ARCHAEOLOGICAL THEORY TODAY

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Many contributions to this volume demonstrate a healthy pluralism in current evolutionary approaches to describing and interpreting the material consequences of human cognition and action. These approaches are sometimes seen to be operating under a unified Darwinian umbrella (Kristiansen 2004), but that appearance is to some degree illusory, particularly with respect to so-called evolutionary (or selectionist) archaeology and human behavioral ecology (HBE) (Boone and Smith 1998). The strict selectionist view originally promoted by Dunnell (1980) – that evolutionary processes can account for variability in artifact form and frequency independent of the processes that shape the behavior that produced those artifacts – is now broadly rejected. Still, Shennan (2008) argues that integrating certain aspects of this and other evolutionary approaches can inform on a wide range of theoretical and empirical problems in archaeology. We maintain that HBE is nevertheless distinct among them owing to its focus on adaptive function. We also stress that while there are important differences between non-evolutionary, agency-based positions and HBE, these very different analytic gambits share common interests in a growing set of questions about the dynamics of individual behaviors, the social, historical, and ecological contexts in which they are embedded, and the material patterns they produce. Several recent reviews provide more comprehensive treatment of HBE in archaeology than we can undertake here (Bird and O’Connell 2006; Broughton and Cannon 2010; Kelly 2000; Kennett and Winterhalder 2006; Lupo 2007). Instead, we focus
on HBE’s basic theoretical propositions and show how they can be operationalized. We stress the importance of actualistic data for evaluating the potential utility of HBE models in archaeology by reference to two ethnographic examples: Meriam intertidal foragers in the Torres Strait Islands and Martu hunters in Australia’s Western Desert. These studies not only show how the models work, but also highlight new questions especially important to archaeologists, and help identify promising means of addressing them.

HBE versus evolutionary archaeology: levels of explanation

Shennan (this volume) and others concerned with integrating elements of evolutionary archaeology (sensu Lyman and O’Brien 1998) and dual inheritance theory aim to identify culturally determined patterns in artifact form, reconstruct lineages defined by diachronic variation in those patterns, and account for their shape and trajectory by reference to the processes of cultural information transmission outlined by Boyd and Richerson (1985). Their goal is phylogenetic: they revisit the culture histories of preprocessual archaeology and reposition them within a formal evolutionary framework, analogous to that of palaeobiology (Mesoudi and O’Brien 2009). Important as that exercise may be, interpretations of archaeological patterning require attention to more than one level of explanation (Bird and O’Connell 2006; Codding and Jones 2010): the differences between the descriptive-historical emphasis of this reformulated evolutionary archaeology and the functional explanations that human behavioral ecologists usually seek are important and often under-appreciated.

HBE asks questions about the function of behavioral patterns in terms of their immediate, contextually contingent adaptive value to individuals (Tinbergen 1963; see also Cuthill 2005). In emphasizing the utility and dynamism of behavior rather than its phylogeny or ontogeny, HBE retains a sense of the everyday use of the term “function” – its practitioners ask “What is the current, adaptive, fitness-related role of behavior x in a subject’s life?” Potential answers focus on the ecological constraints that shape behavior and its material residues. At issue is not how behavior is learned or transmitted between individuals, but how behavior functions in ways that promote locally specific adaptive goals of individuals.
Questions about function

The term “function” is used in many different ways in the biological and social sciences, and for good reason “functionalism” in anthropology has largely fallen out of favor. In fact, in many respects HBE’s focus on a functional level of explanation grew out of its rejection of the classic functionalism in anthropology and biology: the term is used in behavioral ecology to refer to characteristics that persist because of the advantages they confer to individuals, not groups, populations, societies, or institutional structures. The analytical primacy placed on the adaptive value of individual behavior emerges from a fundamental assumption in HBE: that natural selection, at the level of individual differential reproductive success, is the primary process underlying the design features of decision-making capacity (Krebs and Davies 1997; Williams 1966). While specific cultural processes may provide conditions for group-level adaptations (Henrich 2004), the focus on individual trade-offs in HBE forces attention to conflicts of interest among individuals and between individuals and groups, and to the implications of such conflicts for collective action, emergent social arrangements, and their archaeological expressions.

This assumption – that natural selection has shaped us all and that we all face individual fitness-related trade-offs – does not engage any kind of specific determinism, genetic or otherwise, for explaining behavioral variability. HBE assumes that whatever the mechanisms of inheritance, and however history and socialization enfold those mechanisms, people everywhere have, and will always face, problems of life that matter in terms of individual fitness. The nature of the costs and benefits associated with solving those problems is highly contextual, and we expect large differences in adjustments to locally varying opportunities and constraints completely independent of genetic differences. That, in fact, is the (evolutionary) point of behavior, and natural selection is the only general theory we currently have to account for why it evolved.

