

Chapter 2

Historical Ecology and the Explanation of Diversity: Amazonian Case Studies

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Abstract Historical ecology is a research program concerned with the effects of interactions between humans and the environment. These interactions are understood as forms of landscape transformation. Species diversity is one of the principal foci in the historical–ecological study of landscape transformation. In conservation biology, humans are usually not considered to effect increases in diversity except as consequences of secondary succession and the intermediate disturbance hypothesis, if at all. In the study of Amazonia, evidence suggests that humans not only changed forest composition as a result of extensive agriculture (secondary landscape transformation) but also built environments that supported forests that were otherwise nonexistent before human intervention. Human intervention can also account for the existence of some “forest-dependent” species. In light of past human activities and the ensuing effects of these on Amazonian forests, historical ecology provides a working model of explanation of alpha diversity that is more complete than alternative models, including vicariance biogeography, refuge theory, and environmental gradients, when taken in isolation.

2.1 Introduction

Historical ecology is a research program concerned with the effects of interactions between humans and the environment (Balée 2006). By diversity, I mean biological (or species) diversity in given locales, what some ecologists prefer to call “species richness” (e.g., Barlow et al. 2011; cf. Rosenzweig 1995). I prefer “diversity” to “richness” because of the spatio-temporal phenomena that are accommodated,

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however, imperfectly, by notions of alpha and beta diversity (Balée 2010; Erickson and Balée 2006; Rosenzweig 1995; Whitaker 1972). It seems evident that a critical debate both in scientific and political communities concerns how biotic and cultural diversity in tropical rainforests today can be maintained for an authentically globalized world society (Crumley 2001; Hornborg and Crumley 2007). The debate has provoked a number of questions. One is what accounts for that diversity in the first place, and especially, as a subsidiary yet unavoidable question, what role if any have humans as a species performed in it, apart from whatever effects humans as a species are having at the present moment? The issue of the human factor in biological and landscape diversification in what was once, in Western thought, considered to be one of the most undisturbed continental contexts, that is, Amazonia, has led to a burgeoning, international literature since the late 1980s (e.g., Balée 1989; Balée and Erickson 2006; Clement and Junqueira 2010; Denevan 1992, 2001; Erickson 1995, 2000; Heckenberger 2006; McEwan et al. 2001; Pärssinen and Korpisaari 2003; Raffles 2002; Stahl 2002). Popular media have taken up the new view (Mann 2002, 2005; Singleton 2002). This varies somewhat from the belief that humans are detrimental to biodiversity and that their effects tend to simplify and even destroy landscapes. To be sure, ever since Marsh (1885) saw humankind as a landscape-maker (in coining the phrase “Man makes the Earth”), the concept in general has not been new. Yet to apply it to a seemingly untouched wilderness, such as Amazonia, is for the history of ideas recent. And to suggest that humans may enhance landscape diversification and speciosity has even seemed to be an even more radical, if misunderstood (e.g., Barlow et al. 2011; Bush et al. 2007; McMichael et al. 2012) claim. How does one answer the question of diversity’s origins? The Amazon Basin contains the largest contiguous expanse of tropical rainforest in the world, and within that rainforest, many forests can be discerned in terms of different suites of species, climatic conditions, edaphic structures, and human societies, which do not all have the same impacts on the land and the biota found on and in it. Amazonian diversity is a “riddle” (Bush 1994). Like most riddles, it has no simple answer, but rather a nuanced, multi-causal one.

2.1.1 Society, Time, and Diversity

Directing inquiry into origins of diversity on an Amazonian scale requires a sophisticated understanding of time, that is, time in more than one category. Amazon diversity in its temporal dimension is not just a natural science question and can in fact never be answered fully by the axioms, methods, and techniques of natural science alone. Actually, the so-called social sciences have staked out a crucial territory of data that are needed to explain biological diversity, and by that, I mean the extant number of genotypes in a given region. The assertion about the relevance of social science to biodiversity only seems to be paradoxical because of most scientists’ unwillingness or inability to cross disciplinary barriers, and because of a still

