

# Chapter 11

## Human Ecology



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### Introduction

Archaeologists study human ecology in a wide range of contexts asking an equally diverse range of questions. This chapter provides a short overview of major research directions pursued by archaeologists within an evolutionary ecological framework. As outlined in Chap. 1 (this volume), evolutionary ecology (EE) is a Neo-Darwinian approach to understanding diverse phenomena spanning reproductive decisions and population regulation to predation and competition. Drawing from this body of method and theory, human behavioral ecology (HBE) developed as the specific study of human behavior in an evolutionary framework. Research in HBE has addressed many topics, some including reproduction and population regulation, foraging behavior, and social relationships (signaling, territoriality, and cooperation). Assumptions of HBE models are reviewed in Chap. 1 (this volume) and considered in greater depth in individual chapters within this section. But briefly, models in HBE work on the assumption that behavior has economic implications and thus also reproductive fitness implications. Behavior is assumed to be a by-product of decision-making drawing from some combination of learning and genetic and behavioral inheritance (Kelly 1995; Smith and Winterhalder 1992). Consequently, scholars working within HBE frameworks develop decision-making models based in assumption of methodological individualism (Smith 1991; Smith and Winterhalder 1992). Models are typically structured in microeconomic frameworks based in optimality assumptions recognizing that such assumptions are to be tested and refined (Bettinger et al. 2015; Cannon and Broughton 2010). Optimality assumptions are based in the idea of economic rationality and environmental knowledge. The HBE research process is structurally hypothetico-deductive, depending heavily on outcomes of precisely structured empirical research for advancement of knowledge (Kelly 1995; Smith and Winterhalder 1992).

Archaeologists have benefited substantially from development and testing models based in the logic of evolutionary ecology (Bird and O'Connell 2006; Codding and Bird 2015). HBE scholars in archaeology have studied foraging and food production behavior, land use/mobility, tool production/use and raw material transport, socio-ecological relationships, and demographic ecology. Archaeologists face challenges making use of space-like models based in methodological individualism given the inherent challenge of tracing individual behavior in the archaeological record. Archaeologists typically must assume that the archaeological record is accumulated from

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many decision-making events. Testing models from HBE thus requires the assumption that adaptive behaviors will persist over time and thus leave an identifiable signature in the archaeological record. Taking this one step further, this presents the possibility of explaining processing of stability and change in aspects of culture and behavior by use of economic optimization models from HBE. However, given the intense focus on formal testing, the option remains open that simple optimization models will fail either by virtue of problems with embedded specific assumptions or via wider issues with evolutionary process. The most credible critique today of HBE-inspired models comes from niche construction theory asserting that a number of fundamentals structuring, for example, foraging theory, are too simplistic in light of advanced evolutionary thinking that is coming from the extended evolutionary synthesis in the form of niche construction theory (NCT) (Zeder 2017).

Despite critiques, it is clear that human behavioral ecology (and related models) has made substantial contributions to archaeological research. In this chapter, I outline the major areas of contributions within four major themes. First, I consider contributions of foraging theory with a focus on diet breadth, patch choice and use, central place foraging, and food storage. This permits me to explore subsistence intensification and origins of food production drawing in particular upon HBE perspectives. Second, I consider aspects of socio-ecology with a particular emphasis on signaling, territoriality, and cooperation research. There is an emerging debate over the role of HBE-inspired cooperation theory in explanations of sociopolitical complexity (e.g., Carballo 2013) and while this is not yet well-enough developed to warrant a stand-alone chapter, I consider it here. Third, I introduce the basics of ecological demography with a focus on implications of Boserupian and Malthusian models. I follow with a focus on the predictions of Malthusian modeling and its implications for our understanding of demography, subsistence, storage, and social behavior, thinking in particular about conditions favoring competitiveness. Finally, I offer a brief introduction to niche construction theory reflecting again upon the origins of agriculture debate and the potential of NCT to offer wider understanding of global human-linked phenomena.

## Foraging Theory

Foraging theory (also known as optimal foraging theory) developed in biology to provide evolutionary explanations of foraging behavior across the animal kingdom (MacArthur and Pianka 1966). Foraging theory was first broadly introduced to archaeology by Winterhalder and Smith (1981), and it has become a prominent area of research in recent decades, for many scholars substantially replacing Binford's (1977, 1981) middle-range theory approaches to understand subsistence and mobility decision-making (Bettinger et al. 2015). Foraging theory, as applied in anthropology and archaeology, asserts that human decision-makers will seek to maximize net energy return on activities associated with prey choice or diet breadth, choice of foraging places and timing, field processing and transport, and food storage (Bettinger et al. 2015). As the models associated with these topics are considered in greater depth in individual chapters within this section, I focus here on basic definitions, major contributions, and some debates.