HBE thus proposes that a full account of behavior – whatever the proximate motivation, intention, ontogeny, cognitive mechanisms, historical paths, or means of transmission – requires attention to its value in terms of the trade-offs that individual agents face in attempting to make a living, provide for dependents, and maintain the social bonds that such arrangements demand. And as much as they are historically contingent, the values of those costs and benefits are also
fundamentally ecological: they vary as a function of the nature of experienced relationships in local social and environmental contexts. In many ways, understanding those contexts defines most efforts in contemporary HBE, including those applied to archaeological problems.

**HBE versus agency theory: formal modeling**

In its focus on contextually embedded individuals and conflicts of interest, HBE shares much in common with archaeological approaches focused on agency (Shennan 2004). As used in archaeology, agency theory is especially concerned with subjective contexts – both past and present (Hodder 1982). By rejecting structuralism, agency theorists focus on how, despite potentially oppressive social structures, individuals in the past facilitated stability or change through daily practice (Bourdieu 1977; cf. Pauketat 2007). They have also been concerned with the historical conditions that give rise to such agency, and how archaeological patterning and structure emerge from and feed back on relations between individuals and their social and material surrounds (Giddens 1984; cf. Barrett 2001). Further, some explore the recursive nature of archaeological practice itself and how contemporary agents (archaeologists) construct meaning out of “the past” they encounter (Dobres and Robb 2000).

Of these approaches, HBE shares most with those drawn from Giddens’. The differences arise especially in how HBE sets aside the problem of how subjects acquire, evaluate, and give meaning to the contexts that emerge from and constrain social action. Instead, HBE in archaeology proposes that whatever the processes are that affect how subjects come to experience their worlds, we can assume that they have the capacity to evaluate trade-offs that matter relative to adaptive function. This assumption allows us to get on with the task of asking questions about the design of behavior and what maintains it – a research strategy often referred to as the “phenotypic gambit” (Grafen 1984).

HBE thus attempts to characterize behavioral variability relative to the ecologically embedded values of individual agents. These values emerge from and structure decision-making strategies, which for heuristic purposes can be thought of as contingency rules for achieving hypothetical “fitness-related” goals relative to the set of options available to an agent (Smith and Winterhalder 1992). To operationalize this proposition, HBE utilizes formal models to (a) frame a specific problem faced by an agent, (b) identify assumptions about the goal
of behavior, (c) specify the currency in which the trade-offs are measured, and (d) define the constraints that determine the strategy set and its payoffs (Stephens and Krebs 1986: 9). The real utility of such models lies in the specific way that their predictions are at risk of failure relative to observed behavior and its material correlates. Such failures then point towards new questions. If agents do not behave as modeled, it’s not their fault (i.e. it doesn’t necessarily mean their behavior is maladaptive), nor is it the fault of the theory, for that matter. Rather it suggests the existence of one or more problems with the specific hypotheses at risk in the analysis. The theory itself will fail, or simply fade away, only when it ceases to generate productive hypotheses.

With its assumption that individuals should act as if they care about fitness-related consequences, some may charge HBE with being too narrow to tackle many of the complexities of human sociality, some of which may be determined by considerations other than fitness (Bamforth 2002). We respond with two critical points. First, this assumption is derived from the theoretical proposition that natural selection has “designed” our capacity to respond flexibly to varying contexts in ways that should be understandable relative to the costs and benefits of using resources and securing relationships. This proposition is far too broad to be tested in any direct sense, which is why HBE relies heavily on “middle-range” models (sensu Raab and Goodyear 1984) like those discussed below to bridge the broad theoretical statements with potentially observable outcomes. Second, “fitness” itself is theoretical: it cannot be measured in any absolute, universal, or immediate sense – it is the differential reproductive success of specific individuals bearing certain traits and the context-dependent propensity of those individuals to differentially contribute traits to future generations. HBE models do not measure fitness per se, but hypothesize about factors likely to determine it. The theory (natural selection) provides justification for the hypotheses, but does not identify in any direct sense which specific variables matter. Analyses in HBE are thus focused on evaluating the degree to which observable behavior matches the hypothesized variables and their predictive relationships. The real power of the approach lies in its ability to identify and capitalize analytically on the mismatches (Bettinger 2006).