long-held belief by many natural scientists in a rigid separation between nature and culture and the various iterations of that dichotomy. As a case point, McMichael et al. (2012) suggested that alpha diversity might have been increased here and there by indigenous archeological cultures of western Amazonia, but overall, such an impact was negligible and the diversity of the forest cannot be explained by a human presence in the past (also see Bush et al. 2007). The main problem with this interpretation of the data concerns the baseline: The supposed original forest might itself have been a cultural one, in light of long-term occupation of Amazonia by humans, dating from the Pleistocene. Historical ecologists—at least, I think, most historical ecologists—propose that a barrier between social and natural science is empirically false and tends to represent a mystifying obstacle to a more comprehensive and accurate understanding not only of biological diversity in a global context but also of the range, distribution, and changes in regional cultural forms within a diachronic framework as these forms interact with environmental changes that have been sometimes induced for the long term by human beings, such as arguably occurred in the Amazon Basin (e.g., Balée 2010; Denevan 2001; Erickson and Balée 2006). In other words, time is really multi-dimensional in historical ecology.

Partly to understand time in this complex sense, it seems reasonable to refine first the concept of “humans as a species,” regardless of whatever shared nature we have thanks to natural selection and the fortuitous appearance and radiation of anatomically modern humans some one hundred to two hundred thousand years ago. The species falls into an assortment of types of sociopolitical and economic entities, such as egalitarian societies (including many foragers and horticulturalists), ranked societies with weak chiefs exhibiting simple chiefdoms, ranked societies with strong chiefs and complex chiefdoms, state societies composed of tiny priestly elites and vast peasantries dependent on intensive agriculture, and industrial and postindustrial states with social classes, occupational specializations, hierarchies of wealth and ownership, and other inequalities of multitudinous varieties. Instantiations of these and other types of socioeconomic entities can be adduced in the archeological, ethnohistoric, and ethnographic records [on the importance of typology, regardless of whether it is culture-evolutionary, see Earle (2002: 45)]. This differentiation does not mean that they do not overlap or co-exist for certain periods in certain locales.

It is necessary to remember that these are types and not rigid categories. In the Amazon case, it is difficult in a contemporary sense to distinguish historically among the socioeconomic and perhaps ethnic types called “caboclo” and “colonist” (Brondizio and Siqueira 1997), though one can distinguish unlike environmental impacts that have been termed “caboclo” and “colonist” footprints, respectively, since these have been readable by remote sensing technology (Brondizio et al. 2002). Least understood of all such “footprints” are those of indigenous peoples who long preceded the peasantries and urban populations of the Amazon River. However, one looks at history, it cannot be dismissed that Amazon peasantries by definition were always connected to the world capitalist system [they were on its *periphery*, whereas indigenous societies are typically in

the *external arena* of the world system (Wallerstein 1974: 332–339)]. The reason the indigenous footprint has been so obscure is probably not because they made no environmental impression at all, which is a doctrine central to the adaptationist model (see Appendix) of Amazonian diversity (Barlow et al. 2011; Bush et al. 2007; Meggers 1996; Moran 2000; McMichael et al. 2012; see Balée 2010; Balée and Erickson 2006), but rather because remote sensing has not yet distinguished between very old forest fallow and primary forest, though I hope it will be able to do so soon. When it does, we will see a much more substantial landscape signature of ancient societies than is today recognized. Ground-truthing has done that up to a point. What proponents of the adaptationist model [i.e., the standard model (Stahl 2002; Viveiros de Castro 1996) or cultural ecology] call secondary succession is really only very recent secondary forest, better classified as old swidden, not as “forest” per se (Balée 1994); it is not cultural or anthropogenic forest in the sense of forest relics left by earlier societies (Balée 1989). The indigenous footprint exists in a longer, more sweeping timeline than caboclos, colonists, and other socioeconomic entities connected to the world system at any point in time since the sixteenth century; even when there have been influences on indigenous systems originating from outside Amazonia, the impacts have been less intensive and less obvious than in the other two cases, until recently (see Fisher 2000).

