

Ethnobiology as a Bridge between Science and Ethics: An Applied Paleozoological Perspective

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In the face of the global environmental crisis, ethnobiologists find themselves in a potentially helpful position. Ethnobiology represents one of a few bridging disciplines between the philosophical foundations of environmental ethics and the scientific foundations of

environmental science. Environmental philosophers study what ought to be done to address environmental problems at multiple spatial and temporal scales (Borgerhoff-Mulder and Coppolillo 2005; Rolston 1988), focusing on what it means to value nature, how humans do value and should go about valuing nature, and how these ethical footings should inform science and policy. Environmental science incorporates functional roles for many scientific disciplines (Miller 2007). Environmental science and environmental ethics share the goal of curbing the environmental crisis through communication among practitioners from different fields, appreciation of diverse perspectives, and incorporation of vested parties in policies and management decisions (Penn and Mysterud 2007a). Practitioners of ethnobiology communicate and interact across disciplinary, cultural, and temporal boundaries (Lepofsky 2009; Nabhan 2009). Within ethnobiology, applied zooarchaeology (or “applied paleozoology” to include paleontology)—the study of animal remains from archaeological and paleontological sites to provide baseline information relevant to restoration ecology and conservation biology—transcends temporal boundaries and offers an example of a bridging perspective that links ethics to science.

Many of the disciplines represented within ethnobiology offer a perspective of what philosopher Albert Borgmann (2000) terms “disclosure,” a shift in analytical scale such that natural processes (e.g., geological, cultural, and/or biological processes) are more profoundly understood. Examples are cultural relativism¹ in cultural anthropology, the theory of evolution in biology, and deep temporal perspectives in geology and archaeology. Applied anthropologists, for example, mediate between people of radically different cultural backgrounds, the goal being to accomplish the “profounder task” of compromise that values multiple cultural perspectives but also meets people’s needs through processes such as cultural brokerage and social marketing (Van Willigen 2002).

The deep temporal perspective of the time-like sciences (Dunnell 1982) such as geology, evolutionary biology, and archaeology transcends the analytical scale of a human lifetime



Figure 8.1 A conceptual framework of the interaction between the environmental–ecological sciences and environmental ethics, highlighting ethnobiology as a bridging discipline. After Rozzi 1999: 912, Figure 1. Copyright, American Institute of Biological Sciences.

¹Here we mean “descriptive relativism” characterized by Brown (2008: 367), but we acknowledge that this term entails a range of meanings spanning from cognitive anthropology to ethics.

and provides awareness of the contingency of modern phenomena (Oelschlaeger 2000; Simpson 1963). Without this depth, modern solutions to seemingly short-term problems are divorced from evolutionary reality. From a perspective of disclosure, applied paleozoology is highly relevant to conservation biology and restoration ecology. It bridges between environmental science and philosophy (Fig. 8.1). Without such a perspective, the paths to extinction, reduction in biodiversity, and introduction of pest exotic species today are analyzed without understanding the “journey” to the “destination.” Applied paleozoology bridges ethics and science by offering a sense of contingency and urgency because consideration of deep time highlights the environmental crisis by providing a basis for concluding that modern humans *ought* to make changes to reverse the long-term effects of unsustainable environmental policies and habits.

APPLIED PALEOZOLOGY

Applied paleozoology is the use of zooarchaeological/paleontological datasets to provide long-term information on biological changes (Lyman 1996). What species were present in an area in the past (Grayson 2006)? What species should not be there today (Emslie 1987)? How has biodiversity changed in the face of modern human impacts (Stahl 1996)? What are the long-term evolutionary and ecological implications of human impacts on the environment (Russell 2003)? Applied paleozoology offers new answers to important questions and a new perspective on the evolutionary trajectories of ecosystems (Landres 1992). For example, Virginia Butler and Michael Delacorte (2004) studied Holocene paleozoology of threatened and endangered fish species in the Owens River Valley of California. They found that the proposed construction of several wetland and stream preserves may not be the solution for impacts on native fish species, thought to relate to overuse of the Owens River water supply by Los Angeles and other urban areas. The threatened fish species had survived extended periods of low water (droughts) in the past (e.g., the mid-Holocene Altitheermal climate interval), and a greater threat seems to be the more recent introduction of competitors and predators rather than reduction in habitat availability. In this case, the financial cost of constructing and maintaining preserves might result in economic waste. Similarly, there has been extensive debate regarding the status of mountain goats (*Oreamos americanus*) in the Olympic National Park, Washington (Lyman 1998). Park officials were considering the extermination of mountain goats in the park because, based on historical documentation, they thought the goats were exotic. R. Lee Lyman has argued in several publications that the park did not survey the paleozoological record to determine whether or not mountain goats were there in the past; the historical record supports only ambiguous interpretations as to whether or not mountain goats are exotic. These examples and many others (Frazier 2007; Graham 1988; edited volumes by Lyman and Cannon 2004; Penn and Mysterud 2007b; Rick and Erlandson 2008) highlight the importance of temporal scale. Which scale is relevant for conservation biology and restoration ecology?

