats for diverse aquatic biota. Indirect evidence of agriculture is provided by the appearance in southwestern Amazonia ca. 4800 ^{14}C yr BP of habitation sites composed of black soil, diagnostic of the frequently moved settlements of contemporary shifting cultivators (Miller et al., 1992).

In contrast to other parts of the planet, Holocene climatic changes did not significantly improve the opportunities for agricultural intensification and associated cultural development. The perpetuation of the same general way of life throughout the eastern lowlands is attributable to the existence of three permanent environmental constraints: (1) edaphic and climatic impediments to agricultural intensification and to storage, (2) reliance on dispersed wild sources of protein, and (3) intermittent and unpredictable short and long-term drought. The soils of the Guayana and Brazilian Shields are among the poorest on earth as a result of millions of years of leaching and erosion. Although the flora of Amazonia is the most diverse and species-rich on the planet, it is deficient in nutrients. As a consequence, terrestrial herbivores are small, solitary, and vulnerable to over hunting (Alvard et al., 1997; Sioli, 1984; Robinson and Bennett, 2000). Any tendency to increasing population density and sedentism in both Amazonia and the Coastal Strip was truncated by the impact of periodic long-term drought on subsistence resources (Meggers, 1994a).

In Amazonia, the intensity of these constraints is reflected in the dependence of modern settlements numbering only a few hundred individuals on imported food, by the failure of well funded "development" projects to enhance sustainable agricultural productivity, and by the increasing environmental degradation that follows abandonment of indigenous practices. Many characteristics of the subsistence, settlement, and social behavior of surviving indigenous groups are intelligible as adaptations to minimize the impact of inherent ecological constraints and unpredictable subsistence stress (Meggers, 1996a, p. 192, 2001a; Meggers, 2007).

The existence of inherent limitations to sustainable intensive exploitation, population concentration, and sedentism in the Neotropical lowlands continues to be challenged by archaeologists in spite of the environmental and cultural evidence, and the failure of modern efforts at "development." They interpret prehistoric habitation sites extending a kilometer or more along the banks of the Amazon and its tributaries as confirmation of early European accounts describing large and permanent settlements organized into proto-states with powerful rulers (Erickson, 2003). They assert that "chieftaincy developed as much in the interfluvial as in the floodplain areas" and that "ancient Amerindian political and cultural life was of a level of sophistication that rivaled or even exceeded" that of contemporary Europe (Whitehead, 1990, 1994). By contrast, historians warn that "the first Europeans to set foot in Amazonia let their imaginations run away with them and claimed actually to see and hear everything they had hitherto only imagined" (Gheerbrant, 1992, p. 47; Meggers, 1993–1995). The failure of the indigenous inhabitants of

Amazonia and the Coastal Strip to develop the features we equate with "civilization" does not imply cultural stagnation. On the contrary, their success in achieving a flexible and sustainable accommodation to inherent environmental limitations and unpredictable climatic fluctuations is an accomplishment we have yet to match, much less exceed.

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