A reliance on formal models and hypothesis testing can impose an analytical inflexibility that many find incompatible with more holistic approaches, such as agency-based analyses that situate individuals and practice in the dynamics of subjectively defined social worlds (Barrett, this volume). Indeed, the use of simple models as a
source for hypothesis testing makes HBE reductionist in practice rather than holistic: it entails an attempt to break down complex socio-ecological phenomena to capture key features of a given problem. But the reliance on formal modeling is a heuristic, not a descriptive endeavor: it is used to clear the lens of inquiry, forcing the analyst to hold in focus the question at hand and the assumptions that underlie “why” questions about behavior. Most models in HBE thus stipulate a fairly narrow range of variables whose relationships generate precise predictions about potentially observable outcomes. As we discuss below, the more successful of these have emphasized generality (presumably at some cost to descriptive reality) and incorporated variables whose values are fairly easy to measure (Bettinger 2009; O’Connell 1995).

Analytical differences such as a reliance on formal modeling will likely continue to separate HBE and agency theory, but attuning each approach to the other “offers a promising framework for identifying the strategies and responses of individual agents to other actors, as well as to institutional structures over time” (Galle 2010: 20). Below we illustrate this with a discussion of two sets of HBE models now commonly used in archaeology – foraging theory and signaling theory – but other frameworks within HBE also have important links to agent-based approaches, especially those dealing with life-history evolution, colonization, technological change, resource inequalities, and political hierarchies (Bird and O’Connell 2006).

Foraging theory

Though it shares concerns with some postprocessual approaches, HBE in archaeology remains unabashedly processual: it seeks to connect theoretical propositions with predictions about empirical phenomena, and to understand the processes that shape the relationship between behavior and its material consequences (Binford 1977). Many of the questions with which HBE deals have their origins in cultural ecology’s focus on subsistence strategies and social integration among foragers (Steward 1955). As such, especially under the rubric of foraging theory, ethnoarchaeological and experimental studies play an important role in the approach, particularly for questions about variability in subsistence strategies and their archaeological signatures (Lupo 2007).

Foraging theory is a set of models designed to address questions about variability in resource acquisition, time allocation, and
the spatial organization of foraging strategies (Stephens and Krebs 1986; for review of technical details of commonly used foraging models in archaeology, see Bettinger 2009). Unlike classic decision models that focus on binary, mutually exclusive choices, foraging theory sees the exercise as an interrelated hierarchy of decisions (Stephens 2008). At the most general level, and against the background of other activities that matter, an individual must choose whether or not to forage, and if so where. Traveling to search for resources in one patch precludes the pursuit of opportunities available in others. Patches are thus defined by sets of resources that can be searched for simultaneously. Within a patch, experienced foragers can anticipate how often different types of resources are likely to be encountered, how that encounter rate changes with patch residence time, and the expected yield for time spent handling (pursuing, capturing, harvesting, and processing) different prey. Given that background, a forager must make a series of decisions about whether to enter and how long to stay in a particular patch, whether to pursue an encountered resource within that patch, how long to stay in pursuit, how much to process a captured resource at the point of acquisition, and which parts to transport from the procurement locale. Foraging models help one deconstruct and so understand these decisions.

Foraging models require a series of explicit assumptions (more accurately, hypotheses) whose relationships provide a solution to a specified decision variable. Imagine a hunter in a homogeneously structured patch where search time can be shared across a number of potential prey types. By foraging in the patch, the hunter allocates time that could be spent elsewhere, and is therefore concerned about how efficiently resources can be acquired relative to those in other patches. If a prey item is encountered during search, the hunter must decide whether to pursue the item or bypass it and continue to search for other resources. The decision to pursue precludes (for a time) the opportunity to continue searching for other prey.

This “decision tree” is formalized in the prey choice (or diet breadth) model (Stephens and Krebs 1986). Analysts employing the model assume that foragers will act efficiently in capturing nutrients (usually energy), and that once foraging begins, time spent searching is shared across a range of resources, each of which yields a different return rate if handled. Under conditions of declining overall efficiency, the model predicts that foragers should broaden the range of resources exploited in rank order of their post-encounter return rate (energy gained per unit of handling time). The highest ranked resources should always be pursued on encounter, but as encounters
while searching for them decrease, lower-ranked resources will be pursued when their own individual post-encounter return rates exceed the overall patch return rate (energy for time spent searching and handling).