SCALES FOR RESTORATION AND CONSERVATION

There has been much debate as to which temporal and spatial scales are appropriate for restoration (Hunter 1996); we focus on temporal scales, which are relevant from a paleozoological perspective. At issue is the question: what should impacted environments be

restored/conserved to? J. Baird Callicott (2002) outlines three scales from which to choose for determining benchmarks for restoration and/or conservation. The microscale is the scale of a human lifetime or shorter, and it is inappropriate because many human impacts are longer term. The macroscale is the scale of evolutionary/geological time of tens of thousands to millions to billions of years ago. This scale is also inappropriate because at the evolutionary timescale ecological communities, species, and landscapes change in irreversible ways. At this scale phenomena are always in a state of becoming something else. An example of a restoration effort that ignored a paleozoological perspective and mistakenly (unknowingly) based restoration on an evolutionary benchmark was the failed reintroduction of sea otters (*Enhydra lutris*) to the Oregon Coast (Lyman 1988; Valentine et al. 2008). The reintroduced individuals were from an Alaskan sub-population. Paleozoological research highlights that a morphological and genetic cline existed along the coast and that late Holocene Oregon Coast sea otters were a different ecotype than the source population for modern reintroduction. The reintroduced individuals do not appear to have been adapted to the Oregon Coast, which represents an evolutionary scale difference.

Callicott argues that an intermediate scale, the mesoscale, is most appropriate for restoration and/or conservation. This is the scale at which ecological phenomena change. He argues that such change occurs in centuries and millennia. Previous perspectives on benchmarks have been loosely ethnocentric in that pre-1492 conditions in North America (prior to European arrival in the New World) were considered pristine environments. This perspective ignored the fact that humans existed in the New World for at least 14,000 years. On the other hand, the opposite extreme has been adopted, that all human societies create “anthropogenic landscapes.” Some proponents of this perspective suggest that late Pleistocene humans in the New World caused the extinctions of many genera of animals (Martin 1973). They argue that analog species from other parts of the world, which represent “the closest living species” (such as elephants, African lions), should be introduced into North American Pleistocene parks (Donlan et al. 2005). This perspective is inappropriate for a number of reasons. First, if Rozzi (1999) is correct in asserting that a primary cause of the current environmental crisis is that humans are increasingly divorced from nature, the notion that all human impacts universally create anthropogenic landscapes supports that divorce. Second, there is very little to no archaeological evidence that humans caused the late Pleistocene extinctions (Grayson and Meltzer 2003; Hill et al. 2008; Wolverson et al. 2009a), yet the presumption that such was the case is a “poster child” for the anthropogenic landscape perspective (Penn and Mysterud 2007a). Finally, this perspective ignores Callicott’s warning that *because evolution occurs* the evolutionary time-frame is inappropriate for restoration and conservation. Introduction of distantly related “closest living species” might promote an ecological disaster of unimagined “anthropogenic” proportion in a North American environment that has changed substantially during the Holocene (Rubenstein et al. 2006). We agree with Callicott that the mesoscale is most appropriate for conservation biology and restoration ecology.

ANALYTICAL METHODS

We present case studies of our own research, not because they represent better examples of applied paleozoology than other studies, but because these are the examples with which we are most familiar. Paleozoological data are analyzed at nominal (presence/absence) and/or ordinal (rank order) scale using non-parametric statistics, such as Mann–Whitney *U* tests to assess sample differences. This statistical approach avoids assumptions of normality because

paleozoological populations cannot be directly examined nor can they (often) be resampled. It also acknowledges that quantitative paleozoological data are estimates of actual abundances² based on counts of remains that passed through taphonomic histories (Grayson 1984; Lyman 2008).

White-tailed Deer Overabundance in Central Texas

During most of the Holocene (the last 10,000 years) humans and other large mammalian predators (e.g., black bears [*Ursus americanus*], wolves [*Canis lupus*], pumas [*Puma concolor*], and even jaguars [*Panthera onca*]) roamed Texas. White-tailed deer (*Odocoileus virginianus*) represented a common prey resource for these predators during that time. Wildlife biology studies show that in the absence of predation, deer populations explode to extremely high densities (Kie et al. 1983; Simard et al. 2008). White-tailed deer and other ungulates exhibit an interesting adaptation when their population densities are high for extended periods of time (e.g., decades); their body size becomes smaller (Geist 1998; Wolverson 2008a). This response is the result of phenotypic plasticity, which represents an adjustment to short-term environmental changes in food supply without much genetic change. At high population densities, food-available-per-animal declines. An energetic compromise is smaller size (Wolverson et al. 2009b). Native American human hunters and large carnivores no longer exist in Texas, and central Texas is thought to have one of the highest regional white-tailed deer population densities in North America (Teer 1984; Walton 1999). Large native predators were exterminated in Texas to protect ranching interests during the last two centuries, and there are no federally recognized Native American tribal lands in the state. With impacts of pest-level white-tailed deer populations, fire protection (which has disturbed the natural regime), and livestock ranching combined, much of central Texas is currently witnessing ecosystem decay. This is happening in part because over-browsing of native deciduous trees, saplings, and seedlings has given the water-competitive, highly flammable, unpalatable (to deer and livestock) juniper (*Juniperus ashei*) a competitive advantage throughout the region, essentially producing juniper monocultures in many areas (Russell and Fowler 1999, 2004). Central Texas, especially near Austin and San Antonio and in areas to the west of those cities, is a food-poor anthropogenic landscape for the white-tailed deer, which was shaped during the last two centuries. Given that population densities of white-tailed deer are very high in this region and that habitat quality is poor, we expect that the size of deer from Holocene archaeological and paleontological sites from central Texas should be significantly larger than that of modern deer.

