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COMMENTS

ON EVOLUTIONARY ECOLOGY, SELECTIONIST ARCHAEOLOGY, AND BEHAVIORAL ARCHAEOLOGY

Jack M. Broughton and James F. O'Connell

To promote a dialogue between competing but potentially compatible approaches in American archaeology, Schiffer (1996) examined the relationships between two distinct research programs: "behavioral" archaeology and evolutionary archaeology. An approach grounded in evolutionary ecology was not included in that analysis. In this paper, we reply to Schiffer's call for dialogue by outlining the relationships, as we see them, between evolutionary ecology, selectionist archaeology, and behavioral archaeology. We conclude that evolutionary ecology holds the greatest promise as a scientific approach for the investigation of important problems in human behavioral evolution.

Intentando promover un diálogo entre dos acercamientos a la arquelogía americana—arquelogía conductual y arquelogía evolucionista—Schiffer (1996) investigó las relaciones entre estos dos programas de investigación uno en competencia del otro pero potencialmente mutuamente compatibles. No se incluyó en el análisis el acercamiento basado en la ecología evolucionista. Aquí respondemos al pedido para ese diálogo con un bosquejo—desde nuestro punto de vista—de las relaciones entre la ecología evolucionista, la arquelogía conductual, y la arquelogía seleccionista. Llegamos la conclusión de que la ecología evolucionista promete ser la más productiva en la investigación de problemas importantes de la evolución de la conducta human.

In an "explicit experiment in communication," Michael Schiffer (1996) critically examined the "common ground" and "incompatibilities" between behavioral archaeology and Dunnell's evolutionary or "selectionist" archaeology; the distinctive approach known as evolutionary ecology was mentioned only in passing. We agree that it is important to improve communication between archaeologists using different but potentially compatible approaches but, unlike Schiffer, we see evolutionary ecology—the distinctive Darwinian approach he did not discuss— as a more promising theoretical framework for research on past human behavior than either selectionist or behavioral archaeology. For these reasons, we respond to Schiffer's call for dialogue by first summarizing the theoretical framework of evolutionary ecology and an archaeological application of that approach to prehistoric California. We then provide a critical evaluation of both Dunnellian selectionism and behavioral archaeology.

Evolutionary Ecology

Evolutionary ecology may be defined as "the application of natural selection theory to the study of adaptation and biological design in an ecological setting" (Winterhalder and Smith 1992:5). It focuses, distinctively, on the interaction between evolutionary forces and ecological variables in the development of specific adaptations (Hutchinson 1965). The subset of evolutionary ecology concerned with explaining behavioral variability, and thus likely to be of special interest to archaeologists, is called *behavioral ecology* (e.g., Krebs and Davies 1978, 1984, 1991, 1997). Applications of this approach begin with a specific question about behavior; answers typically involve the use of formal optimality models. These require hypotheses about a possible fitness-related goal for the behavior of interest, the alternate strategies to achieve that goal (including constraints that limit the field of possible strategies), the costs and benefits asso-

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ciated with each strategy, and the currencies in which those costs and benefits are to be measured. Combined in model form, these hypotheses predict an optimal pattern of behavior. Comparison between predicted and observed behaviors constitutes a test. Any mismatch implies that one or more hypotheses involving the available strategies, constraints, costs and benefits of different strategies, or currencies is false.

The optimization logic used in evolutionary ecology does not require that the organism under study be consciously engaged in rational choice, nor does it deny the existence of intentionality in decision making. Evolutionary ecology assumes only that natural selection has designed organisms to behave in ways that tend to enhance fitness, whatever the proximate genetic, physiological, or cognitive mechanisms involved in that design.

It also is important to emphasize that this approach does *not* imply that selection will produce the "best imaginable" designs or behaviors (contra Gould and Lewontin 1979; Martin 1983). On the contrary, the optimization logic predicts only that selection will tend to favor the best strategy among *a defined set of alternatives possible in the context of interest*. It makes no claims about optimization in any absolute sense.

Evolutionary ecology has many strengths, three of which are especially important in this context. It is *comprehensive*, capable of generating predictions about any aspect of fitness-related behavior. It is *integrative*, providing a basis for predicting linkages between variation in one aspect of behavior with that in others. Finally, and most importantly, its predictions are *testable*; it demands explicit propositions about the determinants of behavior that can be falsified empirically.

