HOLOCENE BIODIVERSITY: An Archaeological Perspective from the Americas

Peter W. Stahl
Department of Anthropology, Binghamton University, State University of New York, Binghamton, New York 13902-6000

KEY WORDS: archaeology, holocene, biodiversity, prehistoric ecology, anthropogenic environments

ABSTRACT
Any understanding of contemporary biodiversity change in the Americas is likely to be uninformative and misleading if it employs a prehistoric baseline imbued with pristine characteristics. Archaeological evidence clearly displays a protracted history of environmental transformations at varying geographical and temporal scales throughout the Holocene (that is, the past 10,000 years). Because of problems inherent to the interpretation of the archaeological record, the genesis of these transformations often can only be ambiguously attributed to environmental and/or anthropogenic origins. However, at any given time or place, both the distribution of the numbers of different kinds of organisms and their relative abundances were in a constant state of flux since the retreat of glacial cover some 10,000 years ago. Here I review archaeological evidence to illustrate the dynamism of prehistoric biodiversity, which can be attributed to environmental events, to anthropogenic causation, or as a response of these to each other.

If travellers, the moment they set foot in a tropical region, and even while on islands, in the vicinity of the sea coast, imagine that they are within the precincts of a primeval forest, the misconception must be ascribed to their ardent desire of realizing a long-cherished wish. Every tropical forest is not primeval forest. I have scarcely ever used the latter term in the narrative of my travels...

A Von Humboldt (229:193)
INTRODUCTION

Writing at the turn of the nineteenth century, Baron Von Humboldt chose these words to address certain misconceptions resulting from generalizations commonly used in his time to describe natural history. He reserved the special appellation *primeval* (primitive) to describe the South American forests of the Orinoco and Amazon basins that he and his contemporaries Bonpland, Martius, Pöppig, and the Schomburgks explored in such detail. In this quote, written nearly 200 years ago, the Baron equated *primeval* with *impenetrability*, a description he “scarcely ever” used to describe the forests of his travels. We would do well today to remember his caution. All too often the pre-Columbian condition of the Americas is explicitly or implicitly assumed to be a “pristine” or “natural” baseline for comparing contemporary ecosystemic alteration.

The current explosion of interest in global biodiversity issues is spurred in large part by dramatic ecosystemic transformations, developments that can now be publicly observed through a range of media from television to interactive games. Perhaps nowhere are these transformations more dramatic than in the tropics, particularly the immense Amazonian forest, where recent estimates have projected staggering rates of biodiversity loss measured in hectares or acres per minute (157, 226). Moreover, the recent Columbian quincentenary has kindled a renewed evaluation of the historic encounter between hemispheres, once isolated by vast expanses of ocean (e.g. 25, 216, 224, 227).

Whenever we invoke concepts of biodiversity change, we imply that it can be somehow measured or estimated against a standard. The comparative yardstick we choose is usually arbitrary and often imbued with stable attributes, much like a homeostatic “climax” community that had gradually and inevitably achieved equilibrium with its surroundings. In this instance, any subsequent ecosystem disturbance could then be comfortably observed, measured, and hopefully understood. Although we could place our baseline anywhere along a continuum of time—for example, before the appearance of agriculture and urban centers, or after the recession of glaciers—a popular point is the historic encounter between hemispheres in AD 1492.

Much has been written, most notably by Crosby (42–45), about dramatic transformations and the exchange of organisms between East and West. While conquering Europeans set out diligently to re-create familiar landscapes, they also unintentionally introduced organisms previously unknown in their new habitats. However, ample evidence suggests that a large portion of the Americas was also transformed by humans long before the arrival of Columbus. Therefore, we must proceed with caution when applying “pristine,” “virgin,” or “natural” as attributes of a pre-Columbian America (9, 28, 40, 50, 56, 200, 202, 207, 237) and take great care to avoid excess when uniformly ascribing
“environmentalist,” “conservationist,” or “ecological” ethics to its inhabitants (see arguments in 3–6, 23, 29, 31, 85, 99, 103, 120, 137, 170, 180, 182, 204, 209, 225, 237).

