Chapter 12
Human Behavioral Ecology and Zooarchaeology

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Introduction

Human behavioral ecology has contributed to zooarchaeological research for about 40 years (Anderson 1981; Bayham 1979). Most archaeologists were first exposed to HBE models, in particular foraging theory, through the anthropological and ethnoarchaeological literature (Hames and Vickers 1982; Hawkes et al. 1982; O'Connell and Hawkes 1981, 1984; O'Connell et al. 1988, 1990; Smith 1991; Smith and Winterhalder 1992; Winterhalder and Smith 1981). While the ethnoarchaeological literature, in particular, examined archaeologically relevant topics, such as butchery and transport practices, zooarchaeological applications of the HBE models were not as common. Given the differences in the datasets, zooarchaeologists had to adapt the models to archaeological contexts and develop measures to be used with faunal samples.

Jack Broughton's (1994a, b, 1997, 1999) analyses of the faunal remains from the Emeryville Shellmound were the first comprehensive bodies of work that demonstrated how HBE models could be applied to zooarchaeological datasets. He used the three main HBE models (prey choice, patch use, and central place) to develop expectations about diet breadth, foraging efficiency, patch use, and transport that were evaluated using relatively simple zooarchaeological measures. Since then, HBE has been used to study human subsistence in a variety of archaeological contexts and across different types of faunal material (Alvarez 2014; Emery 2007; Faith 2007; Fisher and Valentine 2013; Giovas et al. 2016; Jones 2004; Morrison and Hunt 2007; Neme and Gil 2008; Otaola et al. 2015; Starkovich 2014; Thomas 2007; Whitaker 2010). Numerous reviews of archaeological applications of HBE models also have been published (Bird and O'Connell 2006; Broughton and Cannon 2010; Broughton and O'Connell 1999; Codding and Bird 2015; Grayson and Cannon 1999; Jones and Hurley 2017; Lupo 2007; Winterhalder and Smith 2000; Wolverton and Nagaoka 2018). Many of these reviews examine both ethnoarchaeological and zooarchaeological applications and contributions. This chapter focuses on zooarchaeological studies specifically because the methodology and datasets employed are distinctive from those in ethnographic or ethnoarchaeological studies. I review the foraging theory models typically used in zooarchaeological studies and then discuss the zooarchaeological measures developed and used to evaluate hypotheses generated by these models.

While HBE research has become more established in zooarchaeology, it still faces challenges that are more epistemological and ontological. Zooarchaeological and ethnoarchaeological HBE

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may appear to have similar goals, but the two differ significantly in the nature of their datasets. Thus, a challenge for zooarchaeologists is evaluating the relevance of ethnoarchaeological studies for study of archaeological contexts. Also, HBE approaches are often faced with the criticism that the interpretations they develop do not meet the expectations of an anthropological archaeology. Both of these challenges are reviewed in this chapter.

HBE Models

When examining how fauna were exploited by human predators in the past, zooarchaeologists generally use three foraging theory models: prey choice, patch use, and central place foraging. The most commonly used model is the prey choice model, which addresses the question of which prey foragers should try to exploit (Charnov and Orians 1973; MacArthur and Pianka 1966; Pulliam 1974; Schoener 1971). Two variables related to prey choice that are typically examined are diet breadth and foraging efficiency. Diet breadth is the number of prey types exploited. A narrow diet breadth would be reflected by just a few prey types in the diet, while foragers with a broad diet breadth would exploit a large number of prey types. To determine diet breadth, prey are ranked based on their net returns, the gains of exploiting the prey relative to the costs. Net returns only incorporate post-encounter return rates, and search time is not included because it is assumed that foragers are searching for all prey in the diet breadth simultaneously. Once encountered, the net returns of a prey type include the costs of pursuing, capturing, processing, and consuming the prey. Diet breadth should expand down the rank order of prey until a point of diminishing returns when the next lower-ranked prey type has lower net returns than the mean net returns across all prey types. The encounter rates of high-ranked prey affect diet breadth. When high-ranked prey are abundant and encounter rates are high, diet breadth should be narrower than when they are scarce (Pyke et al. 1977).

Differences in diet breadth are sometimes used to characterize a subsistence strategy as generalized or specialized (Alvarez 2014). For example, the overkill model hypothesizes that early peoples in North America hunted Pleistocene megafauna to extinction (Martin 1973). If so, then the prey choice model provides a means for testing a logical extension of this argument. Diet is expected to be narrow or specialized because high-ranked prey types would have been abundant and the average net return rate would have been high enough to exclude small fauna from the diet (Waguespack and Surovell 2003). However, zooarchaeological analyses indicate that diet was much broader or more generalized than expected and varied across regions (Byers and Ugan 2005; Cannon and Meltzer 2004, 2008).

In addition to diet breadth, foraging efficiency, the net returns per unit time, can also be documented using the prey choice model (Smith 1979, 1991, pp. 185–191; Broughton 1999). Predators are expected to have greater foraging efficiency if they can obtain significant net returns in shorter amounts of time. Like diet breadth, foraging efficiency is affected by the encounter rates of high-ranked prey. When high-ranked prey are common on the landscape, they are encountered frequently and thus comprise a large portion of the diet resulting in higher foraging efficiency.

Declines in foraging efficiency are often linked to resource depression or the decline in prey encounter rates as a result of foraging behavior (Charnov 1976). Depression can occur from direct harvesting that reduces population numbers (exploitation depression), from an increase in anti-predator behaviors (behavioral depression), and from predator avoidance behaviors (microhabitat depression) (Charnov et al. 1976; Wolverton et al. 2012). However, there are other explanations beyond predator-prey interactions that can explain a shift in the proportion of high- versus low-ranked prey. More efficient technology can decrease handling costs of prey (e.g., guns versus spears, motorized vehicles versus horses), which can increase the net returns of that prey (Madsen and Schmitt 1998; Grayson and Cannon 1999; Jones 2006). Thus, what may appear to be a shift away from high-ranked prey could actually be an increase in the net returns and rank of a lower-ranked prey. Mass capture technology can aggregate the returns of single prey items while reducing the overall handling costs such that the net returns per foraging bout increases for that prey type (Jones 2006; Lupo and Schmitt 2002; Madsen and Schmitt 1998). In addition to technological improvements, environmental change can also impact foraging efficiency by creating more or less favorable habitats, which affects population abundances, encounter rates, and foraging efficiency (Ugan 2005; Wolverton 2005).

Patch choice and use models address the question of which patches should be exploited and how much time should be spent foraging in each patch (Smith 1991, pp. 246–256). The prey choice model assumes random prey encounter rates, which would require prey to be randomly distributed across the landscape. If prey are spatially clustered, then there is also travel time incurred between these prey distributions that is not accounted for in search costs of the prey choice model. MacArthur and Pianka (1966) argued that the prey choice model should be applied to each patch or cluster of prey types separately. Which patches a forager chooses to search in is then modeled similarly to prey choice. Patches are ranked based on the net returns gained from each patch. Patches are added to the foraging suite until the net returns for the next available patch is less than the average net returns across all patches. Net returns include the cost of traveling between patches.