Evolutionary ecology has been widely used as an analytic framework in biology for nearly half a century (see reviews in Parker and Maynard Smith 1990; Krebs and Davies 1978, 1984, 1991, 1997). Applications in anthropology have become increasingly common since the early 1980s (see reviews in Bettinger 1991; Borgerhoff Mulder 1991; Cronk 1991; Hawkes et al. 1997b; Kelly 1995; O'Connell 1995; Smith 1992).

Archaeologists and paleoanthropologists have also made extensive use of evolutionary ecology, beginning with early papers by Bayham (1979), Beaton (1973), and Wilmsen (1973). While the range of potential archaeological and paleoanthropological applications is vast, most research published so far has been concerned with subsistence and settlement and has entailed the use of optimal foraging models. Many studies have found close fits between predictions derived from these models and the empirical record of past human behavior (e.g., Barlow and Metcalfe 1996; Broughton 1994a, 1994b, 1995; Janetski 1997; Raab 1992; Raven 1990).

Applications of the Fine-grained Prey Model (or simply, the Prey Model) in recent research on subsistence change in California provide a simple illustration of the approach. This model was designed to predict prey choice by foragers within resource patches (Charnov 1976; MacArthur and Pianka 1966). It assumes that foragers will generally seek to maximize the net rate of energy capture, since this means either more food acquired absolutely, or more time made available to devote to other (fitness-related) activities once a "sufficient" amount of food is in hand. The critical decision variable is whether or not a given prey type should be attacked upon encounter or bypassed in the search for more profitable ("higher-ranked") items. A prey type's rank is determined by its post-encounter caloric return rate. The model predicts that the highest-ranked prey should always be attacked upon encounter, whereas lower-ranked items move into and out of the diet as function of overall foraging return rates for the patch (see Stephens and Krebs 1986).

California anthropologists (e.g., Heizer 1958; Kroeber 1925) have long emphasized the unparalleled richness and abundance of resources available to native peoples of the region. Traditional descriptions of subsistence thus have a decidedly "utopian" quality (see a recent version in Fagan 1995:253). However, certain dietary staples for many groups at contact—acorns (*Quercus, Lithocarpus*) in particular—have been shown to be very expensive to process relative to their caloric returns (Basgall 1987). In addition, acorns appear to have become increasingly important in local diets throughout the late Holocene (Basgall 1987; Wohlgemuth 1996). These data have been read to imply that overall foraging return rates declined during the late Holocene due to human population growth, and per capita and/or absolute declines in the abundances of high-ranked prey (Basgall 1987;

Bettinger 1991; Broughton 1994a, 1994b, 1995, 1997; Cohen 1981). If so, then the prey model leads one to expect that the relative importance of other low-ranked prey types, not just acorns, also should have increased across this period on a regional scale.

Logical arguments suggest and empirical data from experimental and ethnographic settings demonstrate (see Broughton 1994b for references and discussion) that, for singly-handled animal prey, post-encounter return rates are generally scaled to prey body mass. Among Holocene North American vertebrates in particular, the larger the animal, the higher the post-encounter return rate. This fact, combined with the proposition that overall foraging return rates declined in the late Holocene, leads to the prediction that low-ranked (smaller-sized) vertebrates should have become more important in human diets at this time, albeit in a trend likely characterized by considerable spatial and temporal variability.[1] Recent analyses of vertebrate faunas from a number of ecologically distinct regions of California have yielded results consistent with this general prediction (e.g., Bayham and Valente 1997; Broughton 1994a, 1994b, 1995, 1997; Colten 1995; Glassow 1996; Grayson 1991; Hildebrandt and Jones 1992; Jones and Hildebrandt 1995; Raab 1996:76; Raab et al. 1995). Similar patterns also have been found among other resource classes, especially molluscs (Botkin 1980; Broughton 1995:274-275; Chatters 1987, 1996; Raab 1992; Raab and Yatsko 1992).

Where the specific variables that drove the declines in foraging efficiency and expanding diet breadths have been empirically evaluated, *resource depression,* the reduction in prey encounter rates as a direct effect of predation (Charnov et al. 1976), has been indicated as the primary cause. The empirical evidence for resource depression has been derived from detailed analyses of the age structure of exploited vertebrate populations in these contexts since these data inform directly on harvest rates (see Broughton 1995, 1997).

With respect to patterns in archaeological vertebrate assemblages, broadening diets also should be reflected in aspects of damage morphology as measures of processing intensity, and in skeletal-part representation (in relation to utility) as an index of distant patch use and associated increases in resource transport costs. Analyses of pertinent data have so far yielded results consistent with expectations (Broughton 1995, 1997).