Lingering notions that indigenous Americans passively languished in a pristine Urwald both mislead us and denigrate native achievement. Botkin (20a) has explored how divine and, later, mechanical models have historically shaped the views of environmentalists about nature and the role of humans therein. Each scenario presumes that nature attains “on its own” a constant and stable order that we can either perfect or disrupt. Alteration of natural order is generally viewed as bad, or at least unwise. However, “natural humans” can play a good role by living in harmony with nature and by leaving their surroundings essentially intact. Although this scenario has strong psychological appeal, Botkin forcefully argues that the biosphere is not a steady state machine but a dynamic organism with a constantly evolving history in which all humans play an important and dramatic role.

Botkin’s argument is highly amenable to the so-called long view in archaeology, which clearly detects a protracted history of environmental transformation in the Americas. This history includes events at different levels of geographic and time scales, whose genesis can be attributed with varying ambiguity to environmental and/or anthropogenic processes. These ongoing events can dramatically affect the temporal and spatial diversity of life-forms by modifying the distribution of different kinds of organisms (richness) and their relative abundances (evenness). “Biodiversity” is a vaguely defined and often abused concept. However, by exploring these two components we may heuristically illustrate time and space variations that conform to recently proposed definitions (222a). Nevertheless, unlike contemporary ecological field study, which can estimate the richness and evenness of a community with some accuracy, retrodiction (inferring past conditions from present observations) of similar measurements from the buried record is confounded by the nature of archaeological data and interpretation.

This review employs an archaeological perspective to explore various issues related to Holocene biodiversity in the Americas. It briefly reviews the nature of available data and discusses its limitations, specifically for the retrodiction of biological richness and evenness. Subsequent sections review environmental and anthropogenically implicated ecosystem alterations during the Holocene epoch and emphasize their effects on biological diversity since the end of the Pleistocene epoch some 10,000 years ago. Owing to the size and scope of the subject, the bibliography is limited to recent discussions, reviews, and summaries.
Archaeologists unearth various kinds of direct and indirect evidence pertinent to assessing biodiversity before the advent of written accounts and scientific observation. Principal among this evidence are preserved plant and animal remains recovered from secure temporal contexts. Additional adjuncts as diverse as phytoliths, landscape modifications, architectural features, and artistic depictions can have important implications to our understanding of past biodiversity. Nevertheless, inferences based on the buried record are often fraught with difficulties.

Difficulties associated with logistics and visibility can render the simple location of preserved items highly problematic. Ironically, surviving evidence is often discovered through destruction. Depositional contexts that foster preservation can be detected as a by-product of diverse erosive forces such as wind, water, and treasure hunting. In those fortuitous situations where preserved remains are located and excavated for scientific purposes, we usually take a sample from the deposits, often with relatively crude technology. Even when the most sophisticated recovery techniques are employed, there remains a complex relationship between a recovered object’s relative durability and its local burial conditions. Items originally accumulated in discrete episodes often tend to be compacted into time-averaged contexts that obscure temporal resolution. Of course, archaeologists are primarily interested in archaeological sites, which are assumed to be spatially discrete refuse deposits initially created by past human activity. But surely, these targets of study are not unbiased samplings of local paleoenvironments. Further, it can be as difficult to firmly identify the mechanism responsible for initial accumulation as it is to control for what was accumulated and in what amount. Finally, the many factors that can numerically and spatially modify aspects of the buried record, both before and after burial, must be critically assessed.

Retrieving reliable information about past species richness and evenness from archaeological data can be highly problematic; therefore, any clear resolution of former biodiversity most often escapes the archaeologist’s trowel. Numbers, particularly relative abundances, can be highly unreliable (91–93). Retrodiction of past species richness from the buried record must be undertaken cautiously because archaeologists cannot control for initial accumulation and subsequent survivorship of buried materials. In this sense, it is wiser to emphasize presence over absence in archaeological contexts, because the former is verifiable and the latter is not. Retrodiction of past evenness is even more difficult because archaeologists can neither control the amount and rate of initial deposition nor accurately factor in the subsequent loss. Therefore, archaeologists often end up with qualitative estimations understood in broad temporal blocks, poorly defined spatial units, and ambiguous accumulation
histories. Despite these inherent problems, archaeological evidence reveals dynamic changes in the Western Hemisphere that can be attributed to environmental and/or anthropogenic events in the prehistoric past.