Where resources are heterogeneously distributed (searching for one prey set precludes attention to others), foragers face decisions about whether to enter a patch and how long to stay. Increasing patch residence time often leads to diminishing returns. The *marginal value theorem* (Charnov 1976) predicts the point along a diminishing returns curve at which foragers should leave one patch in favor of another. Foragers should spend more time in and extract more resources from patches in poorer habitats, or when travel times between patches are long. Again, opportunity costs underwrite this prediction. If the returns while foraging within a given patch fall below the average available from traveling between all other exploitable patches, the forager should leave that patch and move to another. If average returns from the habitat as a whole decline, the opportunity costs of continuing to exploit a current patch also decline, leading to longer in-patch residence times, less travel between patches, and use of a broader range of resources within any given patch. These developments also increase incentives for improving processing and travel technology (O’Connell et al. 2010).

The archaeological consequences of foraging are determined not only by prey choice but also by decisions foragers make about processing and transporting prey. *Central place foraging models* capture key determinants of those decisions. Regardless of their degree of residential mobility, all humans are central place foragers: they generally transport resources from the point of procurement to a residential base. If a forager takes prey types comprised of parts with different utilities (e.g. meat and bone), has limited transport capability, and is concerned about how efficiently parts of high utility can be delivered home, he or she will face a decision about whether to cull parts of lower utility at the procurement site or transport packages of mixed utility in bulk. Field processing increases the utility of each load, but costs time that could instead be spent acquiring and transporting more resources. The solution to this trade-off – defined by the threshold at which field processing as opposed to bulk transport will increase the home delivery rate of high-utility parts (Metcalfe and Barlow 1992) – provides precise predictions about how transport and depositional behavior should vary relative to changes in load utility with investments in processing. At equal transport distances, those resources characterized by processing that can quickly increase the ratio of high- to low-utility parts are less likely to be transported.
in bulk, and less likely to leave durable archaeological residues near residential locales.

Framed this way, foraging analyses entail built-in assumptions about the goal, currency, and constraints that underwrite the relevant trade-offs. The models assume that foragers have goals related to solving trade-offs where resources are finite, use the stipulated currency to evaluate the costs and benefits associated with the goal, and operate under constraints relative to the distribution of resources and foragers’ knowledge about them. We may be wrong about any or all of these assumptions; the models provide a means to see where we are wrong relative to observed behavior. Moreover, the way that we are wrong can be informative for archaeological issues, especially by highlighting common but questionable assumptions implicit in standard interpretations of archaeological variability.

In the sections that follow we evaluate the utility of foraging models in explaining subsistence transitions, and show how actualistic work supplies information crucial for operationalizing model parameters. The actualistic data we discuss are drawn from our own ethnographic work on foraging and food sharing, though since the mid-1980s such data have become increasingly available (Bird and O’Connell 2006). We use these examples to illustrate how actualistic tests of the assumptions and predictions of models in HBE can generate results that pose new questions with previously unanticipated links to archaeological phenomena. The emergent questions (especially those related to risk and gender) and the theoretical propositions that frame them (especially signaling theory) are taken up in the final sections.

**An archaeological problem: broad-spectrum transitions**

Today, most human populations are densely entangled in highly intensified, globally interconnected agricultural economies. The processes that created this pattern lie in a series of “broad-spectrum revolutions”: trends in ancestral foraging economies towards the use of broader arrays of wild foods, including increasingly diversified strategies for resource acquisition, processing, distribution, and storage (Stiner 2001). Archaeologists have identified a number of factors that may have influenced such transitions, including increasing familiarity with resource quality, increased demand for food in the context of intensifying social relations, technological innovations that affect resource utility, and shifts in the availability of resources as a result of climate change and/or human population
growth. Though all of these hypotheses are plausible, and some combinations of them are probable, few have generated clear predictions or well-defined tests regarding the nature of the newly adopted resources involved, the timing and order of their adoption, or the case-to-case variation in the adoption process evident on a global scale.

Early archaeological applications of foraging theory addressed this problem by reference to the prey choice and patch models discussed above, evaluating their predictions about how selectivity should change with fluctuations in expected overall foraging efficiency (e.g. Bayham 1979; Botkin 1980; Jochim 1976; O’Connell and Hawkes 1981). In general, they proposed that archaeological remains of variable subsistence strategies indicating the step-wise inclusion of lower-ranked resources would support the hypothesis that density-dependent high-ranked resource depression lies at the heart of phenomena commonly characterized as broad-spectrum transitions.