The marginal value theorem (MVT) was developed to address an issue that the patch choice model does not (Charnov 1976). Specifically, it models the time that a forager should harvest resources within a patch given the net returns of that patch and for all patches and the travel costs between patches. In addition, it incorporates resource depression within the model (Charnov et al. 1976). As foragers hunt prey in a patch, they cause a decline in the encounter rates of that prey. Foragers should remain in a patch until the declining net returns reach the average net returns for all patches. Because the MVT develops expectations of foraging time, it is often described as a time allocation model.

Both the prey and patch models were developed to consider predators that consume their prey at the point of capture. But some foragers, such as humans, transport resources back to a central location. Central place foraging models were designed to encompass the additional travel costs of transporting prey back to a home base for consumption (Orians and Pearson 1979; Cannon 2003). Distance and prey loading are important factors in this type of foraging. Distance to prey should increase as prey abundances first decline around the central place (Hamilton and Watt 1970). Over time, the depletion zone should expand with the rate of expansion which will be related to population density. As distance increases, foragers have to make choices about what they carry back to the central place (Schoener 1979). The prey load, or the amount that a forager can carry, also affects these choices. For humans, distance and prey loading have been used to study field processing patterns. If a prey item is too large to be transported whole, then it must be butchered into manageable packages. The costs associated with this are considered handling costs that should vary little across individuals (Cannon 2003). In contrast, butchering a carcass to maximize the delivery rate or prey load is considered a processing cost, which will vary with distance and prey encounter rates. If the distance to the central place is far, then a carcass may be field processed beyond creating transportable packages to discard the lower return parts and maximize the load. If prey encounter rates are low, then more of a carcass may be transported.

Overall, these models have been useful for providing conceptual frameworks that are logically consistent, embedded within evolution and ecology, and generate empirically testable hypotheses. Although the models may appear to provide a monolithic unicausal explanation, the reality is that this structure brings alternative explanations out into the open to be evaluated equally. The goal is not to demonstrate that resource depression occurred but to evaluate the causes for change in diet breadth, foraging efficiency, or carcass exploitation. For example, declines in foraging efficiency are hypothesized to be the result of resource depression. But the pattern could also be caused by environmental change impacting faunal abundances or technological innovations that reduce handling costs or allow for mass capture. Any study on resource depression would have to evaluate these known alternative explanations and rule them out to conclude that resource depression had occurred. So instead of research that focuses on finding data to support an explanation, HBE research is set up to evaluate multiple explanations for how human-prey interactions changed over time and differed across space.

Developing HBE Methodologies for Zooarchaeological Data

Applying HBE models to zooarchaeological contexts can be challenging. The models were developed by evolutionary ecologists who were able to directly observe the behavior of organisms and estimate the costs and benefits of their behavior using the currency of kilocalories. Thus, it should be no surprise then that these models were first used in anthropological and ethnoarchaeological studies on modern hunter-gatherers (Hames and Vickers 1982; Hawkes et al. 1982; O'Connell and Hawkes 1981, 1984; O'Connell et al. 1988, 1990; Smith and Winterhalder 1992; Winterhalder and Smith 1981). These studies illustrated the logic and explanatory power of the models for understanding human subsistence practices. But unlike research conducted on contemporary peoples, zooarchaeologists cannot directly observe costs/benefits in terms of kilocalories per hour. Instead, the zooarchaeological record consists of samples of skeletal remains of organisms accumulated over long time spans by populations rather than individuals (Lyman 2003a; Otaola et al. 2015; Wolverton et al. 2015). Thus, for these models to be applied using the archaeological record, researchers had to modify them for archaeological contexts and develop zooarchaeological measures. These measures are reviewed for six variables commonly used in zooarchaeological HBE studies (Table 12.1).

Foraging Efficiency

Measuring foraging efficiency ecologically and anthropologically entails documenting the net caloric returns per unit time (kcal/h) and determining prey ranks (Smith 1979, 1991, pp. 186–188). Developing an archaeological measure that focuses on net caloric returns requires making numerous assumptions or a significant investment in actualistic studies to determine nutritional value, pursuit

Table 12.1 HBE models used and patterns and explanations evaluated in zooarchaeological research along with some key references

Models	Patterns	Explanations	Key references
Prey choice	Foraging efficiency	Resource depression	Charnov et al. (1976), Broughton (1994a, b)
		Environmental change	Nagaoka (2002), Wolverton (2005)
		Technological innovations	Butler (2001)
		Mass capture	Madsen and Schmitt (1998), Jones (2006)
		Sustainability	Butler and Campbell (2004), Lyman (2003b)
		Taphonomic factors	Lyman (1994a, b)
	Diet breadth	Sampling issues	Grayson (1984), Lyman (2008)
Patch choice	Patch number		MacArthur and Pianka (1966)
Patch use (MVT)	Residence time	Resource depression	Charnov (1976), Nagaoka (2002)
		Environmental change	Jones (2009)
		Technological innovations	Smith (1991)
	Intensification	Resource depression	Nagaoka (2005, 2006)
Central place	Prey load	Transport distance	Broughton (1999), Cannon (2003), Nagaoka (2005, 2006)

costs, and handling costs of prey types. Fortunately, Bayham (1979) developed a uniquely archaeological measure to document changing foraging efficiency using zooarchaeological data. The index uses two taxa that represented high- and low-ranked prey. Body size has been shown to correlate with net returns such that large-bodied prey can provide higher net returns than small-bodied ones (Broughton et al. 2010; Jones 2004; Simms 1987; Ugan and Bright 2001). The taxa used in the index have to be common and present across all samples, whether spatial or temporal, because that means the two taxa were in the diet breadth across all samples. The prey choice model assumes that foragers will take whatever they encounter as long as it is within the diet breadth; thus, the proportion in the index requires a similar assumption that the proportion reflects the abundance of these taxa on the landscape. A high proportion of the large-bodied taxon indicates that encounter rates were high and the taxon was likely abundant in the environment. When high-ranked prey are abundant, the index and thus foraging efficiency are high. Lower index values indicate a greater proportion of the small prey type and thus lower foraging efficiency. These faunal indices may appear to oversimplify a complex process by using two taxa. But as a zooarchaeological measure of foraging efficiency, it is elegant in its simplicity and can be combined with multiple other lines of evidence (Broughton 1997; Munro 2004; Ugan 2005; Wolverton et al. 2008). It should be noted that faunal indices are becoming a more commonly used measure outside of HBE research. Indices have been used extensively in the American Southwest (Badenhorst and Driver 2009; Dean 2001, 2007a, b; Driver and Woiderski 2008; Potter 1995; Quirt-Booth and Cruz-Uribe 1997; Reynolds 2012; Schollmeyer and Driver 2013; Szuter 1991) and can be traced back to Bayham's (1979) research.