Several predictions involving changes in *technology* during late Holocene California also can be derived from the prey model itself given the trend documenting a decline in foraging efficiency. Specifically, it follows from the prey model that as encounters with high-ranked resources decline, foragers will at some point maximize returns by investing less time to the search for them and more time to the handling (i.e., pursuit and processing) of lower-ranked resources. At some point, as more and more resource types are added to the diet, search time may be eliminated completely and all foraging effort will be devoted to handling. It follows that when diets are relatively narrow and search time represents the primary component of foraging effort, improvements in handling efficiency will have little impact on overall foraging efficiency. However, as diets widen, and handling costs represent an ever-increasing fraction of total foraging time, improvements in handling efficiency can dramatically alter foraging returns (Hawkes and O'Connell 1992:63–64). A general prediction can be derived from this model: technological changes associated with improvements in handling efficiency should co-vary positively with evidence for widening diet breadths. Hence, in the California setting, we can predict that archaeological evidence should document technological changes associated with improved handling efficiencies across the late Holocene.

Rigorous tests of this prediction have not yet been conducted. But several well-known technological changes that occurred during the late Holocene may well reflect innovations associated with the reduction in handling costs. Such technological changes include the development of complicated technologies involved in the extraction of toxic alkaloids and tannins from acorns (Gifford 1936; Goldschmidt 1974; DuBois 1935), the proliferation and diversification of basketry and cordage industries for fish traps, nets, seines, and weirs (Kroeber and Barrett 1960), and the well-known and widespread late Holocene diminution of projectile points associated with the introduction of the bow and arrow.

Predictions involving changes in the degree of territoriality and interpersonal violence also can be derived from a consideration of evolutionary ecological models of territorial defense (Brown 1964; Dyson-Hudson and Smith 1979) coupled with the distributional characteristics of low-ranked resources that were increasingly utilized during the late Holocene of California.

Models of territorial defense attend to the ecological variables that influence the energetic costs and benefits of actively defending resource patches. One of the most critical variables influencing the energetics of resource defense involves the density of resource distributions. Specifically, the cost of defending resources that occur in dense concentrations in stationary, spatially-confined clumps is far lower than it is for more mobile dispersed resources. Hence, the degree of resource defense is predicted to be higher among foragers utilizing resources with those kind of distributional characteristics (Brown 1964; Dyson-Hudson and Smith 1979).

Many of the more important classes of lower-ranked resources that were subject to intensified use during late Holocene of California occur in dense concentrations at predictable locations (e.g., acorns, grass seeds, molluscs, slow-water and riverine fishes). It follows that expanding diet breadths in this context should have been connected with higher levels of resource defense and territoriality. Detailed archaeological tests of this prediction have not yet been conducted, however, analyses of the incidence of violent trauma have been conducted on prehistoric human skeletal material in settings such as coastal southern California. Insofar as the frequency of interpersonal violence is a proxy measure of the degree of resource defense and territoriality in these settings, it follows that skeletal evidence of such trauma should increase during the late Holocene. Extant data, in fact, show dramatic increases in interpersonal violence during the late Holocene of the southern California coast (Lambert 1993, 1994; Lambert and Walker 1991; Walker 1989).

Finally, lower foraging efficiency implies greater foraging effort required to meet minimum caloric requirements and an increased risk of malnutrition.[2] Undernourished foragers should experience higher levels of morbidity and mortality, slower growth rates, and reduced adult body size. The long-term decline in foraging efficiency documented in late Holocene California should thus be associated with higher levels of morbidity and mortality and smaller body size and stature among human consumers. The latter two predictions are strongly confirmed by recent analyses of southern California human skeletal material (Lambert 1993, 1994; Lambert and Walker 1991).[3]

In sum, several predictions involving general trends in human behavior and morphology follow from evolutionary ecological models, given the documented decline in overall foraging efficiencies and widening diet breadths. All of these predictions are eminently testable. And although systematic tests for most of these predictions have not yet been conducted, archaeological data from California document a reasonable fit between many of them and the empirical record. Finally, we emphasize that these predictions involve a disparate set of prehistoric behaviors and, while many are explicable in other terms (see for example Arnold et al. 1997; Arnold 1992; Raab 1996), approaching them from the perspective of evolutionary ecology integrates them deductively as elements of the same general phenomenon.