Subsequent applications of these models have further clarified key characteristics of broad-spectrum transitions, the resources involved, and the timing and order of their adoption. Such transitions are typically marked by the inclusion of previously unimportant resources characterized by relatively high post-encounter pursuit costs or by nutrient extraction techniques that entail multi-stage handling or specialized processing gear (e.g. Broughton 2002; Edwards and O’Connell 1995; Henshilwood and Marean 2003; Jones et al. 2008; Stiner et al. 2000). Some of these practices are reported from sub-Saharan Africa by 60 kya BP, but they were increasingly common from 50 kya BP onwards, beginning with the Upper Palaeolithic and spread of Homo sapiens into Eurasia. Resources added to Palaeolithic diets and those involved in subsequent Mesolithic and Neolithic transitions have relatively high handling costs, despite the fact that they are often situationally abundant and have potentially high energetic yields. Their adoption came only with localized declines in the availability of options with higher post-encounter return rates, at least in part because of climate-mediated human population growth (Richerson et al. 2001).

For resources with predictable differences in pursuit costs, there are broadly consistent patterns between expected and observed results: small, fast prey – low ranked because of their ability to elude capture and their low yield – become important in human diets only with increased human population densities and reductions in the availability of larger, slower-moving items (Stiner 2001). While
evidence for the use of resources with high handling costs have been found in some pre-Last Glacial maximum (LGM) deposits (e.g. grass seeds, Henry et al. 2011), complex processing technology indicating far more intensive reliance on such resources only occurs in association with denser human populations, especially with post-LGM shifts marking the onset of Mesolithic and Neolithic economies (e.g. Kennett and Winterhalder 2006). Archaeological evidence for increasing diet breadth since 50kya BP is particularly clear in coastal zones, with depression of slow-moving/immobile but large package resources (e.g. large molluscs, tortoises), and dramatic shifts towards previously unexploited fish (whose pursuit required unprecedented technological investment) and smaller molluscs with lower yields relative to handling costs (e.g. Klein 2004). Likewise in terrestrial circumstances, the kinds of nuts and seeds whose energy requires considerable work and equipment to extract become a major component of Palaeolithic diets only on the heels of spreading modern human populations, or with rapid increases in population density thereafter (e.g. Barker et al. 2007). A number of behavioral ecologists have argued that a reliance on such resources – and the social and technological complexities that underwrite them – can account for many instances of modern human colonization and displacement (e.g. Bettinger and Baumhoff 1982; O’Connell et al. 2010).

We argue that if HBE has successfully informed questions related to broad-spectrum transitions, it has done so in part because of the constraints the models impose on analysis. Working within those constraints requires: (1) a clear statement of the question, (2) selection of an appropriate model, and (3) actualistic work that supplies information about how to measure the model’s variables. While early archaeological applications of foraging models showed the importance of the first two, the actualistic work required to apply the models was initially missing. Until the mid-1980s, for example, analysts had few data on which to base ordinal (let alone interval) rankings of prey types. Something as seemingly straightforward as the possible effects of pursuit costs on the post-encounter return rates for different kinds of prey was often resolved by guesswork. Actualistic studies conducted over the last three decades have not only begun to supply such information, but have also helped identify contexts in which the models “work” and don’t – that is, they have helped make sense of ethnographic observations and led to new questions about ethnographic and prehistoric contexts in which we might expect consistent violations of the model predictions.
Actualistic tests: some ethnographic examples

Shellfishing, prey choice, and transport

Shellfish provide some of the most durable archaeological remains, and evidence of changes in mollusc size and assemblage composition plays an influential role in arguments about the processes involved in broad-spectrum transitions. But until recently, precise quantitative data on the costs and benefits of shellfishing were extremely limited (cf. Meehan 1982). Ethnographic and experimental studies have improved this situation (e.g. Bettinger et al. 1997; de Boer et al. 2000; Hildebrandt et al. 2009; Jones and Richman 1995; F.R. Thomas 2007; D.H. Thomas 2008). The Meriam of eastern Torres Strait provide a case in point (Bird and Bliege Bird 1997, 2000, 2002; Bird et al. 2002, 2004).