While there is ethnographic evidence that body size generally correlates with prey rank, there are also cases where the relationship does not hold. As mentioned above, prey obtained through mass capture techniques will have higher net returns than expected given their size. And extremely large taxa can have lower net returns given high handling costs. Thus, researchers have used other criteria for determining prey rank. Prey mobility and predator defense have been used to differentiate prey ranks (Stiner et al. 2000; Munro 2004). In this case, the two prey types, tortoises and hares, were of similar body sizes, and it was assumed that tortoises (slow prey that becomes immobile in its shell) would have lower pursuit costs and thus higher post-encounter returns than the quicker more agile hares. Alternatively, instead of using faunal indices, evenness measures have also been used to document foraging efficiency (Jones 2004; Nagaoka 2001). Evenness is used to examine changes in the proportions of all prey in the diet. If high-ranked prey are initially abundant and then decline over time, the relative abundance of each taxon should become more evenly distributed.

Many studies demonstrate that over time, a decline in a faunal index or an increase in evenness is caused by resource depression, either through a decrease in the population abundance of the large taxon or a decrease in its availability due to behavioral changes (Allen 2002; Alvarez 2014; Broughton 1999; Butler 2000; Cannon 2000; Giovas et al. 2016; Janetski 1997; Morrison and Hunt 2007; Nagaoka 2002). As discussed above, a decline in foraging efficiency can be caused by other processes besides resource depression. Faunal index values can be affected by anything that can lead to changes in the specimen counts for the small taxon and/or the large one. Thus, there are several alternative explanations besides hunting pressure that could cause a decline in a faunal index that also need to be evaluated. Environmental factors can impact population abundances of the large taxon or the small taxon or both (Byers and Broughton 2004; Jones 2009; Wolverton 2005). Technological innovations can improve handling costs for either taxon (Butler 2001; Smith 1991). And taphonomic factors could lead to differential preservation or fragmentation of either taxon used in the index (Lyman 1994a). All of these potential explanations for a change in the index values should be evaluated.

Diet Breadth

A decrease in foraging efficiency can lead to an increase in diet breadth but only if the average net returns decline such that the returns for the next low-ranked prey type become greater than the declining average (Pyke et al. 1977; Stephens and Krebs 1986). Archaeologically, diet breadth is measured using the number of taxa (NTAXA) represented in the sample. However, this measure has one significant drawback. It is known to correlate positively with sample size (Grayson 1984; Lyman 2008). The larger the sample of faunal remains, the greater the number of taxa identified. Thus, sometimes it is difficult to determine whether a change in NTAXA is due to shifts in diet breadth or sample size. However, if there are enough samples to compare, the relationship between NTAXA and sample size can be used to determine whether or not a shift over time in NTAXA relates to a change in diet breadth or is an effect of sample size. In particular, the slope of the regression line for NTAXA and sample size describes the rate at which taxa are added with an increase in sample size (Grayson and Delpech 1998, 2001; Nagaoka 2002). Thus, if one sample of assemblages has a regression line with a greater slope or a larger y-intercept, then it is adding taxa at a higher rate than the sample of assemblages with a lower slope or y-intercept, which suggests that diet breadth is wider. Like foraging efficiency, other explanations besides resource depression can lead to an expansion of the diet breadth, such as shifting environments or differential preservation or recovery, and they should all be assessed. Given that diet breadth may or may not increase with declines in foraging efficiency, and given the issues with NTAXA as a measure, diet breadth tends to be used as a supplementary indicator of changing subsistence.

Patch Choice and Residence Time

Studying changes in patch choice archaeologically is not common. Much of this stems from the challenge of defining patches and identifying which prey types should be found in each patch (Lupo 2007). Patches should consist of mutually exclusive sets of fauna such that any prey type within a patch has an equal chance of being encountered but prey types from other patches should not be encountered. Some fauna have broad habitats, and for extirpated or extinct fauna, environmental and behavioral reconstructions are required. When patches have been identified in studies, they are often broad habitat descriptions, such as terrestrial versus marine (Cannon and Meltzer 2004; Jones 2009; Nagaoka 2002; Wolverton et al. 2015). These broadly defined patches likely characterize most of the foraging universe, leaving little room for the addition of new patches. Thus, patch choice is not often used to examine if patches were added or removed from the foraging radius.

A more common use of patch models in zooarchaeological research is to examine shifts in patch residence times (Broughton 1994a, b, 1997, 2002; Jones 2009; Nagaoka 2002). Faunal indices and relative abundance data are used to demonstrate that foragers increase/decrease the amount of time they spend in one patch versus others. Relative abundance of prey types of each patch are often used to document shifts in the amount of time spent in each patch. For example, in my research in southern New Zealand, I documented an increase in the time allocated to the offshore fishing patch that corresponded to a decline in foraging efficiency within the two terrestrial hunting patches (Nagaoka 2002). The inland and coastal patches both had large-bodied, high-ranked fauna that declined in abundance over time. As this occurred, offshore fishing of a large seasonal fish species became an important part of the subsistence. As with foraging efficiency, shifts in patch residence time could be explained by other processes besides resource depression. For example, Jones (2009) documented changes in the proportion of riverine, grassland, and forest taxa exploited to show that foragers spent increasingly more time in the grassland patch. Instead of resource depression of resources within the riverine or forest patches, this shift in patch use was linked to changing environmental conditions that favored expansion of the grasslands.

Intensification

Patch residence time can also be used to study intensification. Intensification can be described generally as the process in which foragers put more time into extracting resources of increasingly lower returns (Morgan 2015). Thus, declines in foraging efficiency would lead to conditions in which intensification should occur. In zooarchaeology, intensification commonly refers to how intensively individual carcasses are used. A prey carcass is comprised of meat, marrow, and grease, each of which provides different nutritional returns (Binford 1978). When should foragers intensify their use of individual carcasses and put more effort into harvesting the lower-ranked resources from a carcass?

To address this question, we can use the MVT and apply it to the prey item or carcass as the patch. The question becomes, how much time should a forager spend harvesting resources from a carcass? Zooarchaeologists commonly study the butchery and transport of carcass parts. Theoretically, when foraging efficiency is low (e.g., under conditions of resource depression and/or environmental constraint), foragers should transport as much of the carcass as possible back to their campsites or villages. A separate factor, however, is the impact of transport distance. A forager may focus on transporting only high-value carcass parts not because lower-value parts are not needed but because transport distance requires them to maximize the load (see the next section). One way to address this concern is to study how the transported carcass parts are used at the home base. The resources that are typically examined archaeologically are the within-bone nutrients of marrow and grease. Marrow is found mainly in long bones and can be obtained by breaking into the marrow cavities of bones. The process is relatively simple, and a significant amount of marrow can be extracted depending on the size of the animal and the skeletal element. In contrast, grease extraction entails breaking bones into smaller pieces to maximize the surface area exposed and then boiling them to remove the grease. Thus, it is a more time-consuming and lower return process.

When a carcass is treated as a patch, then the amount of time a forager spends in marrow and grease extraction should be affected by the net returns of other carcasses because marrow and grease are relatively low-ranked resources. When the productivity of other patches is high, foragers should spend less time extracting marrow and grease. If other higher-ranked resources decline in terms of encounter rates and/or other patches decline in terms of average net returns, then time invested in marrow and grease extraction may increase.