2.1.2 *Time as a Multidimensional Analytic Phenomenon*

As these types are not rigid categories but heuristic entities for the purpose of differentiation of environmental impacts, exemplars of these types have also had histories and timelines. Varying developmental concepts of time need to be distinguished in order to understand their histories and effects on the landscape. Time in its mythical versus historical and linear versus nonlinear or cyclical senses of time in the emic analysis of the past, which among diverse Amazon cultures, is well presented in Whitehead (2003), and the various chapters in that work lend support one of my main assumptions here, namely, that time is more than one thing categorically. That assumption, in turn, derives from Fernand Braudel’s concept of the *longue durée* (1993), involving linear processes that take hundreds and sometimes thousands of years to complete in human history. Braudel explicitly recognized that time, for historical purposes, exists in more than one category. I would further argue that for the purpose of understanding Amazon landscapes and diversity today, the timelines are more numerous, involving in some cases millions of years (for species’ genotypes within the school of vicariance biogeography, and tens of thousands or fewer thousands of years within the school of Pleistocene refuge theory). Although that naturalistic time frame for Amazonia is not human historical, it is historical in a broad sense (considering evolution to be a kind of history) and it is relevant to the species distributions first encountered and later modified by human beings thousands of years ago when they first set foot in Amazonia.

Another conceptual usage of time is pertinent here, for it represents a historical moment in Western thought concerning living alterity (contemporary “others”) ensconced paradoxically in the past and representing Western origins. McGrane (1989: 104–105) incisively summarized this nineteenth-century usage thus:

As Lyell’s geology, following Linnaeus, was the first to massively and intrinsically include the element of time *within* the very definition of geography (the earth’s surface is not primeval but the daughter of time), and as Darwin’s biology, following Lamarck, was the first to intrinsically include the element of time immanently within the very definition of the species, so nineteenth-century anthropology was the first to splice the dimension of time immanently inside the experience and definition of the otherness of the non-European Other, inside the definition of traveling beyond Europe, and inside the definition of European “civilization” or “culture”.

In the nineteenth century, different geographic areas that included cultural and social Others constituted in and of themselves a time machine, and in this sense, time and space were merged into a single conceptual framework (McGrane 1989), in a pre-Newtonian way.

Clearly, the impacts that dissimilar sociopolitical entities encompassing human populations through history can have on natural environments and on the resources drawn up into the vortex of the world system’s demand on raw materials are different. This has been so at least since the emergence of a capitalist world system in the sixteenth century (Wallerstein 1974) together with an emic understanding of Europe (and inner Asia distinct and separate from the rest of the world and therefore not insular land masses surrounded by a tempestuous, threatening, and unknown Ocean (McGrane 1989: 34–35). But the emergence of states in general is probably the critical factor in decreasing biological and other kinds of diversity, at the species level and below it. That is why the study of the interactions of humans and the environment takes on such complexity: Human activities are framed in the context of extremely differentiated social, economic, and political complexity, and sometimes these differences are marked linguistically and culturally. Some impacts may affect landscapes in such manner as to enhance their total number within the environment of a local society and its people and traditions, as well as to even increase species diversity (in terms of the alpha, sometimes beta, but not usually gamma indices), whereas other impacts from dissimilar entities (such as global capitalistic, industrialized, and information-age society) may often have the local effect on tropical forests of diminishing diversity of both landscapes and species (Balée 1998).

But the arguments on origins of Amazonian forests and diversity (and the debate applies with modification to tropical rainforests more generally—for West Africa, see Fairhead and Leach 1996) are not simply drawn up as oppositions between nurture and nature, or culture and biology, or history and evolution (Whitehead 1998). A significant reassessment of the time frame of evolution—both of the landscape and of species—has been underway in the last several years regarding Amazonia. Amazonia has been well into the twentieth century and for many people still is a region of “people without history” (see Wolf 1982 for the original definition). This view is a continuation of the nineteenth-century notion

of the non-European. Other, trapped in savagery, frozen in geographic space that really represents “our” own time long past (McGrane 1989; Heckenberger 2006). The reason for the failure by many to recognize historical (and human) process in forming landscapes of Amazonia is because Amazonia in historical comparison with the Andes and Mesoamerica lacked centralized authority. The revisionist school of historical ecology argues that this seeming lack of centralized authority is an interval of history following epidemic disease in the mid to late sixteenth century that essentially wiped out complex society before it could be studied. For that reason, as Whitehead (2003: vii) put it, Amazonia mistakenly still “exists in an eternal present of ‘first contacts’ and ‘marvelous discovery’.” But we are beginning to see the time depth and the historical impact of humans on Amazonian landscapes of the past (as in McEwan et al. 2001) (see Appendix).