For archaeologists, the diet breadth model (also known as the fine-grained prey choice model) is probably the most widely used HBE approach to understanding subsistence behavior among hunter-gatherers and has been discussed extensively in other texts (Bettinger 2009; Bettinger et al. 2015; Kelly 1995). The model recognizes that hunting and gathering people need to make choices as to which prey to pursue when in a field context as affected by the costs of encounter rates and total handling time (handling includes pursuit once a prey item is encountered). The model asserts that prey items will be chosen in reverse order of prey rank (ranking based on caloric return per unit handling time) until search and handling times are approximately equivalent. Thus, a forager would evaluate the relative payoffs for prey packages always choosing the higher-ranked items and excluding

the others as long as search and handling conditions remain about the same. The diet breadth model has been prominent in discussions of hunter-gatherer subsistence intensification, particularly where associated with the problem of declining access to highest-ranked resources, a process often called resource depression (e.g., Basgall 1987; Broughton 1994, 2002; Fisher and Valentine 2013; Janetski 1997; Nagaoka 2005; Munro and Atici 2009). This has led to a wider discussion of the meaning of intensification and the recognition that the term can have multiple meanings and implications whether associated with a maladaptive broadening of the diet under conditions of resource depression or a narrowing of the diet made possible by technological innovations (Chatters 1989, 1995; Morgan 2015). The diet breadth model has also been central to discussions and debates regarding the so-called forager-farmer transition (Kennett and Winterhalder 2006). Essentially, proponents argue that intensification of plants leading to farming can be understood in light of predictions drawn from the diet breadth model suggesting that early food production can be viewed as a greater investment in handling costs favoring a diet focused on low trophic scale items such as maize (Barlow 2002; Gremillion 1996; Gremillion et al. 2014). Niche construction theorists argue that the process of domestication of plants and animals and adoption of agrarian lifestyles is too complex to be explained via simple cost-benefit models, thereby implicating the complex dynamics of niche construction and macroevolutionary process (Smith 2015; Zeder 2016, 2017). Responses to the NCT critique assert that models from HBE are still important for developing an understanding of the economic logic behind decisions to engage in niche construction (Mohlenhoff and Codding 2017).

Another approach to understanding foraging behavior concerns questions of decision-making regarding choice of places to acquire food and how long to stay in those places. The patch choice model is structured much like that of diet breadth and is designed to predict the optimal range of ranked foraging patches (patches are bounded spaces containing a particular set of prey [Smith 1991]). This model also has similar implications to that of the diet breadth model in that, as patch productivity rises, foragers might become more selective in choice of patches, thus reducing inter-patch travel. The inverse would be expected given declining inter-patch productivity (Bettinger et al. 2015). These predictions are reflected in studies of shifts in hunting and gathering behavior under conditions of resource depression. Drawing data from the Keatley Creek site from interior British Columbia, Prentiss et al. (2007) documented that as access to salmon declined, occupants not only diversified their diet but likely added new and more distant patches to summer food-gathering trips. The marginal value theorem (Charnov 1976; Venkataraman et al. 2017) allows researchers to predict optimal time spent in a specific patch assuming that the forager will choose to depart when the net return drops below the net rate of return for the entire environment. The marginal value theorem (MVT) has proven useful in a number of ways, in particular thinking about human colonization and colonization rates in new environments. For example, Kelly (1995) draws on the MVT to model Clovis land-use decisions from which he projects different options for colonization rates in the Americas. The ideal free distribution (IFD) (Fretwell and Lucas 1969) is yet another model that can provide insight into decision-making regarding choices of living spaces as affected by the range of options and associated demographic pressures. At its simplest level, the model assumes that populations will fill most productive habitat first before accepting less productive habitat. The model has been used to address a variety of research questions concerning colonization in various parts of the world (e.g., Kennett 2005; Kennett et al. 2006; O'Connell and Allen 2012). A variant of the IFD known as the despotic ideal free distribution (DIFD) models the process by which packing and associated social competition pushes populations to choose loss of autonomy to avoid being pressed into extremely marginal habitats (e.g., Giovas and Fitzpatrick 2014; Kennett et al. 2009).