Marrow and grease extraction can be documented by using bone fragmentation measures commonly used in zooarchaeological studies. Often, fragmentation is used to measure both marrow and grease. However, since marrow and grease extractions are different processes that likely have different net returns, they should be measured independently when possible (Lyman 1994b; Wolverton 2002; Nagaoka 2005, 2006). Marrow extraction only requires that the shafts be broken to access the marrow cavity. Thus, the proportion of broken shafts indicates that marrow may have been accessed, but marrow was definitely not extracted from whole bones. The measure of "% whole" documents this latter condition. It uses the percentage of the total minimal number of elements (MNE) for each long bone that is whole. For grease extraction, since smaller bone fragments can make the process more efficient, the ratio of the number of identified specimens (NISP) to the MNE measures the number of fragments per skeletal element (NISP/MNE). If carcass exploitation intensifies, there should be a decrease in % whole and an increase in the NISP/MNE. Since both of these measures rely on bone breakage, the impact of taphonomic processes on the assemblage must be evaluated (Nagaoka et al. 2008).

Prey Loading or Delivery Rate

A significant portion of early HBE applications in archaeology focused on carcass field processing and transport (Bartram 1993; Bartram and Marean 1999; Lupo 2001; O'Connell et al. 1988, 1990; O'Connell and Marshall 1989). Binford's (1978, 1981) research, in particular, is credited with using ethnoarchaeological studies to understand how to interpret the zooarchaeological record. He was specifically interested in how skeletal element representation was being used to weigh in on the hunting versus scavenging debate in early hominid research. Even though Binford's ethnoarchaeological research was not directly derived from HBE models, his concept of element "economic utility" is analogous to net returns. Binford argued that each portion of a carcass then has its own nutritional value based on the amount of meat, marrow, and grease associated with it. Higher-value portions were more likely to be transported back to the home base than lower-value ones.

In HBE research, central place foraging models can be used to generate similar expectations about carcass transport patterns. It is often difficult to know exactly how carcasses may have been butchered. However, the butchery process can be differentiated into two steps (Cannon 2003). Butchery required to cut a carcass up into transportable units (e.g., hind limb, rib cage, etc.) is part of the handling costs and should be fairly constant for a prey type. Additional field processing costs are incurred to maximize the prey load and will vary depending on the transport distance to the central place and the prey encounter rates. When transport distance is low, and high-ranked prey are abundant, transporting mainly portions with high nutritional value may be the appropriate strategy. Time could be better spent transporting the choice cuts to the home base and then hunting for more prey than investing more time into maximizing the prey load. If distance increases but encounter rates remain constant, then a carcass may be processed to remove the low-return portions or riders to maximize the load. When prey encounter rates decline, then each carcass becomes more valuable, and there is incentive to extract more out of each carcass. Thus, the carcass may be field processed more extensively, perhaps even to the point of removing and discarding bone tissue at the butchery site (Bartram 1993).

To measure these changes in processing, the nutritional value of each portion of a carcass needs to be determined. Binford (1978) established a methodology for quantifying the value of carcass portion called utility indices. Each skeletal element is associated with a nutritional value derived from actualistic research (Metcalfe and Jones 1988). Utility indices have been generated for a broad range of species (see Lyman 2012, Table 1). If the utility for the species of interest has not been developed, then a proxy species must be used. Binford used utility curves to evaluate the butchery and transport strategy for an individual faunal sample. However, this method is difficult to use for examining temporal patterns. Broughton (1999) developed the mean utility measure, which simplifies Binford's calculations and summarizes the average utility or returns represented in a sample. To calculate the mean utility of a sample, the utility value of an element is multiplied by the MNE for that element, and then the values for all elements are then summed and divided by the total MNE for the sample. When a greater number of high-value elements are represented, the mean utility is high. In contrast, when lower-value elements are more common, mean utility will be lower. Thus, mean utility can be used to evaluate over time whether foragers are selecting and transporting higher utility elements or if the transport strategy is much broader with a diverse range of elements selected.

While mean utility can provide insight into whether high- or low-return elements were transported, other measures are required to evaluate whether increased field processing has occurred. One method is to compare the frequency of individual skeletal elements, especially high- and low-value elements, that may have been transported together. For example, to demonstrate an increase in field processing of moas, I compared the frequency of cervical vertebrae and ossified tracheal rings of moa across time (Nagaoka 2005). There was a significant decrease in tracheal rings compared to the cervical vertebrae over time, suggesting that tracheal rings were discarded when the internal organs were removed in the field, while the necks were transported with the rest of the carcass.

Since these analyses rely on skeletal element representation, the impact of various taphonomic factors on element abundance has to be evaluated (Lyman 1994a). Differential preservation can be assessed by comparing bone density patterns with skeletal element frequency (Lyman 1984, 1992). Differential fragmentation and identification can also impact element representation. Some elements can only be identified from larger fragments. Thus, if fragmentation rates change across time, this can impact the identifiability and representation of those elements in assemblages. This can be assessed by comparing the NISP/MNE for those elements across samples. For example, if the relative abundance of a high-utility element declines while fragmentation rate increases, then a decline in the mean utility may be reflecting differential fragmentation rather than differential transport.

Summary

The challenge of applying HBE models to the zooarchaeological record has been to develop measures using faunal data to evaluate hypotheses generated by the models. Some, like faunal indices, were developed for use in HBE models. Others were common ecological or zooarchaeological measures such as evenness, richness (NTAXA), or fragmentation (NISP/MNE). HBE practitioners have explored, developed, and evaluated different methodologies to suit the type of faunal data (e.g., invertebrates vs. vertebrates) or contexts (foraging vs. food production, etc.) that comprise their samples. Just as important as the measures is the practice of evaluating alternative explanations, particularly taphonomic processes that affect the composition of the faunal data. These steps have made the application of HBE models uniquely zooarchaeological.

Ethnoarchaeological vs. Zooarchaeological

Generally, there have been two approaches to HBE in faunal research—ethnoarchaeological and zooarchaeological. Ethnoarchaeological research has a much longer history and has provided important insights into how human subsistence practices produce the zooarchaeological record (Bartram and Marean 1999; Binford 1978, 1981; Bird and Bliege Bird 2000; Hudson 1993; Lupo 1994, 1995, 2001; Lupo and O’Connell 2002; Lupo et al. 2013; O’Connell et al. 1988; O’Connell and Marshall 1989; Yellen 1991). Unlike research in other archaeological areas, ethnoarchaeological and zooarchaeological HBE research on human subsistence has been less particularistic, leading to more studies building a common knowledge base (O’Connell 1995). The shared theoretical framework means that both groups of researchers are interested in similar processes and expectations under the models. Where they differ is in the scale of research, which then requires differences in methodology, specifically variables and measures that are appropriate for data at the two different scales. From a zooarchaeological perspective, ethnoarchaeological research is useful when it provides insight into processes that impact outcomes. But it can be less useful when the research describes complexities at a finer resolution than the zooarchaeological record and does not provide guidance on how to apply findings to zooarchaeological contexts.