To compare modern and prehistoric deer, we measured the astragalus (ankle bone) of white-tailed deer (Fig. 8.2). The astragalus matures early in life and is likely to reflect differences in adult body size (Purdue 1987). Astragalus size among mid- to late Holocene deer from central Texas is significantly larger than among modern *unhunted* deer from the same region (Table 8.1; Fig. 8.3a). But the size of prehistoric deer cannot be distinguished from a modern population that has been systematically sport-harvested in central Texas for the last 50 years (Table 8.1; Fig. 8.3b). Climate change during the mid- to late Holocene, coming out of the dry and warm Altithermal, likely resulted in a higher quality habitat through time (Ferring 1995), which should not—by itself—have made for smaller deer. A potential concern is that prehistoric deer astragali have not been identified to sex. It is unlikely, however,

²“Actual abundances” can mean several things; paleozoological assemblages pass through histories typically conceived of as a series of assemblages. The “life assemblage” or “biocoenose,” which represents the past living community, is the target variable we are referring to here (see Lyman 2008: 21–26 for discussion).

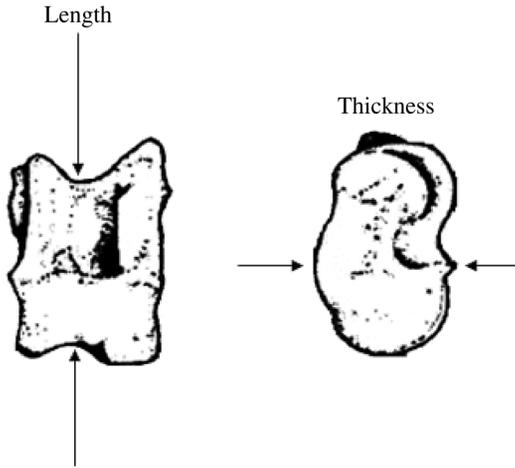


Figure 8.2 Measurements taken on white-tailed deer astragali. Measurements from Purdue (1987:3, Figure 1).

that the difference in size between the modern and prehistoric deer is the result of differing sex ratios. The prehistoric sample comprises roughly the same level of size variability as the modern sample, which contains bucks and does (Table 8.1). A size distribution with bucks and does in equivalent numbers is slightly bimodal and symmetrical. A difference in skewness from symmetry between the two samples would suggest a difference in sex ratio. Pearson’s skewness of 0 represents perfect symmetry and that of ± 0.6 or greater

Table 8.1a Descriptive Statistics Measurements of White-Tailed Deer Astragali, mm^a

Sample	n	Median	Mean	Standard deviation	CV (%)	Pearson’s skewness
Paleozoological						
Length	58	29.85	29.88	1.41	4.73	0.06
Thickness	58	21.30	21.33	1.15	5.39	0.08
Modern unhunted						
Length	29	28.68	28.63	1.18	4.12	-0.13
Thickness	29	20.00	19.88	1.00	5.02	-0.36
Modern hunted						
Length	43	30.06	29.95	1.36	4.53	-0.24
Thickness	43	21.23	21.06	1.15	5.47	-0.44

Table 8.1b Mann–Whitney *U* Comparisons for White-Tailed Deer Samples

Test	<i>U</i> -statistic	p-value
Paleo versus unhunted		
Length	440.0	p < 0.001
Thickness	285.5	p < 0.001
Paleo versus hunted		
Length	1207.5	0.786
Thickness	1092.0	0.287

^aAfter Wolverton et al. 2007: 549.

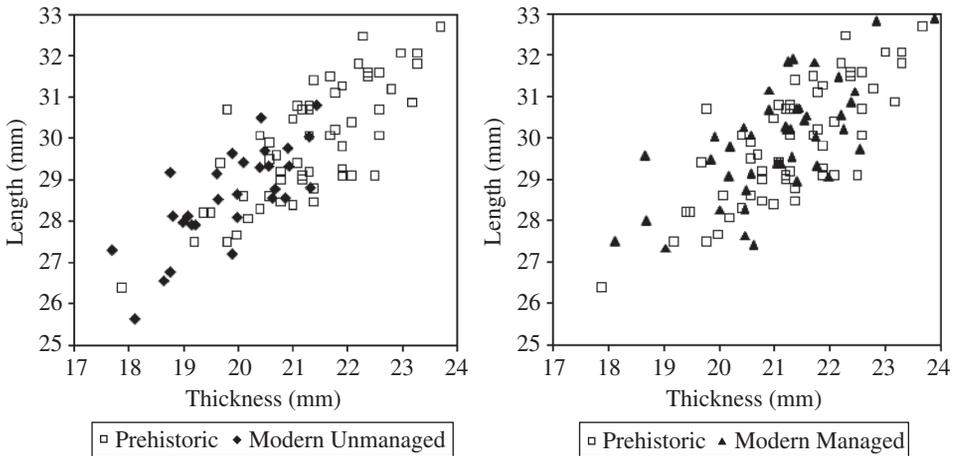


Figure 8.3 Bivariate scatter diagram of white-tailed deer astragalus size: (a) comparing un hunted modern deer to Holocene paleozoological deer from central Texas and (b) comparing hunted modern deer to the same paleozoological assemblage. Related descriptive and inferential statistics are in Table 8.1. Used with kind permission from Springer Science+Business Media: Environmental Management, Vol. 39 (2007), p. 549, Wolverson et al., Figures 3 and 4.