2.2 Origins of Diversity

For understanding diversity, even biological diversity, essentially the problem hinges on what is an origin, and can or should it be contextualized? Is it a beginning of a genotype regardless of its spatial context, or is it the explanation for why an extant genotype exists in a place with specifiable boundaries? Both understandings of origin—the purely diachronic and the diachronic combined with the diatopic (variation in space)—can be conceptualized more holistically than has heretofore been done in order to grapple with the diversity today of genotypes in Amazonian tropical forests, and indeed, in other tropical forests.

Let me briefly review the findings of the four hypotheses on Amazonian diversity—both of landscapes and species—and then propose what I think will be a more comprehensive alternative, one that is inspired in the research program (see Appendix) of historical ecology which promises not only a fuller understanding of biotic diversity but of cultural and sociological diversity as well. From that point, I think we will begin to see that biology and culture share common fates, and their recent histories so are deeply intertwined that when Amazonia is taken as a regional object of analysis, the two cannot be fruitfully understood apart from the other.

There is an essential dichotomy between the first three hypotheses and the fourth centering on human effects on nature—the dichotomy is simply stated as, for the first three, there was none of significance.

2.2.1 *Natural Kinds of Explanation*

Scientists working within the school of thought called vicariance biogeography have studied speciation concepts in a deep time frame. History and “historical” biogeography (Bates 2001) occur over time periods of millions, not thousands

of years. The evidence derives from tectonic events, the Andean orogeny, marine transgressions, and the connection of North America to South America via the uplift of the Isthmus of Panama (Mörner et al. 2001; cf. Lovejoy et al. 1998; Räsänen et al. 1995). These researchers tend not to rely on fossil evidence, which unfortunately is almost wholly lacking, but rather on data from molecular phylogenetics. Vicariance biogeography is a standing critique of Pleistocene refuge theory, based mostly on the time frame of speciation (Colinvaux et al. 2000; cf. Haffer 2001).

Pleistocene refuge theory derives from repeated observations of endemism in a wide variety of taxa. Problems of speciation have been seen in terms of forest reductions, allowing for genetic drift within remaining patches of forest during colder periods in the Pleistocene. Haffer (1969) originally proposed the hypothesis, and numerous scientists in diverse fields (of entomology, botany, herpetology) soon found patterns of endemism among the groups of taxa in which they specialized, and to some extent, the identified refugia of diverse taxa overlapped. One of the principal early critiques of Pleistocene refuge theory concerned its method: It arguably had a sampling bias (collections were made near major cities, such as Manaus and Belém; hence, refugia are found there, and more seldom in interior, isolated areas—see Nelson et al. 1990). Nevertheless, certain primitive organisms still occur in restricted locales, such as cycads, which appear in all refugia thus far identified but not outside them (Daly and Silveira 2002: 59).

A third long-standing hypothesis on Amazon diversity concerns simply the requirements for tropical moist forest (Whitmore 1990). Environmental gradients, which interact and overlap in producing environments as we know them, include latitude, rainfall, temperature, light, and soils. If latitude alone is used, tropical deserts are low in diversity (Begon et al. 1990: 835) in contrast to tropical moist forests. If rainfall alone is used, high rainfall in tropical Asia actually coincides with low diversity (Gentry 1988). The Chocó in the Neotropics receives as much as 10,000 mm rainfall/year, but it is not appreciably higher in alpha and beta diversities than areas getting around 4,000 mm/year on the eastern side of the Andes (Gentry 1988). None of the gradients permit the restriction of gene flow (Colinvaux 1987) which is needed for allopatry and evolution: drift therefore cannot occur under such conditions. Environmental gradients nevertheless represent necessary if not sufficient conditions for explaining diversity in tropical moist forests. At the alpha scale, sufficient conditions may involve human activity (Balée 1989; Denevan 2001; Erickson 2000; Heckenberger 2006; Heckenberger et al. 2008; McEwan et al. 2001).

2.2.2 Historical Ecology and Anthropogenic (Cultural) Forest

What is a forest that is determined by human and cultural activity, and how is it different from any other not so caused? This is a difficult, perhaps tendentious question, but it should be resolved before one can undertake systematic analysis

of Amazon diversity and perhaps to diversity of other tropical forests in other parts of the world. Human history in the environment is the factor behind diversity that is least understood of all, but if incorporated into a general model of Amazonian diversity, based on historical ecology, it could bring all current models into mutual understanding. The essential point is humans moved biological diversity around; they also engaged in the domestication, semi-domestication, and cultivation of species—this had the result of transforming landscapes through time (Clement 1999a, b; Balée and Erickson 2006; Erickson 2006, 2008).