Central place foraging (CPF) models (Orians and Pearson 1979) offer the opportunity to model optimal choices for field processing and transport of resources. In brief, CPF models predict that foragers faced with transport costs for acquired food or other items such as tool-making material will seek to optimize net return by raising the net utility of the item or items in reference to costs of transport (Bettinger 2009; Bettinger et al. 2015). Imagine a hunter-gatherer faced with transporting

a collection of coconuts. Given thick rinds and hard inner hulls, the cost of transporting them to consumers is quite high. However, if the consumers are very close by then, it might be most cost efficient to just transport the unprocessed nuts. As anticipated travel distances get longer, it makes better economic sense to remove thick rinds and possibly the inner shells and, thus, to carry exclusively edible material. In the latter case, the trade-off between higher field labor and reduced transport cost is worth it given the high caloric return on the increased quantity of transported nut meat. A similar argument could be made for decisions regarding prey choice given variation in anticipated prey transport (Bayham 1986). CPF models have proven useful in many contexts associated with subsistence behavior inclusive of plants (Barlow and Metcalf 1996), animals (Cannon 2003), or both (Zeanah 2004). Given their applicability to technological decision-making, Beck et al. (2002) developed an influential central place foraging model to explain differential field processing decisions for Paleoarchaic period quarrying and tool transport finding that more distant quarries from base camps contained greater late-stage reduction debris, thus confirming investment in field processing. Other scholars have relied on similar cost-benefit logic to model optimal decision-making with regard to lithic procurement (Borrazzo 2012; Garvey 2015), design of toolkits (Elston and Brantingham 2002; Kuhn 1994; Surovell 2009), tool maintenance strategies (Clarkson et al. 2015), and lithic core reduction techniques (Goodale et al. 2008).

As noted by Bettinger et al. (2015), there has been little attention to the costs and benefits of different approaches to food storage. Tushingham and Bettinger (2013) presented the “front-back” model to consider costs and payoffs for decisions as whether to invest in front-loaded meaning costs up front to get a food source into storage versus back-loaded where costs incurred after storage. Thus, a resource like salmon can be stored but only after significant effort in smoking and/or drying. In contrast, nuts like acorns can be immediately stored but require substantial work in the form of milling, leaching, and cooking before they are edible. In the latter case, while the back-loaded model is more costly in total handling time, it is also less risky for groups exploring storage option as the process of getting nuts into storage costs little, and thus little is lost if storage caches are raided or otherwise lost. The model provides an explanation for why acorn caching emerged long before salmon storage among residentially mobile hunter-gatherers in California (Tushingham and Bettinger 2013).

## Evolutionary Ecology of Social Relations

Social cooperation has been an area of significant concern to human behavioral ecologists in anthropology and archaeology. Human beings are social animals thus requiring decisions regarding many aspects of cooperation with one another. Fundamentally, cooperation often requires altruism. As noted by Bettinger et al. (2015), p. 194, altruistic behaviors are those “in which an individual sacrifices self-interest (compromises personal genetic fitness) to further the interest (genetic fitness) of other individuals . . .” This is, of course, a problem for frameworks that assert the importance of individual fitness maximization. Consequently a substantial amount of attention has been placed on developing theoretical understanding of the evolution of altruism among populations of genus *Homo* and to consider its implications for the evolution of culture. Explanations for the evolution of altruism have been diverse including the original group selection model of Wynn-Edwards (1962), the inclusive fitness and kin selection model of Hamilton (1964), various models concerned with implications of the prisoner’s dilemma and related models (e.g., Chadeux and Helbing 2010; Hauert and Doebell 2004; Helbing and Yu 2009; Koella 2000; Smaldino and Schank 2012; Smaldino et al. 2013), punishment and cultural transmission (e.g., Boyd and Richerson 1985, 1992; Boyd et al. 2003; Guzman et al. 2007; Henrich and Boyd 2001), and recent reconsiderations of group selection under the guise of multilevel selection frameworks (e.g., Bowles 2006; Nowak et al. 2010; Wilson 2012; Wilson and Hölldobler 2005). Typical research in human behavioral ecology is less concerned with the evolutionary origins of

the capacity for altruism than it is with understanding variability in fitness-enhancing decisions within human societies already including significant degrees of cooperation and thus altruism. Cooperation strategies are diverse and can include managing group size, sharing, signaling, territorial management, defense, and reproduction (e.g., Bettinger et al. 2015; Boone 1992; Borgerhoff Mulder 1992; Hawkes 1992; Kelly 1995; Smith 1991). Testing social cooperation models with archaeological data can be challenging, and consequently not all areas of HBE-inspired cooperation research have been strongly represented in archaeology. Here I focus on three areas that have been prominent or show significant promise for future research: sharing and signaling, land tenure, and emergence of social inequality.