represents significant skewness (Hildebrand 1986). Neither sample is skewed, suggesting that both representatively sample bucks and does (Table 8.1). It is possible that the size difference between modern-unhunted and prehistoric deer represents evolutionary change, but this is unlikely given that white-tailed deer are known to be very phenotypically plastic in terms of body size and given that the Fort Hood deer population dramatically increased in size during the mid-twentieth century as systematic harvesting progressed annually (Fig. 8.4). Fort Hood deer in the mid-twentieth century were similar in size to deer from areas that are overcrowded in central Texas today, but they became larger in size with the thinning effects of systematic managed sport harvest.

The broader implication of this case study is that the “deer problem” is common in parts of North America as deer reach pest population levels, and its effects range from crop damage to increases in automobile accidents (Côté et al. 2004). It is difficult for local municipalities to address the problem without reducing population density through culling. Translocating deer to other areas is expensive, as is sterilization; culling, however, is often an unpopular solution, because many people view killing wild animals as unethical (Rolston 1988). The paleozoological perspective in central Texas can provide a disclosive point of view through the lens of deep time (Wolverson et al. 2007). Given this disclosure, it may be ethical to thin populations through managed harvest or predator restoration.

Black Bears in Missouri

By 1900 black bears (*Ursus americanus*) were extirpated from Missouri (Schwartz and Schwartz 2001); bears were translocated from Minnesota into Arkansas during the mid-1900s (Smith and Clark 1994). The translocated population has grown and now ranges into southern Missouri. Very little is known regarding historical populations of black bears in the Midwest because they were eradicated by Euro-Americans during westward expansion and settlement. Bear remains were excavated from two natural trap caves—Lawson Cave and Jerry Long Cave—in central and eastern Missouri during the 1950s.

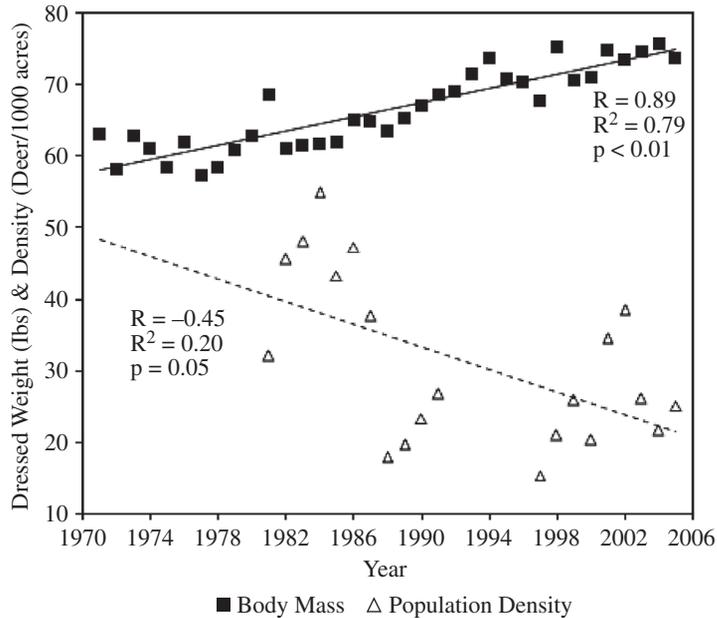


Figure 8.4 Mean field dressed weight (lb) increase in 1.5-year-old bucks at Fort Hood as systematic managed harvest became established and progressed from 1971 to 2005 (closed squares; solid line). A corresponding decrease in population density is recorded for much of the same period (open triangles; dashed line).

The caves are traps because they are deep vertical fissures into which animals fell but from which they could not escape (Wolverton 2006). Radiocarbon dates and associated artifacts indicate that the remains date to the historic period within the last 250 years before present (Wolverton 2001). The remains of 22 individuals were recovered from the caves, and these represent the largest record of Missouri black bears prior to extirpation.

The remains represent relatively large individuals, prompting speculation in the mid-1900s that the deposits were either late Pleistocene in age or that the remains approached the lower limit of grizzly bear size (Wells 1959). Neither of these is the case; instead, the size of the remains relates to age- and sex-specific behavioral characteristics that resulted in the entrapment of young males (Wolverton 2006). Figure 8.5a shows the age distribution of black bears from the caves; Figure 8.5b illustrates that tooth size of the natural trap bears overlaps with the upper half of a size distribution (the male half) from a modern sample. Tooth size of the natural trap bears significantly differs from that of modern females but cannot be distinguished from modern males (Table 8.2). This is of interest to modern wildlife biologists (see below).