The issue of scale is important to consider when trying to apply ethnoarchaeological findings to zooarchaeological datasets. Ethnoarchaeological research occurs at a different temporal and spatial scale than zooarchaeological research (Table 12.2). Which of the variables and processes that have been identified ethnographically are archaeologically relevant? And if they are relevant, how should they be handled analytically? The faunal assemblages that zooarchaeologists study are often

Table 12.2 Differences between ethnoarchaeological and zooarchaeological HBE research

	Ethnoarchaeology	Zooarchaeology
Observable	Human behavior	Bone specimens
Currency	Energy (kcal)	Bone counts
Temporal scale	Hour, day	Decade, century, millennium
Spatial scale	Individual, household	Excavation layer, unit, site

aggregations across time, space, and demographic factors (Lyman 2003a; Otaola et al. 2015). They are amalgams of decades if not centuries of resource exploitation. To use a garbology analogy, zooarchaeological data are analogous to the data that would be generated from studying a city landfill, while anthropological and ethnoarchaeological data are like the data that could be gathered through observations of individuals' refuse behavior. With the latter, we can understand variability across a variety of demographic, economic, social, and geographic variables at a specific moment in time. But with the landfill data, our understanding is likely limited to patterns at the scale of the city over years. Thus, for zooarchaeologists, the challenge is to determine which of the patterns and processes documented by the fine-scale ethnoarchaeological data are relevant for analyzing zooarchaeological datasets.

In some cases, ethnoarchaeological findings can be easily integrated into existing models. For example, Bartram (1993) documented extensive field processing among the Kua, such that skeletal elements were removed and only the meat was dried and transported to the home base. Thus, in some cases, few faunal remains may be returned back to the home base, creating an absence of evidence in the zooarchaeological record of how carcasses were utilized. As a cautionary tale, this research could be used as an example of how taphonomic processes can remove skeletal elements from the archaeological record. But this case study may also provide an extreme end of field processing decisions. When encounter rates for high-ranked prey are low and transport distances are high, there is an incentive to field process to maximize the prey load (Cannon 2003). The significant amount of time spent processing the carcass at the butchery site suggests that time was better spent extracting resources out of carcass than expediently processing the carcass and going out to hunt again. The importance of "missing elements" is easier to understand when the data are evaluated across time or space rather than as a single sample. Instead of seeing just an absence of skeletal elements in one sample, looking across samples allows zooarchaeologists to understand how one or another sample fits into a larger context. Ethnoarchaeological research into transport and butchery patterns has been particularly easy to integrate into zooarchaeological studies because both use skeletal element abundances as their data.

For some ethnoarchaeological research, zooarchaeologists have to assess whether the findings are archaeologically relevant. For example, ethnoarchaeological research has identified a number of factors that can affect transport decisions besides transport distance including prey size, the size of the carrying party, transport method, and processing time (Bartram 1993; Bird and Bliege-Bird 1997; Metcalfe and Barlow 1992; O'Connell et al. 1988, 1990; O'Connell and Marshall 1989). Zooarchaeologists have to evaluate which of these factors are likely to be strong candidates for alternative explanations, which ones may be supplemental, which ones can be dismissed, and which can be measured archaeologically. For example, O'Connell et al. (1988) documented that larger carrying parties could transport more of a carcass back to the central place. Given that zooarchaeologists commonly have data aggregated across numerous foraging bouts spanning decades or centuries rather than data from individual foraging bouts, we may only be able to track a change in the average carrying party size over time. But can average carrying party size be measured in the archaeological record? Whether this can be measureable or not, is there any evidence that party size is a significant factor, more so than other factors? Unfortunately, little guidance is provided in the ethnoarchaeological literature on how to handle these issues archaeologically. Thus, zooarchaeologists choose what variables are important to focus on and determine what is measureable in the archaeological record. In this instance, I would argue that transport distance is probably more important than carrying party size. The central place models emphasize that with increasing distance, there should be an increase in prey load. Thus, average carrying party size should covary with average distance. Also because a carcass is finite, there should be a ceiling for the number of people needed to maximize the prey load no matter the distance.

There are cases when it is even more difficult to assess the archaeological utility of ethnoarchaeological research. This can be illustrated by discussions about the validity of using body size as a proxy for prey rank (Bird and O'Connell 2006; Lupo 2007). There are several well-documented issues with the relationship between body size and prey rank. As discussed above, extremely large species tend to have significant handling costs and lower net returns given their size. And prey obtained by mass capture techniques can have lower handling costs such that its net returns may be greater than predicted by its individual size. In these situations, body size is not argued to be a poor proxy for prey. Instead, it is expected that zooarchaeologists evaluate whether either of them is likely to affect prey ranks in their samples.

In contrast, one discussion has pitted body size against prey mobility as a better proxy for prey ranks. The debate on the importance of prey mobility is split along ethnoarchaeological and zooarchaeological lines. Bird et al. (2009) studied Martu hunting in which they demonstrated that there are more failed hunts for some highly mobile taxa, which can lead to higher pursuit costs. The result is that post-encounter return rates and thus prey ranks may correlate more closely with prey mobility than prey body size. Bird et al. conclude that body size is "often an inappropriate proxy for prey ranks" (Bird et al. 2009, p. 3). In contrast, zooarchaeologists continue to support the use of body size as a proxy for prey rank. Broughton et al. (2011) have provided an extensive evaluation of the relationship indicating that in many cases, large game provides higher net returns and thus would be higher-ranked than small game. Ugan and Simms (2012) question the Martu analysis and how net returns were calculated in the ethnoarchaeological study. Time spent tracking an animal was included with pursuit time rather than search time. Thus, they argue that post-encounter return rates were inflated for some mobile prey. They note that including tracking time differentially increases the costs of larger-bodied fauna because they tend to have much larger foraging radii. Thus, prey mobility really relates to the size of a prey's home range, which should fall under search costs, rather than under predator evasion strategies within pursuit costs (e.g., fast/slow) as Bird et al. determined.

So why the difference in perspectives between ethnoarchaeologists and zooarchaeologists? It is likely that some ethnoarchaeologists consider their research to be zooarchaeological and that translating their findings is not necessary. But the differences in the nature of the data and the scale of the research must be acknowledged. Thus, zooarchaeologists have to determine if the patterns seen in ethnoarchaeological data are contributing to a general pattern that can be seen archaeologically, or are they noise at an archaeological scale? Broughton et al.'s (2011) review makes a strong case that the relationship between body size and post-encounter return generally holds across many contexts and at an archaeologically relevant scale. In contrast, even though Bird et al.'s (2009) data show that the ranks of one or two taxa are significantly altered when prey mobility is used, mobility still correlates with prey size (Figure 6b, Table 2). Given this, it would appear that prey mobility in the Martu study is tracking fine-scale variability that may not be appropriate for time- and space-aggregated zooarchaeological datasets.