When the intertidal reefs that surround the Meriam Islands are exposed, foragers can collect shellfish along the rocky intertidal shoreline, or on the middle and outer reef flat, or they can spearfish in the latter area. On average, adults earn about 1500 kcal/hr – searching + handling collecting on the reef flat, but gain only 300 kcal/hr and 575 kcal/hr, respectively, from spearfishing or by collecting along the rocky shore. Women spend most of their intertidal foraging time on reef flat collecting, where post-encounter return rates for different shellfish range from 500 to >13,000 kcal/hr. As predicted by the prey choice model, women focus on prey yielding post-encounter returns significantly higher than the overall return rate from the patch: harvesting tridacnid clams, Lambis conch, and large Trochus (all with post-encounter returns >2000 kcal/hr), but almost always passing over small Strombus conch, small Trochus, and small bivalves (all yielding <1,000 kcal/hr – handling). They are also attentive to changes in patch return rates and, consistent with marginal value expectations, switch from reef flat collecting to rocky shore harvesting when incoming tides force return rates in the mid-littoral below those available from harvesting closer to shore.

While prey choice and marginal value work well at predicting women’s time allocation and selectivity in the intertidal, they do not predict the frequency of different types of shellfish in either contemporary or prehistoric shell middens. The most important shellfish for modern-day collectors (tridacnids, Lambis) are rare in archaeological deposits, which are dominated instead by the remains of small gastropods (nerites, strombids, Trochus). The differences between ethnographic and archaeological observations result from field processing
and forager age-linked differences in foraging returns. While reef flat collecting, children walk more slowly and encounter high-ranked resources at lower rates than do adults, giving them lower overall average return rates and encouraging a broader collecting strategy that includes smaller gastropods. While both adults and children take high-ranked shellfish whenever possible, only children regularly collect the strombids and small Trochus that dominate the shell middens.

What about the rarity of large clams and conch in those deposits? Differences in field-processing costs and their implications for load utility provide an answer. The central-place foraging model anticipates the observation that Meriam foragers usually cull the shells of large tridacnids and Lambis while on the reef. Women and children commonly forage well beyond the threshold at which transporting these resources in bulk would increase the home delivery rate of edible tissue. Conversely, the smaller shellfish that children often collect in the high intertidal are always moved in bulk. Foragers rarely cross predicted field-processing thresholds while collecting these prey (Bird and Bliege Bird 1997; Bird et al. 2002).

**Hunting, sharing, and risk**

Meriam intertidal foraging also highlights clear violations of predictions that assume a goal of energetic return rate maximization. Meriam men regularly forgo the opportunity to collect shellfish in order to engage in spearfishing, and in so doing greatly reduce their efficiency in capturing energy or other macro-nutrients for themselves and their families. The costs of spearfishing are not offset by benefits gained from cooperative gender specialization in macronutrient harvesting, or by reciprocal sharing (Bliege Bird et al. 2001). Spearfishing is also risky: owing to the evasiveness of targeted prey, nearly half of all spearfishing episodes fail to produce food (Bliege Bird and Bird 2002). Similar differences in return rates and reliability associated with gender-related differences in prey choice are common among foragers world-wide (Hawkes and Bliege Bird 2002), and have been at the center of debates over prey rankings, foraging goals, and their implications for explaining variability in faunal assemblages (e.g. Broughton and Bayham 2003; Hildebrandt and McGuire 2003). Key issues are further illustrated by the results of recent ethnoarchaeological work among the Martu.

Martu occupy a large (136,000 km²) Native Title holding in Australia’s Western Desert. Much of their foraging involves traveling
by motor vehicle from permanent settlements to temporary camps closer to resource-rich patches. Prey taken in the latter are often processed, cooked, distributed, and consumed at those camps. Several foraging options are available at any given camp, each involving mutually exclusive search for different suites of resources (Bird et al. 2009). Two options include sand monitor (lizard) and hill kangaroo hunting, respectively. Sand monitors are taken in dune fields, where dense, old growth spinifex grass is fired to facilitate search for small-to-medium-sized herpetofauna – varanid lizards, skinks, and snakes (Bliege Bird et al. 2008). Foragers working the sand monitor patch forgo opportunities to hunt kangaroo in adjacent rocky ranges.