The question of sharing has drawn considerable attention and debate. A simple model from game theory, the prisoner's dilemma, predicts that in a single play of the game, defecting (not sharing) is always the best option. However, an important study showed that when played across multiple iterations, tit for tat (cooperation in the first round and then repeat of the other player's action in all subsequent rounds) offered a consistently better payoff (Axelrod 1984; Axelrod and Hamilton 1981). Subsequent research demonstrates that outcomes of sharing games vary substantially with assumptions and conditions (Hawkes 1992). Smaldino et al. (2013), for example, demonstrate that over very long time spans, harsh conditions will favor populations of reciprocating cooperators over populations of those who do not reciprocate. Other studies implicate the effects of spatial relationships (Koella 2000), movement patterns (Smaldino and Schank 2012), and wealth accumulation (Chadefaux and Helbing 2010) on persistence of groups of cooperators. An important potential lesson from some of this research is that cooperation decisions are contingent upon a variety of social, geographic, and ecological conditions. It should be no surprise then that anthropologists have recognized multiple contexts whereby the structure of cooperation with regard to sharing of goods varies. Thus, we encounter sharing models including kin selection, tolerated theft, simple reciprocity, cooperative acquisition, mutualism, and signaling (Bettinger et al. 2015; Hawkes 1992; Kelly 1995; Winterhalder 1986).

Signaling theory has garnered attention due to its potential ability to explain behaviors that seem to be otherwise wasteful or expensive in reference to economic payoffs (Quinn this volume). Hawkes' influential (1992) paper raised the possibility that males might engage in economically risky behavior (hunting) in order to signal prowess and gain mating opportunities. While this has led to some debate (Bettinger et al. 2015), the argument was highly influential. The debate over Middle Holocene hunting in California and the Great Basin by those favoring a similar (to Hawkes' argument) signaling hypothesis (Hildebrandt and McGuire 2002) and those favoring a diet breadth model (Broughton and Bayham 2003) is an illustrative example (Winterhalder 2004).

Human groups have highly diverse approaches to sharing access to land (Kelly 1995). As with sharing particular goods, decisions regarding access to land may also have fitness implications and thus can be modeled in cost-benefit terms. Such models may be very useful as hypotheses for archaeologists seeking to understand and explain the structure of ancient land tenure systems. Dyson-Hudson and Smith (1978) published a very important model in which they predicted variation in territoriality among hunter-gatherers on the basis on resource density and predictability. Among other things, the model predicts stable territories when resources are both dense and predictable. In contrast, group dispersion and mobility are associated with low density and predictability resources. Predictions of the model have been partially confirmed in the Great Basin (Thomas 1981) and likely hold in other regions, for example, the Northwest Coast and Fraser-Columbia Plateau where indigenous groups also defended formal territories associated with localities for annual harvest of salmon, sea mammals, clams, and root crops (cf. Lepofsky et al. 2005, 2015; Lyons and Ritchie 2017) not unlike agriculturalists. However, the Dyson-Hudson and Smith model also opens the possibility of other land tenure systems, for example, social boundary defense and passive territories (Kelly 1995). Such models help us to better understand decision-making by groups whose resource structures may be more variable in spatiotemporal terms, thus often increasing variability between groups and promoting the possibility of alternative strategies. Such variable land tenure strategies might have characterized many groups during the Middle Holocene when resources fluctuated seasonally and varied spatially (cf. Habu 2001).