Bears were attracted to the caves by carrion, and it is likely that individual bears entered in the search for food. Remains of cubs are uncommon (one individual is present) indicating that the individuals that fell into the traps were not attempting to establish dens. Other species represented in the fauna tend to be scavengers, such as pigs and turkey vultures (Wolverton 2008b). Why were young adult male black bears attracted to carrion in the caves, and not members of other age/sex classes?

Male bears enter a very stressful period at the onset of and during young adulthood (Bunnell and Tait 1981). They leave the company of their mothers and must establish territories in a matrix of territorial older males through competition for food and mates. Young adult males are known to venture more commonly into areas of human habitation to search for food (e.g., garbage); they are more likely to be drawn to and captured in

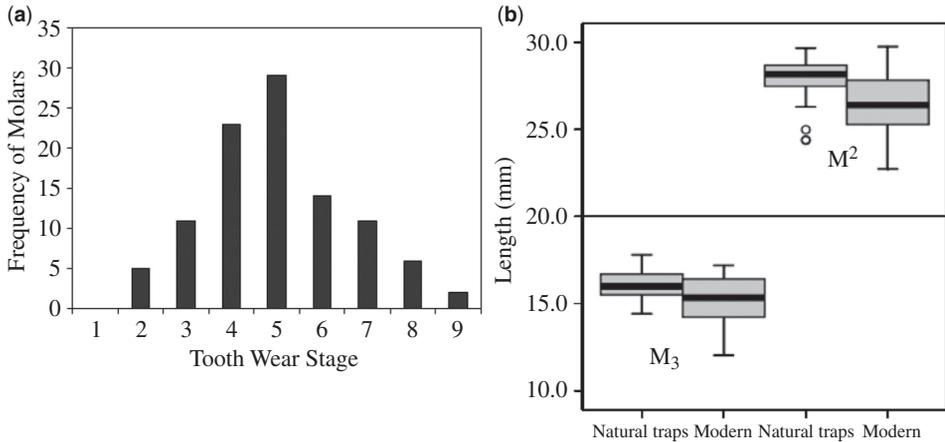


Figure 8.5 Tooth wear age structure (a) for historic-period black bear remains recovered from Lawson and Jerry Long caves in Missouri. Tooth size distributions (b) for modern Midwestern and Lawson/Jerry Long Cave black bears. Related descriptive and inferential statistics can be found in Table 8.2. Reprinted from *Ursus*, Vol. 19 (2008), p. 181, Figure 4.

baited traps and to perish in altercations with humans (e.g., automobile collisions) (Beckmann and Berger 2003; Garshelis and Pelton 1981). Although wildlife biologists know that young adult bears are vulnerable to accidental deaths, conflict with humans, and entrapment, it has not been established whether or not this pattern is a modern phenomenon produced by collapsing territory size or if it relates to life history adaptation in

Table 8.2a Descriptive and Inferential Statistics for Black Bear Tooth Measurements, mm^a

Source sample	n	Median	Mean	Standard deviation	CV (%)
Natural trap					
M ² length	21	28.20	27.75	1.54	5.6
M ² width	21	16.00	15.99	0.95	5.9
M ₃ length	18	16.20	16.09	1.09	6.8
M ₃ width	18	12.80	12.82	0.83	6.5
Modern					
M ² length	30 ^b	26.42	26.41	1.86	7.0
M ² width	30 ^b	15.88	15.95	1.35	8.5
M ₃ length	22	15.34	15.23	1.43	9.4
M ₃ width	22	12.61	12.38	1.46	11.8
Modern males					
M ² length	14	27.86	27.83	1.18	4.2
M ² width	14	17.51	17.02	0.91	5.4
M ₃ length	11	16.06	15.89	0.92	5.8
M ₃ width	11	13.19	13.21	1.11	8.4
Modern females					
M ² length	14 ^b	25.68	25.42	1.27	5.0
M ² width	14 ^b	15.31	15.20	0.88	5.8
M ₃ length	11 ^b	14.22	14.56	1.58	10.8
M ₃ width	11 ^b	11.81	11.55	1.30	11.3

Table 8.2b Mann–Whitney *U* Comparisons for Black Bear Samples

Test	<i>U</i> -statistic	p-value
Males versus natural traps		
M ² length	139.5	0.382
M ² width	65.5	<0.01
M ₃ length	110.0	0.827
M ₃ width	81.5	0.431
Females versus natural traps		
M ² length	38.5	<0.01
M ² width	71.0	0.01
M ₃ length	45.0	0.02
M ₃ width	46.0	0.02

^aAfter Wolverton 2008b: 182.

^bIncludes bears of unknown sex; those assigned to females were smaller than all known females.

bears. Indeed, habitat fragmentation/displacement by humans has greatly reduced the black bear's range during the last four centuries. Our data suggest that the vulnerability of young adult males to accidental deaths and their propensity for risky behavior relates not to modern impacts but to their behavioral ecology. Without the temporal perspective that paleozoology provides, this evolutionary cause of young adult bear mortality could not be determined. A shift in temporal scale reveals that young adult male bears pass through a selective filter that is quite natural and that wildlife managers should not seek to alter that pattern.