Dunnellian Selectionism

The selectionist program, as advocated by R.C. Dunnell (e.g., 1978, 1980, 1982, 1989, 1992, 1996), is founded explicitly on a scientific methodology. Selectionists, however, emphasize the existence of two fundamentally different kinds of science: historical and ahistorical. These, it is argued, have distinctive metaphysical positions on the nature of reality that ultimately influence their respective capacities for explaining *change*. Ahistorical sciences, like physics, chemistry, and ecology (as Dunnell defines it), adopt an *essentialist* view of reality where phenomena are conceived as a set of fixed types. Since phenomena are changeless in this framework, it is possible to construct invariant relationships or laws about them. These laws give such sciences their predictive capabilities. By contrast, historical sciences, such as evolutionary biology, adopt a *materialist* metaphysical position where phenomena are conceived as constantly in the process of becoming. Since relations between phenomena are contingency-bound, universal statements or laws attending them can *not* be made. Prediction is, thus, impossible (e.g. Dunnell 1982; O'Brien 1996a, 1996b:5). Selectionists argue that the differences between these types of sciences can be expressed "in terms of tertiary effects: 'how' versus 'why' questions" (Dunnell 1982:8).

Since a traditional goal of archaeology has been to ask "why" questions in an attempt to explain cultural change, selectionists contend that the materialist perspective of historical science is requisite. It follows that laws or predictive models of human behavior can *not* be a part of the selectionist archaeology (Dunnell 1982:8, 1992:213; O'Brien 1996b:5; O'Brien and Holland 1995a:150).

Following from the selectionist position that the units of explanation in science must be empirical and derived from theory, behavioral inferences or *reconstructions*, it is argued, are incompatible with a scientific approach to archaeology. Since behavior cannot be directly observed in the contemporary archaeological record, "the variables in the theory cannot be defined in behavioral terms" (Dunnell 1980:88). In other words, since we lack the methodology to empirically test whether or not translations from patterning in archaeological remains to past human behavior are correct, the focus should be on aspects of the record that do not require the translation process at all. The solution Dunnell (1989:45) notes,

> is simple if somewhat counter-intuitive at first. Artifacts do not "represent" or "reflect" something else that is amenable to evolutionary theory; they *are* part of the human phenotype. Consequently, artifact frequencies are explicable by the same processes as those in biology.

Those key evolutionary processes and principles that form the heart of the selectionist program are variation, transmission, and differential persistence, including selection and drift. Variation is the raw material upon which selection and drift operate; traits are transmitted and inherited through social learning. Variation in artifact form is viewed as undirected with respect to selection, playing a role analogous to mutation in genetic evolution.

Because the key sorting mechanisms—selection and drift—are seen to operate on different aspects of the hard parts of the human phenotype (i.e., artifacts), a fundamental element of the selectionist theoretical structure is the distinction between aspects of artifacts that influence the fitness of the user and those that do not. The former, termed *functional* traits, influence the energetic costs and benefits or *performance characteristics* of artifacts; hence, their temporal and spatial distributions are determined by selection. Alternate states of artifacts whose properties are not inherently linked to the fitness of the user—those that are selectively neutral—are termed *stylistic*. Since stylistic traits are not constrained by selection, their frequencies are free to vary stochastically (e.g., Dunnell 1978; O'Brien and Holland 1992:46; Jones et al. 1995:26).

To apply the selectionist approach, artifact classification systems are constructed to separate functional from stylistic traits of artifacts. Temporal and/or spatial patterns in the frequencies of defined artifact classes are then revealed in the archaeological record. Arguments are then made linking that variation with the relevant evolutionary mechanism, i.e., drift or selection. The final product is an historical narrative: a description of the historical particulars, including causal mechanisms, attending a specific set of events in a specific time and place (Jones et al. 1995:24). Braun's (1983, 1987) analysis of change in pottery during the Woodland period in eastern North America, widely cited by selectionists as an exemplary application (Neff 1992; O'Brien and Holland 1995a, 1995b), illustrates the basic structure of the approach.

The initial step in this analysis is the documentation of a long-term decline in the wall thickness of ceramic cooking vessels. Since wall thickness affects the thermal properties of the vessel, this variable is identified as functional; hence, the change can be attributed to selection. The selective agent is suggested to be the concurrent shift in dietary importance of starchy seeds. Nutrients from these resources can be assimilated more readily by human consumers if they are boiled at high temperatures for long periods of time. However, such processing places elevated thermal stresses on ceramic vessels. Since thinner vessel walls improve thermal conductivity and are more resistant to thermal shock, as determined by experimental analyses, pots with thinner walls are argued to be more *efficient* at processing those resources and were fixed by selection when they became an important component of the diet (Braun 1983, 1987; Neff 1992:173; O'Brien et al. 1994:293).