A VIEW THROUGH THE ARCHAEOLOGICAL WINDOW

In his seminal article on New World landscapes before Columbus, Denevan (50) compelled us to consider the temporal duration and size of native human populations when assessing their impact on prehistoric American environments. The issues of duration and size are not resolved. In fact, there is sufficient latitude in each to accommodate polar viewpoints. Timing of the earliest human arrivals is clouded by historically competing perspectives, disputes over terminology, and a general lack of agreement on the validity, nature, pertinence, and adequacy of the data. These problems divide opinion about whether the earliest New World inhabitants entered over a connecting land bridge or by other means, long before or shortly after 12,000 BP (19, 59–61, 96, 132, 145, 146, 233). Although many of the vectors responsible for population decrease after contact are well known, accurate estimation of native population size remains elusive. Retrodiction of prehistoric figures is usually based on some combination of early historical testimony, backward projection of contemporary demographic data, extrapolation from archaeological and ecological evidence, reconstruction of social structure based on modern analogues, and informed guesswork. Population estimates for the entire hemisphere at the time Columbus arrived have ranged from just a few million to well over one hundred million inhabitants (52, 62, 116, 159, 179, 216, 217, 222, 224, 244).

Even if we choose conservative estimates, we would still need to appreciate the cumulative environmental impact of millions of humans over more than 10,000 years. Resolving causation archaeologically can be very difficult. What was environmental? What was anthropogenic? Which of these was a response to the other? Data from the buried record make it possible to infer major environmental changes at varying temporal and spatial scales since the retreat of the Pleistocene ice cover. This Holocene record suggests a dynamic ecological history that impacted plants, animals, and native human populations on a hemispheric scale. Occasionally the buried record yields considerable evidence of human impact on the pre-Columbian environment. This includes dramatic anthropogenic alterations at varying temporal and spatial scales, from short-term localized impact to the construction of long-term regional landscapes.
The boundary between the Pleistocene and Holocene is conventionally placed at 10,000 BP. Although decidedly arbitrary, this date broadly separates two epochs in the earth’s geological history in which environmental conditions were markedly different from each other. Interpretation of the paleobiological record suggests that with gradual and oscillating climatic amelioration during the end of the Pleistocene, previously equable climatic conditions were eventually replaced with greater seasonal extremes in temperature and moisture. The Pleistocene fossil evidence appears to support the existence of “disharmonious” or “intermingled” faunal and floristic communities for whom no contemporary analogue exists. It is suggested that these diverse assemblages of now allopatric taxa once existed in environments characterized by a low climatic variability that could support relatively high biodiversity. The onset of warming produced greater climatic extremes that facilitated increased environmental homogeneity. Local community composition then changed as various species of flora and fauna suffered subsequent ecological incompatibility or “misadaptation.” Community change was particularly pronounced in continental land masses at higher latitudes, whereas refugia could exist in lower latitudinal lands (79, 89, 90, 95, 100, 130, 230, 242). Not only were extant ice-free habitats continuously altered, but the recession of glacial cover and increased availability of waters melting from glaciers exposed new land while inundating littorals.

How did faunistic and floristic communities react to these changing habitats? Communities did not migrate as single organisms. Rather, each taxon responded individually to habitat change in time and space (90, 130). In this scenario, local richness and evenness of any biota would be in a state of constant spatial and temporal flux as each component acted and reacted according to its own ecological needs depending upon changing circumstances.

However, stable conditions did not necessarily begin at the onset of the Holocene (15, 87, 101, 109, 136, 171, 223). All available evidence points to variability in the climatic record as it set out on a long cooling trend toward another glaciation. At different times throughout the Holocene, different areas experienced warmer and drier conditions. These events were variably associated with geographical and elevational shifts of floral and faunal taxa over periods as long as many millennia. Various refugia throughout the Holocene have been postulated, particularly at higher elevations in the Northern Hemisphere and throughout tropical basins in the Southern. Apparently within the past 4000 to 5000 years climate has been unsteadily growing colder and wetter, interrupted by oscillations referred to as the “little ice age cycle” (87). At various times in the recent past, a set of “little” climatic optima and at least

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**Holocene Biodiversity and Environmental Change**

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one “little ice age” have been interpreted for the entire Western Hemisphere on the basis of assorted data.