Even if prey mobility can be identified as an appropriate proxy, then the next question would be how can prey ranks based on prey mobility be determined zooarchaeologically? Unlike body size which can be estimated based on average species weight, prey mobility is more challenging to measure for archaeological contexts. In the Martu study, the costs associated with prey mobility, particularly the tracking costs, were influenced by several variables such as the extent of home range, speed, and predator evasion strategies. Prey mobility was rated on a 5-point scale based only on prey speed relative to hunters as well as the need for capture technology. But the size of the home range was also important, particularly for hunt failure, since the prey with high hunt failure rates were also ones that had large enough ranges such that they may not be encountered even after tracking. Thus, archaeological prey ranks could be estimated based on any one of these variables or a combination of each of them. Some of these variables would require assumptions about prey behavior or hunting capabilities. It is likely that, as in the Martu study, prey mobility would be ordinal categories with faster prey as low-ranked and slow prey as high-ranked.

To extend this hypothetical situation further, if prey mobility can be used to rank taxa, then how will this affect the index as a measure of foraging efficiency? In Bird et al.'s (2009, Table 2) Martu dataset, two commonly hunted taxa, the hill kangaroo and the skink, vary significantly in prey ranks and net returns depending on whether tracking time is included or not. The hill kangaroo is the largest species (21 kg) in the diet, while the skink is only 300 grams. When tracking is not included in the net return calculations, the hill kangaroo is second ranked with an average return rate of 58,973 kcal/h, while skinks are third ranked with almost 1/3 of the net returns of kangaroos (21,188 kcal/h). When tracking time is included, skinks become the taxon with the highest net returns of all fauna (20,403 kcal/h), while hill kangaroos drop to fifth with net returns of only 3844 kcal/h. In a faunal index based on prey mobility net return rates then, skinks would be the high-ranked prey and kangaroo the lower-ranked prey:

$$\text{skinks}/\left(\text{skinks} + \text{hill kangaroos}\right).$$

A decline in the faunal index should still reflect a decrease in foraging efficiency with the less mobile, high-ranked skinks comprising a smaller portion of the diet. However, evaluating whether resource depression was reflected in the index would be more challenging. Hill kangaroos, as a larger-bodied species, have a lower reproductive rate than skinks and will likely experience greater declines in population abundances with continued harvest pressure. If resource depression occurred, especially exploitation depression, then hill kangaroo populations would decline at a greater rate than skinks, and the faunal index will likely increase rather than decrease. Thus, the index using prey mobility to determine prey ranks may be able to document changes in foraging efficiency. But the measure could no longer be directly linked to resource depression of the large-bodied prey type when those prey types are no longer considered high-ranked. Thus, another measure would be needed to evaluate the cause of the change in prey choice.

Ethnoarchaeological research has played an important role in the development of zooarchaeological HBE studies. Both are unified by a common conceptual framework, which has made it easier to incorporate ethnoarchaeological findings into faunal studies. However, the difference in the scale at which each operates makes each approach distinct. The results of ethnoarchaeological studies more closely resemble anthropological studies because both are conducted at a much finer temporal and spatial scale than what is recorded in the archaeological record. As a result, the challenge for zooarchaeologists is figuring out how ethnoarchaeological findings can be incorporated methodologically. Unfortunately, the work of evaluating how to use these findings in archaeological contexts often falls upon zooarchaeologists. In this sense, zooarchaeologists are consumers of ethnoarchaeological research rather than ethnoarchaeologists being providers of new zooarchaeological methodology. This is an important distinction because when the latter is assumed without consideration of zooarchaeological needs, then ethnoarchaeological research aligns with criticisms identifying the role of ethnoarchaeology as deconstructionist or "obnoxious spectator" rather than as a means for bridging the divide between the past and the present (Simms 1992).

Anthropological vs. Ecological

Another area where HBE practitioners diverge is when anthropological interpretive goals conflict with ecological (or scientific) ones. Criticisms of evolutionary ecological models in archaeology highlight the perspective that anthropological interpretations are missing from these studies. HBE models have been criticized for being environmentally deterministic and for not incorporating individual intentions and motivations (Boone and Smith 1998). However, these models were never intended to delve into this area of human behavior. Instead, they are designed to study humans as simply another living organism interacting as a predator in an ecological community. Thus, the focus is not on what makes humans unique but what we have in common with other organisms. This is not to say that "culture" is unimportant, only that the models were developed to study organisms from an ecological perspective. While other organisms may or may not have a rich internal life, ecologists do not study how their subjects feel or think. So HBE models provide a specific way of looking at human behavior, an ecological or evolutionary one.

Generally, HBE studies in zooarchaeology assume natural selection is the driving mechanism for the foraging choices that humans make. However, two other processes, sexual selection and niche construction, have recently come to the fore. Both focus on behavior that is more in line with anthropological interpretations. Research using these processes have become opportunities to explore aspects of humanity from an evolutionary perspective that foraging theory does not. However, even within both of these areas, there is conflict between the ecological focus and the anthropological expectations within archaeology.

An area of research that explores sexual selection as the explanatory mechanism is costly signaling. Costly signaling is one aspect of signaling theory research that focuses on how organisms convey messages to others that ultimately impacts their fitness (Cronk 2005; Hasson 1997, Zahavi 1975). Sexual selection becomes the mechanism for determining the fitness of a behavior when signals impact mating success. Organisms can signal their fitness to potential mates through mating behavior and morphological features such as antlers or plumage. These signals become costly when they are disadvantageous from the perspective of natural selection. For example, they may require a significant input of energy (e.g., large morphological features such as antlers) or may hinder predator avoidance or evasion (e.g., brightly colored plumage). In ethnographic HBE studies, costly signaling is typically used to explain differential fitness of hunters based on their ability to hunt and capture game. Hunters can "show off" by pursuing large game that can be shared with others, signaling their value as a mate (Bliege Bird et al. 2001; Hawkes 1991; Smith et al. 2003). The cost of this behavior is that the forager may ignore resources that would have been within the diet breadth using an energy-maximizing approach to pursue prey that are higher in social prestige. Thus, there is a trade-off of greater net returns for enhanced access to mates.

Since costly signaling related to hunting strategies involves prey abundances, it would seem a natural topic for zooarchaeological researchers to study. One example of costly signaling research using zooarchaeological data resulted in a debate about the validity of the research. Hildebrandt and McGuire (2002, 2003, McGuire and Hildebrandt 2005) used an increase in the artiodactyl index to argue that deer hunting increased because of costly signaling. This research was critiqued by Codding and Jones (2007) for not adequately addressing the conceptual and empirical issues with this area of research. They agree that being a good hunter may confer fitness based on sexual selection, but the problem is differentiating good hunters from lesser hunters archaeologically. They question whether the artiodactyl index can reflect evidence of greater hunting of prestige-prey than should be expected by an energy-maximizing strategy. Codding and Jones also critique how Hildebrandt and McGuire simplify costly signaling to an evolutionarily stable strategy that consists only of honest signals with uniformly positive evolutionary outcomes. Signaling is a diverse strategy with honest and dishonest signaling that result in both positive and negative fitness outcomes depending on the context. Thus, archaeologically, signaling was conceptualized in a progressive manner (of course the strategy should be used; it is advantageous) rather than evaluated for its advantage or disadvantage as a driver of hunting behavior. McGuire et al. (2007) responded to Codding and Jones' critiques as "no can do" archaeology because they interpret the criticisms to state that costly signaling is outside the realm of what archaeology can know.