There are several fundamental contrasts between selectionist and evolutionary ecological approaches to explaining variation in the archaeological record. These involve the analytic roles of behavior, the utility of predictive modeling, the relationship between evolution and ecology, and inductive versus deductive research strategies. The positions taken by selectionists on these issues follow from several fundamental epistemological positions of the approach. They are also frequently violated in substantive applications.

In programmatic statements, selectionists reject an interest in behavior because of the alleged absence of any means of accurately reconstructing it from archaeological evidence. It then follows that theory and models constructed in behavioral terms, like those characteristic of evolutionary ecology, lack empirical sufficiency in the archaeological record and so cannot be a part of a scientific evolutionary archaeology.

This position, which holds that only directly observable phenomena can be studied within a scientific framework, is a radical form of empiricism that has been abandoned by virtually all modern sciences (Boone and Smith 1998). In fact, as both Schiffer (1996:650) and Boone and Smith (1998) have noted, selectionists actually make little effort to avoid behavioral inferences in practice. For example, Dunnell's (1989) notion of waste, a formulation founded explicitly on principles of group selection, is replete with behavioral variables. Evolutionary ecologists contend that to be anthropologically meaningful, theoretical constructs in archaeology must attend to behavior, although reconstructing it from the archaeological record will rarely be a straightforward process.

Another point of contrast between selectionism and evolutionary ecology lies in the role afforded prediction and formal modeling of ecological processes in relation to evolutionary problems. Following from their materialist position, selectionists reject the notion that regular relationships exist among phenomena, say a particular ecological variable and a form of behavior. Formal models that include deterministic rules or laws thus cannot be a part of an evolutionary archaeology. Such formulations, they suggest, are only possible in essentialist, ahistoric, sciences like physics or *ecology*, as they define it (Dunnell 1980; 1982, 1989, 1996: see also O'Brien 1996b:9). Accordingly, ecologically-oriented approaches in archaeology are often characterized as unscientific: "The kinds of 'explanations' that usually result from mechanistic application to humans of concepts such as optimal foraging strategy are not science, they're just-so stories" (O'Brien 1996a:25–26).

In fact, perceiving a fundamental dichotomy between evolution and ecology was the key revelation leading to the development of the selectionist program:

> [It] was when I rejected the "ecological approach," that I parted ways with orthodox processualism . . . and began to seek counsel in sciences, most specifically [evolutionary] biology (Dunnell 1996:ix).

Indeed, Dunnell (1996:vii–viii) attributes the current situation wherein the selectionist approach represents only a minor theme in archaeology, in part to a persistent confusion between evolutionary theory and ecological theory.

Holding such a rigid distinction raises obvious questions about how selection is assumed to operate, ignores the long-established integration of evolutionary and ecological processes in the field of evolutionary biology, and also is inconsistent with many selectionist applications. Evolution simply cannot occur in an ecological vacuum, even in the narrow materials-science contexts to which Dunnellian selectionism has so far been most frequently applied.

In evolutionary ecology, the warrant for predictive modeling is gained by the recognition that behavior has been shaped by natural selection—a mechanism that, within constraints, is assumed to construct organisms that act in ways that enhance fitness. Although behavior is viewed as inherently malleable, the broad patterns to its forms in any given ecological context are predictable owing to the nature of its design.

Rejecting both the existence of predictable regularities in the effects of selection on behavior and the utility of formal predictive modeling, selectionist applications faithful to the basic epistemological elements of the approach adopt an inductive research strategy. Historical trends in phenotypic variation are first revealed archaeologically. Arguments are then made linking that variation with fitness and selection. At this stage, ironically, advocates strongly endorse the use of optimization design analyses in building those links (e.g., Jones et al. 1995:27; O'Brien and Holland 1995b; O'Brien et al. 1994); but only to produce plausible post hoc arguments. The inductive strategy thus inevitably precludes the generation of testable predictions and limits the achievement of an "empirical standard of truth."

We note that many selectionist applications break with stated principles of the general program by constructing and testing *predictive* models based on assumptions about regularities in the operation of selection on behavior. Such applications can be grouped in two categories: 1) those based on rules or regularities among behavioral variables that are simply asserted and whose links to evolutionary theory are unstated; and 2) those that utilize optimization analyses in a predictive research strategy.

Dunnell's (1994) theoretical framework for addressing variation in subsistence illustrates the first approach. It is founded on a fundamental dichotomy between "generalized" and "specialized" subsistence systems:

> In the first case, the organism relies upon a diverse group of unrelated resources. The diet therefore is characteristically "even" and often "rich" ... Specialized systems exploit a small group of related resources, or ... exhibit diets that are characteristically highly uneven (Dunnell 1994:10).