We can see that climate change science has well demonstrated current human influence on species' plentitude and on the biosphere generally to be greater than at any time in history. Our geological epoch, thus, has been called the Anthropocene because humans are a "global forcing agent" (Zalasiewicz et al. 2010: 44). The effects include extinctions, invasive species, and climate change. This constitutes a modification of earlier classifications that posited the forcing agents to be geological, natural, or astronomical. At the same time, the term perhaps obscures the fact that humans have had a variety of quantitatively distinct impacts, and because of this, we need a finer-tuned model of human-mediated disturbance of natural environments (Isendahl 2010). Historical ecology has such a nuanced approach. Yet some researchers continue to regard ancient indigenous impacts on Amazonian biotic distributions, frequencies, and mass as negligible, or part of natural, expected processes of intermediate disturbance. They criticize use of univariate metrics such as species richness (i.e., diversity) rather than focusing on rare species. As such, they run the risk of perpetuating the myth that ancient cultural forests consist of common species, and only high forests are characterized by, or harbor, rare "forest-dependent" species (Barlow et al. 2011).

The case of the forests of the Beni, Bolivia (Llanos de Mojos) illustrates how humans impacted diversity upward but not through intermediate disturbance, but rather significant primary landscape transformation. Clark Erickson and I determined a cultural factor at work in order to explain the origins of tree species diversity at the mound site of Ibibate (Erickson and Balée 2006), and here, briefly, I recap that evidence. Ibibate is a *terra firme* forest of about 7 ha in extent; it is located on an anthropogenic mound measuring approximately 18 m in height at its highest point (Erickson 1995). At the base of the mound is a man-made ditch that maintains water year round; at least one causeway emanates from the mound and seems to cross the adjoining pampa at a distance of 4–5 km to the current Sirionó village of Ibibate, also located on a mound, though smaller in height and extent than Ibibate (Erickson 1995, 2006; Erickson and Balée 2006; Sington 2002). Two one-hectare inventories of forest were carried out in the environs of Ibibate mound, which is found within the Sirionó Indigenous Territory, about 40 km due east of the city of Trinidad. The first hectare of forest is located directly over the crest of the mound. It is 20 × 500 m in dimension with forty subplots of 10 × 25 m each; all trees ≥ 10 cm dbh (diameter at breast height) were collected (in 1993–1994) and identified, if not always to family, genus, and species, at least to morpho-species (see Campbell et al. 2006 on the validity of morpho-species as an analytic construct for describing diversity based on inventory data). There were 448 individual trees and woody vines in 55 species on

Table 2.1 Ten most dominant species, Ibibate mound

Species	Relative dominance
<i>Attalea phalerata</i> Mart ex. Spreng. (Arecaceae)	18.3
<i>Gallesia integrifolia</i> (Spreng.) Harms	15.35
<i>Ampelocera ruizii</i> Klotzsch (Ulmaceae)	10.96
<i>Astrocaryum murumuru</i> Mart. var. <i>murumuru</i>	9.27
<i>Hura crepitans</i> L. (Euphorbiaceae)	7.71
<i>Ficus pertusa</i> L.f. (Moraceae)	3.97
<i>Calophyllum brasiliense</i> Cambess. (Clusiaceae)	3.39
<i>Sorocea guilleminiana</i> Gaudich.	3.31
<i>Dendropanax cuneatus</i> (DC) Decne. & Planchon (Araliaceae)	3.07
<i>Hirtella triandra</i> Sw. subsp. <i>triandra</i>	2.9
Total	78.23

this plot. This measure of alpha diversity is high for the region, given the environmental gradients of latitude and rainfall (ca. 14° S latitude which is southerly and 1,520 mm/year, which is low for tropical moist forest). The ten most dominant species from Ibibate account for 78 % of the relative dominance of all 55 species on the plot; it is an “oligarchic” forest (Peters et al. 1989) insofar as it is heavily based on a few species, when seen in this perspective (Table 2.1).