These two perspectives on costly signaling research diverge because of their differing perspectives on empirical rigor and archaeological interpretations. HBE has been a way to provide empirical expectations or hypotheses about the zooarchaeological record. Although resource depression has become a common explanation, it is often based on multiple lines of evidence that support resource depression and rule out other explanations. Codding and Jones are advocating for this type of approach in zooarchaeology. An increase in a faunal index value could be caused by costly signaling practices, but it could also be caused by other factors, such as environmental conditions or technological innovations, which improve the encounter rates for the large-bodied taxon or decrease them for the smaller-bodied taxon (Broughton and Bayham 2003). All of the potential explanations should be evaluated before claiming that a particular explanation is the cause (see Grimstead 2010; Whitaker and Carpenter 2012). In contrast, McGuire et al. are less concerned with the empirical rigor of their analyses and the validity of the faunal index for measuring costly signaling. Instead, they favor a more complete anthropological study of the past, which can be provided by a costly signaling interpretation. Codding and Jones criticize this approach as creating "just so" stories that advocate for an interpretation rather than empirically evaluating the many possible interpretations. One could argue that McGuire et al. relax their expectations about empirical rigor normally found in HBE zooarchaeological studies to prioritize the more anthropological interpretation.

Another example of this trade-off between scientific rigor and anthropological interpretation can be seen in research involving niche construction. In the evolutionary biology literature, niche construction theory (NCT) is used to understand how environmental engineering by organisms impacts the fitness of those organisms (Odling-Smee et al. 1996). The classic example is beavers who modify their environment, creating their own niches and thus enhancing their evolutionary success. The utility of NCT as a distinct evolutionary process is still being debated within evolutionary biology. Many evolutionary biologists argue that NCT is unnecessary because much of what is proposed under NCT can be explained using established mechanisms (Scott-Phillips et al. 2014). However, applying NCT to archaeological contexts seems an obvious research avenue to pursue given that humans can be characterized as the consummate environmental engineers (Smith 2007). In archaeological contexts, NCT has been introduced as a framework to explain important cultural developments such as the origins of domestication and agriculture (Broughton et al. 2010; O'Brien and Laland 2012; Smith 2007, 2015; Stiner and Kuhn 2016; Zeder 2016, see also Riede, this volume).

There have been two approaches that archaeologists have used NCT to explain the past. In one approach, humans are inherently different from other organisms simply by the degree to which we modify the environment to suit our needs and improve our situation (Smith 2015; Zeder 2016). NCT is thus used to portray humans as actively modifying their environment to their selective advantage in contrast to being at the mercy of the environment as under natural selection. In this sense, NCT is directional, a chosen path that is always beneficial. However, this approach to NCT has been critiqued for being tautological (Codding and Bird 2015). For example, NCT is argued to be oppositional to foraging theory in the archaeological literature because it is more appropriate to prioritize humans as different or exceptional rather than treat humans as any other rate-maximizing organism (Smith 2007; Zeder 2016). NCT is not just argued to be appropriate in some conditions but held to be the better explanation than foraging theory in any context. However, in contrast to foraging theory, NCT proponents have not developed the means to measure and evaluate niche construction. Instead, NCT is presented simply as the starting point and the end point, the question and the answer.

The alternative approach to niche construction treats humans as other organisms and environmental engineering as just another strategy that may or may not be intentional or have selective benefits

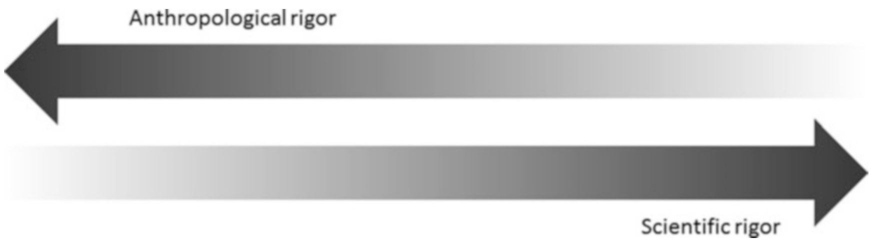

Fig. 12.1 The relationship between the expectations of anthropological and scientific rigor

(Laland and O'Brien 2010; Broughton et al. 2010; Codding and Bird 2015). Thus niche construction is not directional and can result in either positive or negative impact on an organism. Some researchers argue that niche construction is not oppositional to foraging theory models but can be incorporated into these models through established processes such as resource depression (Broughton et al. 2010). Resource depression qualifies as niche construction because humans are modifying the environment and the availability of resources. In this approach, researchers generated expectations across multiple lines of evidence and used zooarchaeological data to evaluate these hypotheses, concluding that the human-altered environment led to increased time allocated to agriculture.

These contrasting perspectives on costly signaling and niche construction reflect not just differences in how HBE models are applied or whether they are seen as valuable for understanding subsistence change. They reflect a conflict embedded within the structure of processual archaeology. When laying out the New Archaeology, Binford (1962) argued that archaeology should have two goals. It should be less particularistic and unstructured (i.e., more scientific) and should also strive to contribute specifically to anthropological theory. Processual archaeologists have long assumed that we can achieve both the anthropological and scientific goals within archaeology, even though critics such as Dunnell (1980, 1989) have argued that achieving both is difficult if not impossible. The differences in perspective relate to how we perceive the relationship between the anthropological and scientific goals. We often assume that both goals are positively correlated and measured on a similar scale so that if we are more anthropological, then we are more scientific. However, this only works if the anthropological goal is prioritized. Few would agree with the statement that if we are more scientific, then we are more anthropological. Thus, I argue that the anthropological and scientific goals and standards are measured on two different scales that are inversely related to one another (Fig. 12.1). Under this model, archaeologists have to make a choice between prioritizing the anthropological or the scientific. In the diagram, the far right side would represent more scientific, less anthropological archaeological research. HBE research falls on this side of the diagram where humans are studied as an organism for which ecological and evolutionary processes are important for explaining human actions. On the far left side would be more humanistic research such as post-processual archaeology that does not claim to pursue a scientific goal. Anthropological archaeology occupies the wide range in the middle. We could see these as different approaches to archaeological research, each of which provides different products. However, the anthropological goal is often prioritized in a way that devalues the research on the scientific end of the spectrum.

The anthropological is paramount in processual archaeology. We envision archaeology as an anthropological sub-discipline that studies human cultures, societies, or the human past. The mantra of "archaeology is anthropology" makes it clear that the anthropological goal should be prioritized (Willey and Phillips 1958, p. 2) and determines what archaeologists consider "good" research. Job announcements for academic positions in the United States often describe their ideal candidate as an "anthropological archaeologist." The major funding agency in the United States, the National Science Foundation, funds research that "furthers anthropologically relevant archaeological knowledge" (National Science Foundation Archaeology and Archaeometry program page: https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=11690). "Scientific" may be implied, but anthropological is explicit.