Late Holocene Freshwater Mussel Biogeography in North Texas

Freshwater mussels (unionids) have experienced a dramatic decline in numbers and distribution throughout the United States. It has been estimated that, of the 297 species in North America, 12% are extinct and 23% are threatened or endangered (Galbraith et al. 2008). Freshwater mussels possess biological characteristics that render them susceptible to range reductions and extirpations through habitat fragmentation (Vaughn and Taylor 1999). Unionids are long-lived, sedentary organisms that spend a portion of their lives as fish ectoparasites. As a result, anthropogenic impacts such as overharvesting, stream modifications, water quality deterioration, introduction of alien species, and apathetic land management policies have reduced many unionid populations (Bogan 1993; Lydeard et al. 2004). Unfortunately, the magnitude of these impacts has not been well documented, and in regions where historical records are absent, it is unclear whether or not contemporary surveys are representative of past and present freshwater mussel communities.

This case study compares the late Holocene and modern unionid biogeography of the Upper Trinity River using zooarchaeological data with a focus on the bankclimber (*Plectomerus dombeyanus*). The Trinity River in north Texas comprises the Clear, West, and Elm Forks along with their associated tributaries. The rivers were impounded between 1914 and 1957 for flood control (Dowell and Breeding 1967). Archaeological sites relevant to this study are located near impoundments. These sites date to the late Holocene between 1450 and 600 years before present based on radiocarbon dates of ash deposits (Lintz et al. 2008) and associated artifacts (Ferring and Wolverton, unpublished data).

Little is known about the distribution of freshwater mussels in the Upper Trinity (Neck 1990). The few historical records concern the Elm Fork near Dallas (e.g., Neck 1990; Read 1954; Strecker 1931) and the Clear and West Forks near Fort Worth (Mauldin 1972). Surveys have focused on reservoirs and nearby rivers (Howells 2006), and contemporary biologists describe the Upper Trinity River as being intermittent upstream from Dallas but supporting a diverse community of freshwater mussels (e.g., Neck 1990). This high diversity is thought to relate to diverse habitat and fish stocking in nearby reservoirs (Read 1954). During the early 1950s investigators observed the deleterious effects of industrial effluent on mussel populations near Dallas, causing the extirpation of at least one unionid species (Read 1954).

Unionid biogeography within the Trinity River has been categorized into an “upland” and “lowland” component (Neck 1990). The upland component of the Trinity is delineated by the absence of species thought only to occur in large perennial sandy-bottomed streams, characterizing much of the lower Trinity River north of Houston. The upland habitat of the Trinity River near Dallas and Fort Worth was thought to have been poor for certain lowland species (Strecker 1931). The classification of the Trinity River into these two faunal components stems from a small number of early surveys near Dallas following the impoundment of the Trinity River (Neck 1990). Consequently, these surveys are likely *representative of human impacts related to construction of impoundments on and release of wastewater effluent into the Trinity River*. The unionid species within the upper Trinity during the 1930s should be those that are tolerant to changes in hydrological characteristics associated with impoundments and modern wastewater release (see Vaughn and Taylor 1999; Watters 1999). Given the problems with historical unionid records (see above), the late Holocene zooarchaeological record provides a means to test whether or not lowland species existed in the Upper Trinity prior to impoundment.

Twelve unionid species were identified from four archaeological sites in the Upper Trinity River drainage. The bankclimber (*P. dombeyanus*) is considered a member of the lowland component of the Trinity River (see Table 8.3). Shells of this species have been recovered at archaeological sites on the Clear and West Forks of the Trinity River and on Denton Creek, suggesting a ubiquitous distribution during the late Holocene. This species predominately occurs in perennial sluggish lowland rivers, near stream banks, and in shallow waters with mud sand or gravel substratum (Howells et al. 1996). In Texas, modern records for this species occur mainly in the eastern and southern portions of the state downstream from the Upper Trinity River.

The presence of *P. dombeyanus* at these four zooarchaeological sites represents an extra-limital record for this region. The habitat requirements of this species suggest that the Upper Trinity River and associated tributaries were not intermittent but were in fact shallow, slow

Table 8.3 List of “Lowland” Species and their Presence or Absence in the Upper Trinity River Drainage

Lowland species	Common name	Upper Trinity River
<i>Fusconaia flava</i>	Wabash pigtoe	A
<i>Megaloniaias nervosa</i>	Washboard	A
<i>Plectomerus dombeyanus</i>	Bankclimber	P ^a
<i>Strophitus undulatus</i>	Squawfoot	A
<i>Truncilla donaciformis</i>	Fawnsfoot	A

^aDenotes late Holocene paleozoological presence in the region.

moving, sand bottomed rivers prior to impoundment; other species found at these archaeological sites support this assertion (Randklev et al. 2009). The historical distribution of lowland species in the Trinity River most likely reflects a tolerance gradient to human impacts and a paucity of historical distribution records. The absence of historical records for the bankclimber in the Upper Trinity may reflect poor sampling of species intolerant of the acute changes that have occurred in this region. Modern studies of freshwater mussels describe extirpation gradients downstream of impoundments; that is, species richness tends to increase with linear distance from these impacts (see Vaughn and Taylor 1999). Interestingly, the bankclimber is considered an opportunistic species tolerant of anthropogenic impacts (Miller et al. 1992; Peacock and James 2002). Why are these species and other lowland ones not found in the Upper Trinity River today? Additional zooarchaeological data could provide answers to this question by providing appropriate time frames to assess when lowland component species were reduced in both abundance and distribution in the Upper Trinity River.