Several of these species may also be found in seasonally flooded environments (such as *Hura crepitans*, *Astrocaryum murumuru*, and *Attalea phalerata*), and of these, *H. crepitans* is millions of years old; arguable vicariance accounts for the evolution in inundated environments of such species (Bush 1994), but they can also be located on the mound, where they are completely protected from river flooding, river avulsion, and other tectonic events as well as lateral channel migration otherwise common in areas of meandering rivers, which is what characterizes the lowland habitats of this area (Pärssinen and Korpisaari 2003). That is, evolved by vicariance in natural selection, and also selected for by historical, human activity. By way of comparison, and in a roughly equal time frame of landscape transformation, it has been recently found that from an inventory of old growth forest on top of the geoglyph known as Três Vertentes (Balée et al. in press), there were 149 species greater than or equal to 10 cm DBH per hectare. Geoglyphs are massive geometric formations of circles, squares, and rectangles; many of them have been uncovered for aerial viewing by deforestation (Pärssinen et al. 2009). The geoglyph of Três Vertentes, which is a gigantic circle larger than 1 ha in size, is also an oligarchic forest in the sense that the first ten most dominant species account for 71 % of the total dominance, and of these 10 species, two are palms (*Iriarte deltoidea* Ruiz & Pav., which is the most dominant species, and *Euterpe precatoria* Mart. var. *precatoria*) (Table 2.2). Although the geoglyph forest is much richer in species than Ibibate (at a total of 149 species vs. 55 per hectare), there are similarities between the two sites in terms of the cultural and historical *kinds* of species present. These are kinds of species that are affected by human movements and landscape transformations; their distributions are comprehensible in terms of historical ecology.

Table 2.2 Ten most dominant species, geoglyph Três Vertentes

Species	Relative dominance
<i>Iriartea deltoidea</i> Ruiz & Pav. (Arecaceae)	18.7
<i>Tetragastris altissima</i> (Aubl.) Swart.	12.2
<i>Cecropia</i> sp. 1 (Moraceae)	8.58
<i>Acacia</i> sp. 1 (Fabaceae)	7.29
<i>Euterpe precatoria</i> Mart. var. <i>precatoria</i> (Arecaceae)	5.82
<i>Castilla ulei</i> Warb. (Moraceae)	5.40
<i>Brosimum lactescens</i> (S.S. Moore) C.C. Berg (Moraceae)	5.01
<i>Acacia polyphylla</i> DC (Fabaceae)	3.05
<i>Virola duckei</i> A.C. Smith (Myristicaceae)	2.56
<i>Celtis schipii</i> Standl.	2.51
Total	71.12

The ancient people of Ibibate and environs evidently preferred to occupy the upland/wetland interface (Lombardo and Prümers 2010), and in this environment, they transformed the landscape. A second inventory at the base of the Ibibate mound, on the other side of one of the causeways leading out from the mound, was carried out in 1997. The dimensions of this plot were 100 × 100 m, and the area is seasonally flooded, unlike the site at the crest of the mound, which is never flooded. I had anticipated that species diversity here would be much lower (in terms of tree species, the lowland, flooded savanna that surrounds Ibibate is clearly lower in species diversity), as a transitional zone to the pampa (savanna). But at 425 individuals in 53 species, the diversity index is not statistically of significant difference from Ibibate. The two plots share 21 species, so the Jaccard coefficient $(a/a + b) \times 100$, is $21/108 \times 100 = 19.4$. That is actually relatively high correspondence for adjacent tropical moist forest of different types (cf. Balée 1994: 134). But what is most important to grasp is that the current alpha diversity at the height of the mound would not exist had it not been for human intervention, the building of the mound in the first place, and that took place during a roughly 1,000 period ending roughly five or six hundred years ago (Erickson 1995); most of the mounds of the region of Ibibate appear to have been occupied during the period AD 400 and AD 1400 (as reviewed by Lombardo and Prümers 2010). It is quite possible that forest from the mound has spilled over onto the adjoining lowland area, expanding itself autochthonously at the expense of preexisting savanna (this hypothesis in regard to forests of the Baurés area to the north is argued in Erickson 2000); another possibility is that the seasonally flooded forest along the savanna margin, which like the forest on the mound itself, is rich in useful species (fruit trees, fuel species, and so on) that could have been used and protected by the ancient inhabitants of the mound. Barlow et al. (2011) argue that conservation should not be focused on common species in secondary forests as the result of human action, but rather on “forest-dependent” species. What they seem to miss is that perhaps some of those species are dependent in historical fact on human activity that in the past built forests. Actually, protection of some species on the