Importantly, Dunnell (1994:11) contends that subsistence specialists (e.g., farmers) are more "efficient" and productive than generalists, and tend to change by becoming more efficient, "losing diversity over time." On the other hand, the less-efficient generalists "tend to change by increasing diet breadth." Since specialists are more efficient, they experience higher fitness, support larger populations, and outcompete generalists in the particular environment in which their targeted resource occurs. Specialist systems are unstable, however, since any environmental change that affects the productivity of the few utilized resources can lead to collapse of the system. Since generalists utilize a wider array of resources, according to Dunnell (1994:11), they are less sensitive to any given environmental perturbation.

Dunnell's subsistence model defines two polar subsistence types to which a set of assertions about efficiencies, historical trajectories, and competitive potentials are attached. In addition to violating the selectionist position on the use of behavioral variables in unit construction, this "predictive model" violates a key axiom of the approach: that invariant relations between behavioral variables can *not* exist. It also violates the notion that units and relationships between them must be logically derived from evolutionary theory. It is never specified, for example, *why* specialized systems are more energetically efficient, or even *why* energetic efficiency should be linked to fitness or evolution at all.

Ironically, several (but certainly not all) of these assertions can be deductively derived from behavioral ecology. For example, it follows directly from the prey model that, within a specific context, broadening diets should reflect declining foraging efficiencies. Since foraging theory assumes that subsistence efficiency is linked positively with fitness, it also follows that expanding diet breadth should be associated with declining overall fitness. Thus, the selectionists, who adamantly reject the utility of optimality models, have reinvented certain predictions that can be derived from those models and have used them as interpretive algorithms to explain variation in the archaeological record. Nowhere, however, are the variables and assumptions contained in the prey model that allow the derivation of such predictions described or discussed. Without making explicit the assumptions that narrower diet breadths result from high overall return rates and a consequent focus on the most highly-ranked resource types—as the prey model does—there is no logical basis to assume that specialists should exhibit, in general, higher foraging efficiencies than do generalists.

The other type of deductive selectionist application entails endorsements of key goals and epistemological positions of the approach, but then uses optimization analysis in a predictive framework to implement particular analyses. Some of these applications conform more or less closely to the general structure of behavioral ecology, yet fail to acknowledge their intellectual debt to that field (e.g., Maxwell 1995). Others explicitly frame archaeological analyses in the context of models from behavioral ecology (e.g., Graves and Ladefoged 1995; Ladefoged 1995; Larson et al. 1996).

In sum, contradictions abound between statements contained in the selectionist programmatic literature and actual archaeological applications. Particularly striking is the prescriptive rejection of behavioral inference and the use of optimization logic and the reliance on both in practice. In our view, the reason why contemporary archaeologists pay less attention to the selectionist literature than Dunnell thinks they should is not because they fail to appreciate the difference between ecology and evolution, but rather because they understand the essential relationship between the two, something many of the selectionists, including Dunnell himself, still find problematic.

Behavioral Archaeology

The stated goals of behavioral archaeology are to *reconstruct* and *explain* variation in past human behavior (see Schiffer 1972, 1976, 1983, 1987, 1995). As it happens, most of the work that might be included in this approach has been directed at the first of these goals. As critics (most recently, McGuire 1995) have frequently observed, the stimulus for this work is encapsulated in what might be called the "mantra" of the New Archaeology:

> The loss, breakage, and abandonment of implements and facilities at different locations ... leaves a "fossil" record of the actual operation of an extinct society. This fossil record may be read in the quantitatively variable spatial clusterings of formal classes of artifacts (Binford 1964:425).

Beginning in the late 1960s, Schiffer (1972) and many others undertook a systematic assessment of this proposition, primarily through programs of experimental and ethnoarchaeological research in which behavior and its archaeological consequences could be observed directly and simultaneously. In Schiffer's version of the exercise, results were often expressed in formal statements, sometimes called "laws," that described the interaction of key variables (e.g., the "McKellar Principle"; Schiffer 1976:188; see also McKellar 1983).