Certain periodic and localized events connected with long-term and continuous processes can have profound impacts on regional biodiversity. The combined forces of earthquakes, tsunamis (giant sea waves produced by undersea earth movement), and volcanoes have played a constant and relentless role in shaping the landscapes of tectonically active areas throughout the Western Hemisphere. Largely concentrated along the boundaries of crustal plates, most earthquake activity has been recorded around the margin of the Pacific Ocean Basin, which defines the westernmost edge of the New World. Through subsidence and uplift, earthquakes can cause changes in land levels, which have been implicated in the appearance and subsequent demise of vegetation formations (71). Tectonically produced alteration of surface hydrology has been connected with prehistoric agrarian collapse (150). Ground movement, e.g. earthquake-associated liquefaction and faulting, has also been detected in the prehistoric past (162, 187, 241). Fault-induced seafloor displacement or undersea landslides are prevalent in the Pacific Basin and are directly responsible for tsunamis, which have been implicated in pre-Columbian settlement shifts in western South America (17).

Volcanic activity is found where geological plates subduct, e.g. around the Pacific Ring of Fire, which includes 75% of the world’s active volcanoes. Resultant magma flows, escaping gases, airborne and waterborne ash and dust, fast-moving glowing ash clouds, falling rocks, and mudslides can combine and cause massive landscape transformations. The effects can include fires, hydrological alterations, reduced solar radiation, increased erosion, and defoliation or destruction of plants and animals. Long-term benefits include the release of fertilizers, which can support a rich and abundant flora and fauna (161, 193, 211, 240). The archaeologically visible evidence of Holocene volcanic activity and its possible effects have been recorded for various periods throughout the tectonically active zones of North and South America (35, 115, 193, 194, 214).

Cyclical and roughly predictable climatic perturbations can produce short-term and potentially reversible changes. On a global level, the well-studied El Niño/Southern Oscillation (ENSO) event periodically reappears with variable “teleconnections” (different events in widely dispersed areas that are caused by the same initiating event) lasting from one to three years. Past Super-ENSO and Mega-ENSO events may have lasted from a decade to even a millennium. Torrential rains and flooding on the western coast of South America can be associated with droughts, wildfires, storm activity, flooding, and heavy snows at different latitudes and elevations throughout the hemisphere. ENSO events often affect surface hydrology, assist erosion, originate beach ridge formation and dune encroachment, and strongly modify animal and plant life
both on land and in water. In the buried record, evidence of paleo-ENSOs has been found in ice cores, tree rings, marine invertebrates, fossil diatoms, and palaeo-landforms. These events have been implicated in prehistoric agrarian collapse and large-scale population displacements. However, their buried signatures are potentially similar to those of annual or seasonal storms, floods, and droughts (58, 134, 149, 151, 154, 155, 166, 184, 196, 206, 231).

Against this backdrop of environmental fluctuation over vast areas, we must also consider the effects of isolated and sporadic phenomena on past biodiversity. Fire is a major agent in ecosystemic alteration and was undoubtedly important throughout the Holocene. With current global estimates of as many as 100 cloud-to-ground discharges per second, lightning is a regular and significant cause of fire, except in moist tropical and ice-covered areas (88, 178). Fire is an important instrument in shaping ecosystems and determining the distribution of species, particularly through the creation of vegetative mosaics and increased heterogeneity. Fire facilitates nutrient recycling; alters seed beds; controls parasites; and assists in the flowering, germination, and seed dispersal of many plants while directly or indirectly devastating others (81, 88, 126, 178). Vertebrate communities tend to exhibit greater stability in the face of conflagration. Taxon diversity remains fairly constant through replacement, though with a proportionate increase in ground dwellers (14).

Various forms of aeolian or waterborne deposition may also be archaeological proxies for the destructive forces of seasonal storms, tornadoes, hurricanes, or floods (47, 74, 102, 123, 163, 169, 213, 220). The archaeological record can also register capricious hazards such as ice overrides (49) and mudslides (80). Any way we approach it, the accumulated evidence clearly supports Goudie’s (87:94) observation that “the concept of a stable Holocene environment is quite untenable.” This position is further justified when we consider humans as active participants in continuous landscape transformation.