The impact of the anthropological goal on archaeology is also evident when contrasting introductory archaeology textbooks to those in paleontology or paleobiology. The first section of most archaeological textbooks discusses how archaeology fits within anthropology or how archaeology uses an anthropological approach (Renfrew and Bahn 2010; Thomas and Kelly 2006; Sutton and Yohe II 2008; see also Lyman 2010). A textbook with direct roots to the New Archaeology defines archaeology as "the study of human societies that emphasizes the interaction between human behavior and artifacts" (Rathje and Schiffer 1980, p. 390). This definition has morphed into archaeology as "the study of the human past," sometimes qualified with "through analysis material culture." Thus, our definition focuses on human societies or the human past as what we study. We study people just like anthropologists. The emphasis on archaeology as a sub-discipline of anthropology suggests we simply do anthropology of the past. In contrast, paleontology textbooks do not discuss the discipline's relationship to geology or evolutionary biology. Paleontology is not set up as ecology of the past. Instead, paleontology is presented as its own discipline, one with its own unique dataset—fossils (Foote and Miller 2007; Prothero 2003; Tattersall 2010). Paleontologists study fossils to understand the evolution of organisms and use its own set of methodologies to contribute a different product and perspective on those ecological and evolutionary processes (Lyman 2007). Archaeology could prioritize the archaeological record as a unique dataset that can be used to generate a different kind of product through empirically rigorous analyses, but the interpretations produced are unlikely to look anthropological (Dunnell 1971).

While processual archaeology appears to be a unified approach, the reality is that the methodology and products vary depending on whether researchers prioritize the anthropological versus the scientific (or in the case of HBE, ecological) and by how much each is prioritized. The costly signaling debate provides an example of this. For the archaeologists accused of producing the "just so story," identifying specific measures to differentiate costly signaling from other explanations is not as important as demonstrating the validity of the costly signaling interpretation. The "no can do" archaeologists would rather see an empirically rigorous analysis than paleoethnographies or "stories." Each side is using different standards to measure the quality of the archaeological output. The difference is that the archaeologists prioritizing empiricism have no qualms about giving up the anthropological goal. But those focusing on the anthropological insist that their argument is empirically sound, thus achieving both goals. The niche construction research also illustrates how the different approaches manifest themselves in archaeological research. Broughton et al. (2010) use multiple lines of evidence to evaluate expectations generated from NCT and foraging theory models about when domestication might have a selective advantage. Smith (2015) and Zeder (2016) generated an anthropological narrative on domestication by using data to support the claim that niche construction occurred. The former focuses on the empirical evaluation of hypotheses, while the latter emphasizes empirical support for the anthropological interpretation. The products for these different approaches vary markedly. It is likely that "appeal" or "preference" will determine which approach a zooarchaeologist will follow rather than the strength of any argument. Thus, critiquing the different approaches typically does not alter researchers' views. However, when researchers argue that they are serving both anthropological and scientific goals, it is often based on the assumption that the two goals are correlated rather than following scientific standards that would be recognized by other disciplines.

The recent debate on the origins of agriculture provides another example of this conflict between the scientific and anthropological goals (Gremillion et al. 2014a, b, c; Mohlenhoff et al. 2015; Smith 2014; Zeder 2014, 2015). In this debate, niche construction theory was argued to be a better explanatory model rather than a different approach to HBE in understanding the origins of agriculture (Smith 2014; Zeder 2014, 2015). NCT is a more anthropological-friendly approach because it focuses on humans as unique environmental engineers and it has a more relaxed interpretation of scientific rigor that includes analogic reasoning, an advocacy rather than evaluative analytical structure, and the use of plausibility to determine validity (Smith 2015). Since the HBE researchers are not focused on similar anthropological interpretations, their critique focused on the evaluation of scientific rigor. They found the use of analogy and limited empirical analysis of alternative explanations as less scientifically rigorous than HBE analyses. But the NCT proponents countered that the HBE results were not "compelling" (Smith 2014). Dunnell (1989, pp. 36–42) has argued that these types of debates between researchers arise because "reason-giving" associated with anthropological interpretations is conflated with or treated as equivalent to "scientific cause." An example of reason-giving is providing evidence to support a particular interpretation. In contrast, to evaluate scientific cause, data are produced to evaluate all possible interpretations. This difference in approaches suggests that anthropological and scientific goals are assumed to be autocorrelated within anthropological archaeology but are often two separate goals within HBE research.

The challenge for HBE research is how to persist in a context dominated by anthropological archaeology in which anthropological and scientific goals are both seen as equally achievable and the anthropological goal is deeply embedded within the psyche of Americanist archaeology (Lyman 2007). HBE research, in contrast, often focuses on the scientific rather than the anthropological goal. Most HBE studies approach humans as biological organisms rather than as cultural beings. Thus the archaeological product may look more ecological than anthropological. Indeed, some HBE researchers may be more likely to describe themselves as paleoecologists rather than anthropologists. HBE and anthropological archaeology could be valued as different approaches to the archaeological record. However, anthropological archaeology is the dominant perspective and often the gatekeepers for determining what good archaeology looks like. Thus, HBE studies are critiqued for being environmentally deterministic and not incorporating humans' capacity to make their own choices (Zeder 2016). The implication is that "good archaeology" rather than "good anthropological archaeology" provides anthropological interpretations in which humans are dynamic actors and the products are paleoethnographies. HBE researchers would argue that "good HBE research" prioritizes scientific rigor over generating paleoethnographies by focusing on the empirical expectations of the models and evaluating interpretations through multiple lines of evidence. In many ways, anthropological archaeology is antithetical to HBE.

The impact of this anthropological focus in archaeology will likely have only a few outcomes for HBE zooarchaeological research. It is likely that HBE research will continue to be deconstructed by anthropological archaeologists as being not anthropological enough. Since anthropological archaeology is the dominant paradigm in North American archaeology, this perspective can have long-term impacts on funding and publications. Alternatively, HBE researchers could relax their scientific standards to develop interpretations that are more anthropological. However, this approach will likely be criticized by other HBE archaeologists. The ideal outcome, however, would be for HBE to simply be recognized as a different approach to archaeology, one that prioritizes a narrow definition of scientific rigor and makes no claims of being anthropological. In this way, HBE would be analogous to post-processual archaeology, an approach that is ontologically different from anthropological archaeology so not held to the same standards or an approach that more closely aligns with history than anthropology (Cruz Berrocal 2013). But the challenge for HBE research is not just cutting ties to the anthropological goal but also advocating for a different perspective of what scientific research looks like.

Conclusions

HBE models have proven to be useful for understanding certain aspects of human subsistence change using zooarchaeological data. Researchers have applied these models across different types of faunal data, taxa, and archaeological contexts. While zooarchaeological HBE research has gained significant insights from anthropological and ethnoarchaeological studies, the success of this approach in faunal studies is linked to the development of its own set of archaeological expectations and methodologies for its unique zooarchaeological datasets. Researchers are exploring other areas of human subsistence such as the relationship between HBE models and niche construction, which could be useful in integrating the study on the origins of agriculture using both plant and animal remains. However, as long as HBE is considered an approach within processual archaeology, the challenge will be advocating for its unique product as an alternative to the anthropological interpretations for which it is ill-suited to generate.

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