Although progress on the second goal of behavioral archaeology, that of *explaining* past behavior, has been limited by comparison, recent works by Schiffer and associates (e.g. Schiffer 1992, 1995; Schiffer and Skibo 1987, 1997) have begun to focus on this issue, giving special attention to artifact design. The basic expectation is that design will be "optimal" with respect to function:

> Performance characteristics usually have optimal levels or states. For example, in ... butchering game, a knife should have the ability to cut cleanly, should be easy to grasp, and should not wear out quickly.... the tinkering artisan tries out different technical choices, attempting to optimize an artifact's activity-relevant performance characteristics (Schiffer and Skibo 1987:237).

Explaining technological changes observed archaeologically involves showing how these changes represent solutions to problems posed by a shift in, say, diet, environment, or social setting. As McGuire (1995:167) observes, "In all the case studies [Schiffer] presents, the primary explanation for change rests in functional modifications to solve pragmatic problems."

There are two important points to be made about Schiffer's approach. First, behavioral archaeology has definitely had a salutary effect on efforts to reconstruct past behavior. Possibly the best example may be the challenge mounted, initially by Binford (1981) and later by Blumenschine and Marean (e.g., 1993), to the notion that Plio/Pleistocene archaeological sites like FLK "Zinj" and FxJj50 represent residential base camps, comparable to those produced by modern hunter-gatherers (Isaac 1978). This argument identifies a substantive question about past human behavior, systematically examines under modern conditions the operation of processes likely to be relevant to the formation of the archaeological record, and reconsiders conventional interpretations of that record accordingly. As a result, the notion that these sites represent near-kill accumulations of animal bones, rather than base camps to which meat and bone were moved over long distances, as originally thought, now seems fairly well-established. Important, though still largely cautionary, implications about Plio-Pleistocene hominid social organization follow accordingly.

Second, and more important, behavioral archaeology as practiced by Schiffer generally avoids identifying "big picture" problems in human prehistory, and perhaps for that reason, lacks a coherent, comprehensive theoretical framework needed to attack them. Fundamental questions about human behavioral evolution and diversity are seldom mentioned, let alone substantively addressed.

This problem is not unique to Schiffer's work, but is in fact characteristic of most of the research variously known as actualistic, behavioral, experimental, or ethno-archaeology (O'Connell 1995; Simms 1992). Consider the Binford-Blumenschine and Marean example noted above. The strength of this work lies in the demonstration that processes observable in the modern world—on-the-spot carcass disarticulation and consumption by human and non-human actors and subsequent chemical and mechanical attrition—are sufficient to account for prominent patterns in large animal body part representation and damage morphology at certain Plio/Pleistocene archaeological sites. Previous suggestions that these sites were central places, at which hominids organized along the lines of modern hunter-gatherers shared meat transported from distant kills, are falsified. Inferences about an early date for the first appearance of a sexual division of labor coupled with the practice of male provisioning of mates and offspring, lose support accordingly. This result, firmly grounded in the approach advocated by Schiffer and many others, is unambiguously important.

However, this same approach provides no basis for taking the argument about early hominid behavior, the main focus of anthropological interest here, any further. Hominids ate the meat of large game animals near kills. Now what? How can we proceed to understand key features of their economy and social organization? What is required is a general body of theory, applicable to any hominid, that produces testable hypotheses about the relationship between relevant ecological variables and specific forms of behavior and morphology. Such an approach is clearly essential where the hominid in question is morphologically and behaviorally different from any living primate, as it was at Zinj. But it is also required in *any* archaeological situation that lacks a close, clear-cut ethnographic analogue. Nothing in Schiffer's approach, or that of most other scholars with similar interests, provides the tools needed to deal with this problem.

Summary Comments

Selectionists and evolutionary ecologists clearly share some common ground. Both hold that statements about the past must be evaluated empirically and agree that Darwinian evolutionary theory provides the most promising framework for archaeological inquiry. Both also recognize the advantages of treating people in the same analytic terms as other organisms, an approach that avoids appeals to untestable, often circular, assertions about "intentions" or "culture" in attempting to account for archaeological phenomena.

Beyond these points of agreement lie major differences, especially in the analytic focus of archaeology and the means by which a Darwinian approach is best employed. In their purest form, selectionists are exclusively concerned with archaeological phenomena, reject any use of predictive modeling in dealing with them, and deny the relevance of ecology to any part of their work. Evolutionary ecologists are interested in behavior and regard the archaeological record as the primary (if problematic) source of information about how it may have varied in the past. They embrace predictive modeling warmly, and regard the appreciation of ecological context as a fundamental element of any argument about evolution.

We also recognize some basic agreement between evolutionary ecologists and behavioral archaeologists, mainly on the importance of establishing the relationship between behavior and its archaeological consequences and determining the most effective means of doing so. Unlike selectionists, both contend that this is best approached initially in the modern world, either in ethnographic or more narrowly controlled experimental settings, where behavior and its material impact can be observed simultaneously.