Holocene Biodiversity and Anthropogenic Change

One of the most popular and controversial topics in American archaeology involves the concurrent appearance of Clovis hunters and disappearance of megafauna at the close of the Pleistocene. Proponents of a “prehistoric overkill” hypothesis argue that this apparent coincidence is the result of the arrival and rapid advance, or “blitzkrieg,” of skilled human hunting populations specializing on large mammalian prey. Proceeding as a wave or front, an initially small group of hunters quickly exterminated its quarry on both continents over a few generations. The patterns of sudden large mammalian extinctions without species’ replacement, the time-transgressive span of these global events after the appearance of human populations, and the survival of small continental faunas into the Holocene support overkill and undermine hypotheses invoking “natural change” (138–140, 156).
However, numerous problems, many of them methodological, weaken the overkill hypothesis (e.g. 89, 90, 94, 95, 165, 230, 233). In particular, a chronology of sudden extinction events at the time of the appearance of humans has been questioned, as has the actual extent of taxa involved. Not only is it claimed that most extinction events had occurred by 12,000 BP, but there appears to be little consensus about when humans first arrived in the Western Hemisphere. However, Guthrie (100:290) has cogently stated that “It is possible to argue that both the megafaunal extinctions and the expansion of humans are features of the same climatic event, an event that opened the door in the Arctic to human expansion while at the same time bringing the environmental changes that led to the extinctions.” Seen in this light, we should perhaps be more cautious than to blame a new and highly ingenious predator with the full extinction of Pleistocene mega-fauna in a changing environment (98, 108, 230).

Prehistoric faunal depletion by overhunting has been suggested elsewhere in the archaeological record (110, 120, 200, and see 117, 131). However, the establishment of causation remains enigmatic for reasons already discussed. Diamond (57) has elucidated this problem with a clever analogy to the extirpation of Southeast Asian tigers. Although we know that these felines were pushed toward extinction through hunting, harassment, and habitat destruction, future archaeologists would likely seek and find other reasons, i.e. environmental change and volcanic catastrophe, owing to the paucity of direct evidence for causation (e.g. skeletons with mortal bullet wounds). Contemporary examples suggest that both habitat alteration and the introduction by humans of other animals are likely more important in extinctions. Diamond suggested that extinction is more plausibly the outcome of a “sitzkrieg,” or slow war of attrition, rather than a “blitzkrieg” of rapidly advancing hunters (57; see also 88, 181). Many examples of extensive and intensive habitat alterations by humans creating favorable conditions for themselves are evident in the prehistoric archaeological record.

Consider first the intentional use of fire by prehistoric Americans. How much native peoples used fire has been widely documented and debated (40, 88, 127, 178, 185, 236), but it appears to have been a regular resource and important tool for hunting, gathering, horticulture, herding, fuel, and general landscape management. Except in very specific contexts, the identification of an anthropogenic origin for any fire is usually approached through historical documents because it is difficult to establish human causation based on archaeological evidence (13). However, there are important data on ancient anthropogenic fires in the tropical forests of Central and South America. Despite the greatest magnitude of thunderstorms, natural conflagration was likely rare in these areas as evidenced by lengthy fire return intervals and the apparent absence of evolved adaptations among forest flora to the ravages of fire (118,
However, evidence does indicate that fires occurred over large areas of the northern tropics from Panama to the Amazon basin during much of the Holocene (173, 174, 186, 188). Some events are associated with evidence of human presence, and others may correspond to periods of drought. It is also possible that their origin lies in a combination of both.

Fire and deforestation are interrelated processes. Humans use fire to remove trees and underbrush for landscape management and crop these plants principally for fuel, building, and tool manufacture. Widespread deforestation has been documented at various times in the New World archaeological record (2, 16, 24, 27, 30, 74, 78, 109, 124, 129, 158, 173, 174, 210, 223). While fire can be used to remove forest trees and understory, deforestation also augments the likelihood of fire. Fuel loads, temperature, wind speed, vapor pressure, and the quantity of ignition sources are increased as ambient humidity decreases (118, 119). Forest removal can also increase the rate and degree of erosion and sedimentation and affect local faunal communities by eliminating established habitats and creating new ones. Certain requirements for larger herbivorous browsers and grazers, often the desired prey of humans, can be notably improved.