The Biogeographic Potential of Archaeological Organic Residues

Over the past 20 years, the popularity of organic residue analysis in archaeology has increased (Eerkens and Barnard 2007). In part, this is due to improvements in analytical chemistry as well as the realization that organic compounds such as DNA, proteins, lipids, alkaloids, and starches can be preserved for lengthy periods in a wide variety of contexts including in bone (Evershed et al. 1995), within ceramic artifacts (Craig et al. 2005), in mummified remains (Pääbo 1985), on lithic tools (Kooyman et al. 2001), and in fossils (Asara et al. 2007).

Archaeological residue studies have focused on addressing questions of artifact function and/or dietary practices (e.g., Craig et al. 2005; Eerkens 2005). They have also addressed other topics such as the origins of domestication (Outram et al. 2009) and the translation of Mayan hieroglyphs (Hall et al. 1990). The success of these studies and others has resulted from collaboration between researchers from diverse disciplines relying on a “weight of evidence” approach (O’Hara 1988). Outram et al. (2009), for example, use skeletal morphology, dental wear patterns, and organic residue analysis in concert to demonstrate the likely domestication of horses in Kazakhstan circa 5500 years before present.

As the development of organic residue analysis continues, we believe that the study of archaeological residues has the potential to shed light on the past when other lines of evidence, such as faunal remains, are unavailable (Lyman 1996: 120). Further, the information gained from such studies can also inform us about the biogeography of prehistoric taxa.

Proteins, in particular, hold promise for biogeographic studies of prehistoric organisms. Although they present methodological challenges, including the difficulty of extraction from ceramic artifacts (Craig and Collins 2002), protein residues possess qualities ideally suited for biogeographic research. As products of DNA, many proteins are taxonomically specific; with some exceptions, their unique amino acid sequences can be attributed to particular genera or even species of organisms (Barnard et al. 2007). Proteins are more abundant than DNA, increasing their likelihood of survival and subsequent extraction (Barnard et al. 2007). Also, the very properties that make them difficult to extract from ceramic matrices ensure that they are not lost from archaeological samples through exposure to water. Surprisingly, protein residues have even been demonstrated to adhere to non-ceramic surfaces for several thousand years despite exposure to moisture (Kooyman et al. 2001). The

popularity of proteomics, particularly in medical and forensic sciences, provides a growing body of research on protein extraction and characterization in addition to ample opportunities for collaboration.

Protein residues recovered from artifacts can provide evidence regarding the past distribution of species. This can be used to guide modern conservation/restoration efforts. Although consideration of temporal and spatial provenience of artifacts is required in order to rule out the confounding effects of long distance transport (Lyman 1996), the identification of taxa via residue analysis could play important roles in several debates.

The Missouri Department of Conservation (MDC) considered reintroducing elk (*Cervus elaphus*) to a region of the Ozark Highlands in the light of historical accounts documenting their presence prior to the mid-1800s. Noting the failure of the MDC to consider alternative lines of evidence, Harpole (2004) inventoried Missouri paleozoological samples with elk remains to ascertain whether elk ever lived within and around the proposed reintroduction area during the Holocene. She concludes that the absence of elk remains within the reintroduction area argues against the MDC's reintroduction plan. Although Harpole's point is well made, she explains that the scarcity of faunal remains in this region highlights a need for skepticism of her results, which may lead to her data being ignored by policy-makers. Analysis of artifact residues could extend her claims. Ceramic remains are common in late prehistoric archaeological assemblages in Missouri (O'Brien and Wood 1998), and if several artifacts from multiple sites in the reintroduction area were to yield quantifiable and identifiable residues (a probable outcome) the results would be relevant. If no residues from elk were to occur, Harpole's (2004) cautionary note on the proposed reintroduction by MDC would be supported. Protein analysis offers a unique opportunity to evaluate the debate over Pleistocene megafaunal extinction. Although we are skeptical regarding claims of overkill, a comprehensive residue analysis of Clovis-era projectile points could provide the "smoking gun" by demonstrating which species were being hunted by Pleistocene peoples. Kooyman et al. (2001) have already demonstrated the feasibility of this strategy, identifying protein residues on stone tools that link Late Pleistocene hunters to previously undocumented prey such as felines (Felidae), bears (*Ursus* spp.) and the extinct North American horse (*Equus conversidens*). Further studies, if successful in identifying a wide range of now extinct species on artifacts, would be a meaningful line of evidence in the extinction debate. Hyland et al. (1990) are among the first to explicitly recognize the relevance of protein residue analysis to biogeography. In their study of archaeological residues from the Shoop site, Pennsylvania, they identified cervid protein residues on a Paleoindian uniface. Unfortunately, they were unable to resolve which particular species of cervid was present. However, they insightfully commented that, "depending on the type of cervid ultimately identified, very different environmental reconstructions may be developed for this part of central Pennsylvania" (Hyland et al. 1990: 110).

There are several methodological and interpretive issues in archaeological residue analysis, and caution is required in the evaluation of results (Brandt et al. 2002). Nevertheless, we believe that its continued development, particularly with regard to the use of protein-based strategies, will provide useful qualitative and quantitative data in a wide range of disciplines.