However, evolutionary ecologists differ sharply from Schiffer's version of behavioral archaeology in their approach to explaining variability in human behavior. Schiffer advocates the construction of "new social theory" from empirically-derived "experimental laws." Evolutionary ecologists contend that pertinent theory has been developed over the last 150 years, significantly sharpened in the last four decades, and applied effectively in the study of human behavior for the last 20 years. Certainly, new formalisms often will be required to tackle specific problems (e.g., Metcalfe and Barlow 1992), but these do not in any sense constitute "new theory"—they are simply extensions of the existing analytic framework.

We illustrated the predictive power and comprehensive scope of this approach with an example from late Holocene California, but note that many deeper questions in human evolution and behavior are being explored with this framework as well. Research involving the evolution of hominid life history characteristics represents once such example.

As we noted above, work that falls comfortably under the heading of behavioral archaeology as defined by Schiffer has been crucial to the testing and falsification of a widely favored model of hominid foraging, food sharing, and social organization. We also noted that progress on the development of alternate models has been limited, largely because of the lack of suitable predictive theory.

Recently, analysts operating from the perspective of evolutionary ecology have begun to formulate just such a model, with testable implications for the paleoanthropological and archaeological records. Working ethnographically, Hawkes and associates (1997a, 1997b) have shown that among modern low latitude hunter-gatherers, post-menopausal women have an important impact on their daughters' overall reproductive success by provisioning their weaned but still dependent grandchildren. The foods provided are those that can be procured on a regular basis and at relatively high rates by adults, but that weaned children cannot effectively handle. The practice of food sharing between mothers and grandmothers and their weaned offspring is rare among the higher primates. The pattern in humans allows offspring to be weaned earlier, and mothers to produce more of them at a faster rate, than would otherwise be expected in a primate of human size (Hawkes et al. 1998a). Hawkes et al. (1997a, 1998a) argue that the initiation of this practice at some time in human evolutionary history has been critical to the evolution of long lifespans with menopause characteristic of all human populations. They suggest that it was provoked by a specific pattern of climatic and environmental change, which led to adjustments not only in hominid life span, but also in overall body size, brain size, maturation rate, digestive anatomy, technology, foraging range, geographical distribution, and social organization (Hawkes et al. 1998b). Importantly, a wide variety of testable predictions involving Plio-Pleistocene climatic, human paleontological, and archaeological records follow directly from this model (see especially O'Connell et al. 1998). Research in this context by behavioral archaeologists has thus far been informative in strictly cautionary terms, but no more. It is a realm that the selectionist approach has yet to penetrate.

In sum, Schiffer's (1996) analysis focused on two narrowly defined research programs: Dunnell's evolutionary, or "selectionist," archaeology, and Schiffer's version of "behavioral" archaeology. Our primary objection to Schiffer's thoughtful analysis turns on the implication that "selectionism" represents the only Darwinian school in modern American archaeology worth discussing. This not only privileges a framework that has so far produced limited insight on any important problem in human evolution but, more importantly, ignores the contribution of evolutionary ecology, a paradigm with a rich history in evolutionary biology that has been applied substantively to the study of human prehistory for more than 25 years.

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Notes

[1] Insofar as spatial and temporal variability characterized the balance between human population densities and subsistence resources, overall foraging returns and diet breadths are anticipated to vary accordingly. For example, a disease-related, proto-historic population decline (Erlandson and Bartoy 1995; Preston 1996, 1997), should be associated with increasing foraging returns for surviving groups and contracting diet breadths (Broughton 1997:859). Certainly the nature of resource abundances and human population densities was dynamic and locally variable in *earlier* periods in California prehistory, producing an equally dynamic pattern in foraging behavior (see for example Erlandson 1994).

[2] Lower overall foraging returns also should place human populations at increasing risk to periodic climatic fluctuations and associated reductions in the availability of critical resources (see Raab et al. 1995; Raab and Larson 1997).

[3] We note that several indicators of morbidity, mortality, and interpersonal violence that generally increase during the late Holocene, exhibit reversals (declines) in sites dating between ~450 and 170 B.P. (Lambert 1993; Lambert and Walker 1991). This may reflect a proto-historic population decline, resurgence in foraging efficiency, and a relaxation in the degree of territoriality, violence, and nutritional stress. Finer-scale chronological control for this time period will be required to test this hypothesis.

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