mound has occurred in the recent past, by the Sirionó themselves. Indeed, some of the species on the height of the mound do not tolerate flooding and are not encountered, according to knowledgeable Sirionó elders, ever outside the boundaries of the high mounds. One of these is *turumbúri* tree (*Sorocea guilleminiana* Gaudich., mulberry family), used in making a ceremonial, fermented beverage of the Sirionó used in important rituals (Balée 2000). Arguably, the tree *turumbúri* is a rare and endemic species: Namely, it is endemic to areas disturbed by humans.

2.3 Conclusion

The various models of diversity can be interwoven to some extent with the research program of historical ecology. The timelines in the case of Ibibate can be entertained in terms of evolution of phyla, adaptation to environmental gradients, and historical factors of human disturbance. As to species evolution, some species extant on Ibibate existed millions of years ago, probably in the context of the original formation of the Amazon River Basin itself, following the Andean orogeny. Species diversity in Amazonian forests is also obviously limited by synchronic, environmental gradients of latitude and rainfall. Other timelines are much more recent. It is possible that some of the species on the Ibibate mound migrated out of centers of endemism from elsewhere in the Amazon by principles related to the refuge model, though there is little endemism in the area as a whole, either in undisturbed or transformed landscapes. Floristic diversity (which usually is associated with faunal diversity, as the refuge theory holds) is nevertheless high for the area (a wetland savanna) in general. The calculation of the origins of this diversity takes into account speciation events at millions of years ago, possible speciation events at tens of thousands of years ago (à la a modified form of the refuge theory), environmental gradients (in this case, latitude and rainfall), and human history, occupation, and development of the area within the past two thousand years. This history is not a case of intermediate disturbance, which Barlow et al. (2011) proposed as the only method by which humans can increase alpha diversity. Rather, it is a case of *primary landscape transformation*: a complete upheaval of species and replacement of these by different species. That is, grasses and sedges were replaced by trees and lianas on Ibibate, due to human influence. The human history of the area involved a built environment (the mound) that permitted the growth and maintenance of a *terra firme* tropical moist forest, and the alpha diversity of that forest can only be understood once the human factor is taken into account. This is probably the case with many forests of Amazonia as yet unstudied. There are still geoglyphs, for example, covered in forest (Pärssinen et al. 2009), though perhaps not for long, given the velocity of habitat fragmentation in eastern Acre and environs.

Historical ecology therefore admits of varying timelines in the total explication of diversity, but the one indispensable feature is human activity. That is because human activity accounts for the distribution patterns observed in the present at the

alpha level and perhaps also at the beta level (when considering the addition of the forest on the mound/savanna margin). For Amazonia, then, the timeline of diversity focuses on three general reference frames: millions of years ago (Miocene), tens of thousands of years ago (Pleistocene), and hundreds to thousands of years ago (Holocene, including the human, historical presence). This approach to time and diversity in Amazonia, which breaks time down into significant segments relating to the origins of species diversity, may be understood to be a working model within the framework of historical ecology.

Appendix

Viveiros de Castro (1996) uses the term “standard” model of Amazon ethnology to refer to what I am calling the adaptationist model.

Recent evidence posits that Incan civilization, in a military if not also economic and cultural sense, did indeed penetrate and influence Amazonian prehistory, at least in the upper Amazon (Pärssinen and Korpisaari 2003).

I mean “research program” in the sense of Lakatos (1980) and would distinguish it from the “paradigm” concept of Kuhn (1970) (though I did not do so originally—Balée 1998). The reason for the distinction is historical ecology is probably not a paradigm (cf. Biersack 1999: 8–9), since paradigms demand overwhelming consensus in the scientific community, and all essential problems (in this case, research problems concerning humans and the environment) need to have their own models of explication and deduction that originate in the axioms of the paradigm. Such consensus does not yet exist in historical ecology. The term research program is less rigid and more appropriate to the notion of historical ecology, allowing as it does for less consensus but a relatively widely connected body of research, and does exist in historical ecology (e.g., Crumley 1994, 2001; Balée 1998, 2006).

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