The geologically recent grasslands, including various North American prairies and steppes and South American pampas and campos, are interesting cases in point. Contemporary landscape studies, bolstered by historical accounts, connect the important role of anthropogenic fire with the extension and management of grassland habitats, particularly for improving wildlife and—later—livestock rangeland (63, 86, 88, 97, 106, 168, 178, 228). This has led to speculation about an anthropogenic origin for assorted grassland habitats. However, palynological and ecological evidence suggests that these formations were naturally established at various times, with some pre-dating the arrival of humans (21, 37, 105, 144, 223). Of course, this does not rule out human agency in the prehistoric extension and subsequent maintenance of local natural grasslands (24, 86, 122, 223).

The high-altitude Andean puna grasslands appear to have been the setting for early exploitation, management, and domestication of native camelids. Archaeological evidence indicates a proportionate shift in dependence upon camelid resources as early as 5000 BC, which suggests the appearance of domesticated taxa. Whereas llamas can adapt to various settings but thrive on the dry forage of unmanaged puna, alpacas are best suited to high-altitude landscapes and need natural or artificial wetlands (bofedales). Dated evidence in the form of bones, corral structures, and pottery depictions successfully document the time-transgressive movement of domesticated camelid stock outward from their heartland to areas throughout the prehistoric Andean world. Analyses of mummified remains suggest greater anthropogenic control of breeding stocks, and early documents record expansive imperial herds before
the arrival of Europeans (11, 26, 77, 142a, 197, 205, 232, 238). Certainly since
the early arrival of domesticated dogs into the New World, native peoples had
been manipulating, deliberately transporting, and inadvertently introducing
animals throughout the hemisphere. These included domesticates such as dogs
(36), muskovy duck, guinea pigs (209, 238), and turkeys (175), as well as cap-
tive or transported macaws and parrots (39, 148), wild jays (7), island foxes
(34), tinamous, and various rodents (239).

The local distribution and relative abundance of various animal taxa were
further manipulated as a direct consequence of habitat alteration for plant
management. The success of “garden hunting” of desired game animals in an-
thropogenic habitats, ranging from manipulated stands of useful plants to hort-
icultural clearings and house gardens, is a function of increased foraging op-
portunity created by habitat disturbance and the additional lure of edible
plants. Of particular note is the increase of large browsers such as white-tail
deer, whose bones are ubiquitous in archaeological deposits on both conti-
nents. Indeed, Linares (128) suggested that garden hunting may have been the
neotropical counterpart of prehistoric animal domestication. The vicinity of
native anthropogenic clearings is usually characterized by high overall species
diversity (10, 215), and we must also consider the wide range of indigenous
silvicultural management techniques documented at different times through-
out the hemisphere (9, 12, 20, 40, 53, 70a, 82, 83, 127, 176, 177, 234). Re-
cently, Balée (9, and see 70a) estimated that at least 11.8% of terra firme for-
est in Brazilian Amazonia is anthropogenic.

The actual magnitude of prehistoric forest clearance dedicated to prototypi-
cal slash-and-burn horticulture is open to question on technological and
analogical grounds (51, 65). However, we are certain about the great antiquity
and geographical extension of genetically transformed plant cultivars through-
out the hemisphere (38, 70a, 189). Native peoples actively encouraged in-
creased crop yields and expanded growing ranges for their domesticates using
genetic manipulation and highly sophisticated agricultural techniques. After
1492, improved New World plant stocks spread rapidly worldwide and are to-
day responsible for feeding much of the planet (142b). Remnants of impres-
sive native agricultural infrastructure, which aided the expansion of plant cul-
tivation into areas normally too cold, wet, steep, and/or dry remain observa-
ble in the archaeological record.

In its many forms, indigenous raised field agriculture involved the artifi-
cial elevation of cultivation surfaces, usually in association with contiguous
water conduits. This technique effectively increased the geographic range
and/or intensity of crop yields, especially in marginal agricultural lands. Natu-
ral wetlands and periodically inundated areas could be fashioned into produc-
tive agricultural lands through the removal and subsequent control of standing
water. Artificially raised surfaces also increased soil depth and quality, while
facilitating weed control. Adjacent canals and ditches expedited water management and helped to regulate microclimate, while also serving as compatible sites for nutrient cycling and intensive aquaculture. Documented at various times in low elevations and high-altitude environments throughout northeastern, midwestern, and southeastern North America, Mexico, Central America, Colombia, Venezuela, the West Indies, Surinam, Ecuador, Peru, Bolivia, and northeastern Argentina (24, 46, 54, 65, 67, 68, 70, 76, 84, 176, 191, 198, 203, 212, 221, 235, 243), remnant prehistoric fields represent significant regional-scale human landscape modifications.