The emergence of wealth-based inequality has been of significant interest to social anthropologists and archaeologists working within human behavioral ecology frameworks. A variety of models have been developed to explore key issues in the evolution of inequality. These can be collectively reviewed as those concerned with conditions versus actions. From the standpoint of conditions, a variety of research projects point to three critical factors associated with emergent wealth-based inequality: resource defensibility, transmittable wealth, and population pressure (Mattison et al. 2016). Ethnographic studies strongly back up these conclusions (Borgerhoff Mulder et al. 2009; Smith et al. 2010), and archaeological research increasingly offers similar support (Kohler et al. 2017; Prentiss et al. 2012, 2014). Eerkens (2013) and Bettinger (2015) point to shifts in the control of goods as precursors to inequality. Their argument is the nonkin free riders are costly, and under some conditions, it is worthwhile engaging in strategies to prevent free riding that might include privatizing certain resources, restricting cooperating groups, and introducing punishment for free riders making the latter inherently more expensive. Several models focus on adaptive strategies that result in inequality. Smith and Choi (2007) develop a model termed managerial mutualism linking inequality to decisions made to permit managers greater control of resource decision-making in contexts of complex information loads. Boone (1992) argues that patron-client relationships can develop when there is emerging differentiation in access to critical subsistence items. Prentiss et al. (2007) argued for a process similar to Boone's (1992) model regarding the development of inequality at the Keatley Creek site in British Columbia. Boone (1998) added that signaling could be advantageous even when costly to establish cooperating groups under competitive conditions. Kennett et al. (2009) develop a DIFD model to explain how control of space played a critical role in emergent inequality in the Northern Channel Islands of southern California.

## Ecological Demography

Demography has been an implicit and explicit factor in the development of models in human ecology. Decision models in optimal foraging theory are typically dependent upon variation in access to critical resources. Optimal diet breadth can be affected by demographic packing and dispersal. Likewise, field butchering decisions are dependent upon anticipated transport distance and that may be affected by search costs associated with most-desired resources which may be overharvested if population sizes become out of balance with local resource structures. Choices of which patches to use and how long to stay may also be impacted by local demographics. Models of social inequality typically also have a demographic component concerning population needs and access to critical resources. While the effects of demographic variability are not the specific goal of the latter models, they are clearly important and thus worthy of study. Scholars in demographic ecology have developed an array of models to explore the interactions between resource variability, food harvest, processing, and storage, demography, and social cooperation and competition (e.g., Lande 1993; Lee 1986, 1993; Lee et al. 2009; Lee and Tuljapurkar 2008; Puleston and Tuljapurkar 2008; Puleston and Winterhalder this volume; Puleston et al. 2014; Winterhalder et al. 2015; Wood 1998). This work offers a range of explicit predictions that may be used to hypothesize a variety of trajectories of demographic, economic, sociopolitical change in the near and remote human past (e.g., French 2016; Holopainen and Helama 2009; Kirch et al. 2012; Morrison 1994; Prentiss et al. 2014). I introduce the basics of the Boserupian and Malthusian approaches to demographic ecology as they are relevant to archaeology.

Boserup's (1965) model concerned with the impact of population growth on agricultural intensification has been extraordinarily influential. In brief, she argued that by viewing steady population growth as the independent variable, it was possible to anticipate the need to intensify production of crops by virtue of expanding cropping frequency or some other process elevating production. In the short term, this meant reducing relative per capita income associated with higher labor costs, while

in the longer term, it meant innovation would be rewarded (Lee 1986). Thus, in the larger picture, subsistence intensification and technological evolution could come about in a largely maladaptive process driven by steadily rising population. This model influenced processual archaeologists in a substantial way encouraging them to think about the forager-farmer transition and the emergence of complex society as outcomes of population pressure (Cohen 1977, 1981) and packing (Binford 1968, 2001). The model was also influential to foraging theorists seeking to understand diet changes and variation in food handling decisions in contexts of rising populations and local resource depression. Broughton (1994) documented expanding choice of lower-ranked prey over time in the Sacramento River Valley, thus a hunter-gatherer version of intensification in Boserup's (1965) sense. However, increased ratios of limbs to axial skeletal parts also reflected the possibility of extensification (Boserup 1965), assuming investment in field butchery for prey acquired at greater distances or use of a wider landscape, another costly strategy driven by local (to villages) resource depression. This fit a wider pattern of intensification and extensification in California as documented by other scholars (Basgall 1987; Beaton 1991). Intensification and resource depression has been recognized in many other contexts (e.g., Butler and Campbell 2004; Fisher and Valentine 2013; Janetski 1997; Nagaoka 2005). Subsistence intensification, however, has also come to be recognized as an adaptive process in cases where technological innovations enhance harvest such that higher energy returns can be had with reduced labor investment (Morgan 2015). Net and storage technologies in the Pacific Northwest have been suggested as examples (Chatters 1989, 1995; Prentiss et al. 2005). The logic of Boserup's model has also influenced recent theorizing of population growth and cooperation and the development of ritual traditions and social inequality (Stanish 2017).