Two observations important to archaeologists emerge from studies of this activity. First, zooarchaeologists have commonly used prey body size as a proxy measure for post-encounter return rates. Where that holds, decreasing ratios of large- to small-bodied game are read to indicate density-dependent, high-ranked resource depression, leading to increased reliance on smaller game (e.g. Bayham 1979; Broughton et al. 2008). However, for Martu resources, there is no relationship between prey size and rank: for many types of small game, a hunter can expect post-encounter return rates significantly higher than those for larger game. The reason is simple: in Martu country, small game are far less likely to escape when a hunter begins to pursue them. Time invested in pursuing sand monitor or skink is associated with a failure rate of <10% per hunt; that spent going after hill kangaroo has a failure rate of 70%. A failed hill kangaroo pursuit is also more costly, given that encounters in this patch are rare. Hill kangaroo hunts fail outright, through both lack of encounters and failed pursuits, 80% of the time. Failed pursuits while sand monitor hunting are far less costly: multiple encounters in the course of single hunt are common, and a hunter rarely finishes the day empty-handed (Bird et al. 2009: Tables 1–2). Based on these and similar results from other studies (Hawkes et al. 1982: 391, 1991; O’Connell et al. 1988; Smith 1991: 230–1; Winterhalder 1981: 95–6), we have argued that archaeologists need better-justified parameters of variability in prey behavior to predict prey rank and the outcome of changing prey–predator relationships (cf. Jones et al. 2008; Lyman 2003; Stutz et al. 2009).

This brings us to the second set of results important to archaeologists. Like Meriam spearfishing, Martu kangaroo hunting is a risky way to get food. But it also yields occasional bonanzas that make for high overall average returns. If a forager’s goal is to maximize mean overall energetic return rate, sand monitor hunting is a poor choice: hunters achieve only half the average efficiency they could expect.
from hill kangaroo hunting. But even when both options are available from a dinnertime camp, many Martu choose to hunt for smaller game. Perhaps not surprisingly, there are differences in who chooses which activity. Over 70% of women’s total foraging time is spent sand monitor hunting; <2% is devoted to hill kangaroo. In contrast, only 25% of men’s foraging time is devoted to sand monitor hunting while 20% is spent on hill kangaroo.

Bliege Bird and associates (Bliege Bird and Bird 2008; Bliege Bird et al. 2009; Coddington et al. 2011) propose that two interrelated factors determine this contrast: risks of acquisition and risks of non-reciprocity in distribution. While hill kangaroo hunting offers greater overall average efficiency, its coefficient of variation is four times that of sand monitor hunting. The high rate of average efficiency in kangaroo hunting is driven by the rare successful bonanzas, and in seeking those bonanzas a forager trades off the opportunity to search for smaller but far more reliable prey. Kangaroo hunting risks are not reduced by reciprocal sharing. Kangaroo shares flow from those who have made kills to those who have not, regardless of long-term differences in labor investment, nor are successful hunters who share paid back with other foods. Given the amounts kangaroo hunters keep for themselves and dependents after sharing, they would almost always increase their foraging efficiency by sand monitor hunting, where they can control the harvest size relative to labor invested (Bird and Bliege Bird 2010).

Coddington et al. (2010) recently explored the implications of these observations for arguments about variability in ancient faunal assemblages. Underlying many classic interpretations of archaeofaunal patterns is the assumption that the proportion of large versus small prey is a function of differences in time allocated to acquiring different prey, and that increasing proportions of larger prey (higher “abundance” indices) are evidence of greater overall foraging efficiency and gendered division of labor (e.g. Broughton et al. 2008). Coddington et al. show that no matter how much time foragers spend hunting for high-variance prey (large game in general), only that allocated to more predictable items (small game in general) predicts variation in the abundance index. This is again a function of differences in risk associated with different types of subsistence activities: among Martu, successful kangaroo hunts result in a high abundance index, but investing more labor in this activity does not, simply because success is too stochastic. Why, then, would foragers sometimes choose such risky activities? Understanding circumstances in which some individuals are more or less sensitive to such risk has relevance not only for how we approach changing subsistence patterns, but also
for broader arguments about the symbolic value of behavior in general.

**Signaling theory**

Signaling theory is concerned with information exchange, and in particular with how costly “displays” transmit information critical for maintaining relationships between actors with potential conflicts of interest (Grafen 1990; Johnstone 1997; Zahavi and Zahavi 1997). It has been employed in the study of a broad suite of behaviors and their material correlates, ranging from questions about monumental architecture, craft traditions and warfare, to issues of gendered social strategies and inequality, prestige hunting, conspicuous consumption, ritual behavior, and religious commitment (e.g. Alcorta and Sosis 2005; Bliege Bird et al. 2001; Boone 2000; Galle 2010; Hawkes and Bliege Bird 2002; McGuire and Hildebrandt 2005; Neiman 1997; Roscoe 2009; Sosis and Alcorta 2003; see Bliege Bird and Smith 2005 for review). Take the problem identified above: why would some Martu hunters consistently choose activities that put the results of their labor at risk? The group may eat well if some hunt kangaroo and share it out evenly, but each individual would do better by controlling the products of his or her own labor through sand monitor hunting. Risks of non-reciprocation following successful kangaroo hunts are especially high, increasing the opportunities for others to free-ride on a hunter’s labor, making their work a public good and exacerbating conflicts between group and individual interests (Hawkes 1993).