The prehistoric terracing of naturally sloping surfaces has left its mark on the contemporary landscape. Highland bench terraces were used on the steep slopes of elevated terrain to increase the horizontal and vertical extent of agricultural growing surfaces. Various forms of weir, barrage, pit, and sloping terraces primarily improved growing conditions in less steep topography. Over time, especially where aridity or seasonal water shortage was a concern, prehistoric terracing appears to have approached the latitudinal limits of aboriginal agriculture from southern Utah and Colorado through Mexico, Central America, and the Andes to Chile and Argentina. Most agricultural slope modifications were primarily directed at some form of water management, such as drainage or equitability of water distribution. These were often supplemented by artificial irrigation and sustained by check dams or reservoirs that could effectively control and store surface runoff. Terracing also deepened planting substrates, improved soil qualities while arresting erosion, and controlled microclimatic conditions for non–frost-resistant crops such as maize that would normally suffer in high-altitude valley basins (e.g. 55, 63, 65, 66, 69, 75, 176, 191, 201, 218, 235).

Massive networks of prehistoric canal irrigation spanned huge tracts of arid land throughout the American Southwest and northern Mexico and stretched along the coastal plains lying to the west of the Andes. Predictable sources of water were controlled and redirected into these and other regularly or periodically arid regions through a variety of irrigation projects. Availability of cultivable land and intensification of crop yield were greatly augmented by systems linking ingeniously engineered water catchment and control features with expansive redistributive mechanisms. These systems incorporated a wide array of technological sophistication and employed natural and artificial impoundments, wells, filter galleries, cisterns, channelized streams, dikes, weirs, dams, gates, canals, ditches, furrows, berms, and terraces. Archaeology has documented the great antiquity, evolution, and sophisticated engineering prowess involved in a host of prehistoric water redistribution schemes, ranging from smaller localized systems to monumental infrastructure and massive intervalley efforts. Careful study of the surviving evidence has also revealed episodes of construction, continuous remodeling, and innovation in response
to dynamic conditions. Expensive irrigation systems certainly reduced short-
term risk, yet they remained vulnerable to natural flooding and tectonic activ-
ity that could have also led to eventual collapse and abandonment (64, 72, 74,

Finally, we must consider extensive landscape modification through the
steady accretion of human communities ranging from isolated encampments
to immense pre-Columbian cities. The substantial impact of prehistoric settle-
ments is recorded even in settings where structural remains rarely survive.
Amazonian soil taxonomy recognizes a separate and extensive terra preta do
indo anthrosol, found in an assortment of geomorphological contexts and iso-
morphic with former human settlement (202). Throughout the Western Hemis-
phere, it is often difficult to find areas where the imprint of previous habita-
tion is lacking. However, the overall magnitude of environmental transforma-
tion is most spectacularly confronted in the pre-Columbian city. Beginning at
least in the millennium before Christ, permanent and densely settled commu-
nities began to appear on the American landscape. Over the ensuing millennia,
large settlements grew, evolved, and collapsed long before invading Europe-
ans described the immense and magnificent cities that awaited their arrival.
The archaeological legacy of these great pre-Columbian settlements extends
southward from the impressive Cahokia Mounds to the vast Andean cities of
South America (8, 28, 33, 104, 114, 152, 172, 192, 195).

The massive scale of landscape modification motivated by large and
densely populated centers can be estimated according to labor cost involved in
monumental architectural construction (1). Similar expenditures were re-
quired for expansive public spaces (111), domestic dwellings, and other infra-
structural demands (11) needed by a heterogenous populace not directly in-
volved in subsistence production. Analogous to the tip of an iceberg, most
large centers had numerous minor centers, each with their own sustaining hin-
terland. Linking structures such as simple trails to sophisticated road networks
interconnected each system with itself and its neighbors, which resulted in a
complex communication network whose imprint also remains etched into the
landscape of the Americas (113, 183, 219). In placing heavy demands on local
surroundings for food, water, fuel, construction material, and waste disposal,
pre-Columbian cities were plagued by an assortment of environmental dilem-
mas not unlike those of their contemporary counterparts (48).