DISCUSSION

Ethnobiology brings an explicitly evolutionary perspective to environmental science and ethics; this is especially the case with applied paleozoology because of its inherently

temporal perspective. Although Callicott's recommendation that benchmarks for conservation and restoration are most pragmatic at the ecological mesoscale, the effects of modern human impacts are evolutionary in proportion (Russell 2003). Because human impacts (e.g., chemical contamination and habitat fragmentation) change allele frequencies in species' gene pools, they are indisputably evolutionary. An excellent example is the impact of the pollutant tributyl tin (TBT), which is used as an anti-molluscicide on boats and piers, on marine populations of dog whelks (*Nucella lapillus*). Experiments show that TBT causes imposex (the development of male sexual characteristics by females) through increasing testosterone production in this mollusk, which results in the growth of a small penis in females that can block egg production (Walker et al. 2001). The impact of TBT pollution thus is a direct population-level response in this species. Some individuals simply cannot reproduce. Gibbs (1993) discovered that individuals in one population evolved modified genitalia that allowed them to persist in the presence of TBT, which represents a substantial shift in the evolutionary history of this species. Though these impacts appear to be reversible and short term, pollution control of TBT cannot reverse the evolutionary, permanent effects on the dog whelk's gene pool, and humans have changed the trajectory of evolution in this species. That ethnobiologists commonly work with the evolving relationships among humans and ecosystems (including constituents of ecological communities, such as dog whelks) from an evolutionary perspective puts them in a position to disclose the evolutionary impacts of the current environmental crisis in terms of culture and biology.

Although recognizable with some effort, the link between ethnobiology and environmental philosophy and environmental science is not very explicit for several reasons (Lepofsky 2009). First, though environmental science is inherently interdisciplinary, its practitioners are only recently acknowledging a need to extend the communication of their results more clearly through education, policy, and public outreach. Environmental philosophy, particularly in the realm of ethics, can assist development of policy in collaboration with environmental scientists. However, the sparse record of collaboration between these two parties indicates that there is a large communication gap. Ethnobiologists can bridge this gap, because the products of our research, by the nature of the field itself, transcend cultural, temporal, and spatial boundaries.

A second reason has to do with methodology. Environmental sciences, particularly subdisciplines such as ecotoxicology and environmental chemistry, are experimental. Experimental results are highly controlled and replicable, but such is not the nature of methodology in ethnobiology. Ethnobiologists rely on the weight of evidence to draw conclusions (*sensu* Ereshefsky 1992; O'Hara 1988); hypotheses are rejected as explanations for patterns and trends when there is no, or very little, evidence to support them. Swetnam et al. (1999) provide excellent examples from the realm of historical ecology in which they use multiple lines of evidence, including repeated photography, dendrochronology, aerial photography, and historical records to infer whether or not changes in plant communities are the product of natural changes (e.g., the products of fire histories) or modern human impacts (e.g., overgrazing by livestock).

A third reason is the distraction of "anthropogenism." Much attention has been devoted to dismantling the myth of the "ecologically noble savage" (Alvard 1998; Peacock 1998; see references in Penn and Mysterud 2007b), but this myth has been replaced with an equally damaging dogma implying that because humans do not conserve resources in ecologically noble ways all humans cause major environmental damage. Rozzi (1999) attempts to erode the epistemological difference between humans and nature; he views such erosion as essential if humanity is to value nature in ways that solve environmental problems. At what point

in human evolution did human actions prevent *more* ecosystem services than they provided? Whether or not hunter-gatherers *intentionally* practiced conservation, though important anthropologically, may not be of great concern to environmental scientists because the spatial and temporal scales (local and regional) of their impacts were low compared to those of industrial and post-industrial societies (continental and global). Hunn (1982) terms the lower environmental impact of such small-scale societies “epiphenomenal conservation,” which operates through a process of what Wyndham (2009) refers to as “subtle ecologies.” Subtle ecologies are human–environment interactions comprising “slow relations that rely on diffuse causalities and micro-effects related to invisible or fleeting action” (Wyndham 2009: 272). A monolithic anthropogenism ignores these subtle ecologies.

CONCLUSION

Paleozoological, paleoethnobotanical, and/or historical ecological datasets must be consulted in diverse ways. Indeed, taphonomic histories of archaeological and paleontological assemblages vary by context (Lyman 1994; Nagaoka et al. 2008). The task of the paleoethnobiologist is then to recognize the diverse nature of these records (which most practitioners do) and their unique potential applications in conservation and restoration (see Lepofsky 2009; Lyman 2006; Stahl 1996; Swetnum 1999; Wolverton et al. 2007). The most important value of these applied-paleo approaches, however, may not be the precise outcomes of case studies; instead, it is the shift in temporal scale that they provide. “Sustainability” is defined in environmental science as “solutions to environmental problems that benefit *future* generations.” We find the perspective of applied paleozoology priceless in terms of promoting long-term solutions. This advantage, however, needs ethnobiology and its constituent disciplines as a bridge lending multiple disclosive perspectives to modern environmental science through transcendence of spatial, temporal, and cultural paradigms.

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