The Malthusian demographic model asserts that population growth is not necessarily an independent variable but rather a by-product of low population demands relative to technology and food resources (Lee 1986; Malthus 1796; Puleston and Winterhalder this volume). This has the implication that population dynamics may fluctuate over time depending upon resource conditions, technological enhancements, and even sociopolitical factors (Lee 1986; Wood 1998). Recent modeling by Puleston et al. (2014) has defined several stages that well illustrates the Malthusian cycle. The copial period is a period of slow growth following the establishment of a settlement in a new context. This is followed by a shorter transition phase where food shortages increase mortality and reduce fertility and a subsequent Malthusian phase where there can be a true demographic crisis in maintaining a population. An outcome of this and other modeling (Lee et al. 2009; Lee and Tuljapurkar 2008; Puleston and Tuljapurkar 2008) is the recognition that loss of very young and old during these events can lessen crisis conditions though if human losses extend into productive age adults, the process can be catastrophic. Other implications concern the effects of investments in storage (Angourakis et al. 2015; Winterhalder et al. 2015) and ecosystem vulnerability (Kirch 2007). Archaeological exploration of the predictions of Malthusian models have demonstrated its utility for better understanding subsistence intensification (Kirch et al. 2012), investment in storage (Kuijt 2015; Prentiss, Foor, and Hampton 2018), development of social inequality (Prentiss et al. 2014), and settlement abandonments (Holopainen and Helama 2009). Social inequality can be a by-product of social competitiveness linked to differential food storage arising during a transitional or full Malthusian period (Winterhalder et al. 2015; see also Boone 1998; Hegmon 1991).

## Niche Construction Theory

Niche construction theory (NCT) developed from discussions during the 1970s and 1980s concerning the influence of organisms on their environment (e.g., Lewontin 1970a, b), the concept of extended phenotype (Dawkins 1982), and, as applied to human beings, conceptions of dual inheritance (Boyd and Richerson 1985) creating parallel evolutionary cultural trajectories with the potential for impacts

on organic evolution. Formalized in a series of papers by Odling-Smee and colleagues (Odling-Smee 1988, 1995; Odling-Smee et al. 2003), NCT recognized that organisms can play a significant role in affecting their selective environments with *Homo sapiens* being the ultimate niche constructor. Riede (this volume) details a range of means by which the human niche has been created with significant evolutionary impacts. Particularly dramatic examples include use of fire as a tool for modifying landscapes, shaping tools, and preparing food; domestication of animals and plants; and cognitive niche construction. Domestication as niche construction has become the center of an extensive debate over the domestication process and the origins of agriculture. Smith (2015) and Zeder (2016, 2017) argue that agriculture is best understood as the by-product of a niche construction process by human groups making conscious decisions to enhance productivity and reliability of subsistence resources. Aligning their arguments with the emerging concepts of an extended evolutionary synthesis, they argue that agricultural origins are better understood as more than the effects of cost-benefit decision-making as argued by foraging theorists (e.g., Gremillion 1996). However, Stiner and Kuhn (2016) point out that both models may offer insight, cost-benefit decision-making explaining daily decisions and NCT placing outcomes of those decisions across longer time spans in a more inclusive evolutionary framework. Mohlenhoff and Codding (2017) view niche construction as a form of patch investment with such decisions contingent upon considerations of net economic benefits. If NCT offers novel insights into a major human process such as domestication and the “Neolithic Revolution,” then NCT may also hold the potential to help us understand contemporary human impacts on global climate and perhaps to begin modeling realistic means by which we might lessen the predicted adverse effects. This is reflected in the active discussions surrounding NCT and conceptions of the Anthropocene (Riede this volume).

## Discussion

Archaeological research in evolutionary ecology remains diverse and essential to our wider interests in human bio-cultural evolution. Chapters in this section of the book illustrate the vibrancy of this research agenda and its important contributions and ongoing debates. Nagaoka and Gremillion review the important contributions of foraging theory to understanding the economic logic and potential fitness consequences of foraging decisions and associated behavior. As noted by Gremillion, these models have important implications for our understanding of wider processes, for example, domestication and the development of food production. There are also economic and reproductive impacts from an array of behaviors widely classified as signaling (Quinn, this volume). On a wider scale, the interactions between resource conditions, foraging and food production behavior, and social and reproductive behavior clearly impact demography as reviewed by Puleston and Winterhalder. Additional nuance to human ecology and the debate over aspects of the cultural evolutionary process is enhanced by considerations of the effects of human niche construction as reviewed by Riede.

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