Summary and Conclusion

Without doubt the rapid and massive transformations of global biodiversity
caused by contemporary human populations will have serious repercussions
for this and future generations. Habitat degradation, destruction, and the dra-
matic loss of species richness and overall ecosystemic health are events that
can be recorded and compared on a scale of seconds—with the passing of a
bulldozer’s blade—and on a scale of years—with the chronic abuse and mis-
management of natural capital. The scale we choose is arbitrary, but the popu-
lar comparative yardstick of an assumed “pristine” or “natural” pre-
Columbian America is both uninformative and misleading.

The often ambiguous archaeological record clearly demonstrates a pro-
tracted history of environmental transformations at different temporal and
spatial scales throughout the Holocene. At any given time and place, environ-
mentally and/or anthropogenically induced alteration set both the numbers of
different kinds of species and their respective proportions into a continuous
flux. Individual taxa responded to changing conditions according to their
unique demands, such that a dynamic patchwork was the norm and not the ex-
ception. Similarly, the protracted imprint of substantial pre-Columbian human
populations variably increased and decreased the temporal and spatial pa-
rameters of biological richness and evenness, according to particular strate-
gies or circumstances.

Whatever the prehistoric magnitude of human impact on Holocene land-
scapes and biodiversity in the Western Hemisphere, that impact was surely
less profound than many of the dramatic changes wrought since Columbus.
Nevertheless, it is important not to paint the resource utilization practices of
native American peoples, both past and present, with a broad ecological
brush. Some groups likely approached a “conservation” ethic, but others
likely did not. Regardless, as long as we pigeonhole native deeds into oppos-
ing dichotomies our representations will likely be uninformative and mislead-
ing. For contemporary native peoples who view themselves as integral parts
of nature, the Western idea of conservation as a strategy of short-term restraint
for long-term sustainability (6) and the opposing notion of ecosystemic devas-
tation are inherently flawed. Either concept implies that an ecosystem can be
potentially ruined by one of its elements, a position that must be somewhat
foreign to peoples who view themselves as living within nature.

Enormous biodiversity change resulted from the hemispherical turf war
that raged after the arrival of Columbus. In this new arena, the Bible (Genesis
1:28) had ordained that nature could be dominated, and fixed ownership in a
market-based economy eventually secured its treatment as property. The in-
troduced notion of land as the essential commodity ensured further biodiver-
sity loss. Resources were purchased, sold, conserved, or depleted by burgeon-
ing populations, according to the whims of an extractive global economy. Na-
tive peoples were drawn into this battle over land rights from its inception.
Rushing to seize their piece of America, resource-starved newcomers pro-
jected stereotypes of “savage” and “uncivilized” Indians to justify their appro-
priation of land. Today, the struggle over real estate continues as natives and
newcomers compete for land and resources and in how they are to be util-
ized—concepts that are inextricably bound into notions of entitlement and
identity. This relationship is eloquently described by Cronon et al, who wrote (41:15):

The more settlers invested their labors and their dreams in the land, the more they belonged to that land and the more the land belonged to them. Indeed, the longer they (and their children and their grandchildren) perceived themselves in such terms, the less one could call them invaders. Before very many years had passed, they too were defending the homes of their ancestors. ‘Europeans’ and ‘Africans’ and ‘Asians’ had become ‘Americans.’

ACKNOWLEDGMENTS
For their valued input and help with references, I thank Donald Chrisman, Charlie Cobb, Al Dekin, Clark Erickson, Paul Fish, Suzy Fish, John Isaacson, Dan Janzen, Bill Isbell, Michael Little, Randy McGuire, Mike Muse, Ann Stahl, Andrea Wiley, and Jim Zeidler. Deepest thanks are extended to Michael, Clark, and Ann for reading an earlier version of this manuscript, and for their protracted support and enthusiasm in this and related projects; however, I alone must remain responsible for the contents of this paper.

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