Theoretically, all forms of exchange involve some risk, but the amount and kind of risk vary with the flow of resources. The risk of non-reciprocity is especially salient when exchange benefits flow unilaterally, from those who produce to those who are unlikely to. When actors jointly negotiate agreements with binding terms, the risk of non-reciprocity is reduced. But what about where reciprocity is “generalized” as opposed to “direct” (Sahlins 1965)? Why risk giving when it is difficult to control distribution towards those who are likely to reciprocate and away from those who are not? Such questions point towards the symbolic value of strategic interaction and remain at the core of a range of age-old problems attacked by social exchange theorists (e.g. Lévi-Strauss 1969; Mauss 1924; Veblen 1899).

Signaling theory directs our attention to the fact that risks of non-reciprocation are often necessary conditions for individuals to dem-
onstrate their trustworthiness – when trust is ensured, collective action can be realized. In fact, acts of trust and evaluations of trustworthiness can be made only in risky situations – that is, reputations of trustworthiness can be built only under those conditions where individuals have the opportunity defect from interactions that might be mutually beneficial (Cook and Rice 2006). Where there are risks of non-reciprocity, what matters is not merely the material benefit of the interaction, but what the interaction itself says about the agents. This is what is meant by the *expressive value of reciprocity* – these are the ways that the act of sharing itself communicates information about the agents (Molm et al. 2007). When reciprocity is uncertain, the act of giving can convey expressive value by communicating regard for the exchange partner and one’s willingness to invest in continuing the relationship.

The persistence of such risky behavior might seem counter-intuitive relative to the giver’s success, especially in terms of fitness. Signaling theory helps frame such questions relative to how the very costs embedded in risky acts ensure the reliability of the information conveyed. Costly signaling explains – in terms of evolutionary stable strategies – how “honest” signaling can be maintained between actors who have potential conflicts of interest, say through sharing without conditions of direct reciprocation.

Returning to the issue of social exchange: increasing the risk of non-reciprocity increases the expressive value the act of giving – that is, the risks increase the broadcast fidelity of the act. These acts are costly signals: those who can bear the costs of putting their energy on the line demonstrate their underlying qualities, motivation, and commitment. The costs ensure the honesty of the signal. Standardizing them allows for fine-grained judgment of the quality of the signal. And ritualized signals – especially when wrapped in fitness-related currencies such as energy acquisition and distribution – have an enduring impact (Alcorta and Sosis 2005).

Problems in applying signaling theory to archaeological phenomena remain, mostly because middle-range models like those described above in foraging theory have proven more difficult to develop when dealing with strategic interaction. Galle (2010) provides an illustration for how we might proceed in her analysis of variation in signal levels among men and women in eighteenth-century slave communities in the Chesapeake region of Virginia. She generates a series of predictions drawn from a model linking signaler quality to the costs and benefits of the signal, anticipating the timing of changing levels of costly display. In the model, signaling strategies specific to individuals in different circumstances (e.g. gender, status, and household
composition) should vary in amounts (discard rates) and types of costly display (fashionable buttons versus refined ceramics) with changes in audience composition (peaks in plantation market diversification) and social position within a given plantation. The results give fine-grained insight into the contexts that structured consumption strategies that served to maintain social relationships of exchange in spite of the precarious environment.

Conclusion

Human behavioral ecology is concerned with exploring the socio-ecology of individual agents and the dynamic contexts that define the cost and benefits that they encounter. While it shares a common Darwinian heritage with other evolutionary schools of thought in archaeology, it differs from them in its attention to the material correlates of individual decision making and a defining interest in functional questions about behavior. With its focus on the individual as the fundamental nexus of human relations, and a concern with complex behavioral strategies that underlie artifact patterns, it has much in common with agency-based approaches in archaeology. It differs from these especially in its use of formal models to generate theoretically situated hypotheses about potentially observable phenomena. While constraining in some ways, the use of such models provides clarity of tests and a catalyst for new types of questions and theorizing. But operationalizing these models requires actualistic data – experimental and/or ethnographic work designed to supply values for the models’ parameters and contextualize their utility. To the extent that it does this, HBE stands to contribute significantly to both social and evolutionary theory by identifying new directions for testing and refining theoretically based explanations of complex behaviors and their archaeological correlates.

References

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