



Review

The Broad Spectrum Revolution at 40: Resource diversity, intensification, and an alternative to optimal foraging explanations

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ABSTRACT

More than 40 years ago Kent Flannery coined the term *Broad Spectrum Revolution* (BSR) in reference to a broadening of the subsistence base of Late Pleistocene hunter-gatherers in the Near East that preceded and helped pave the way for the domestication of plants and animals and the emergence of agriculture. Set within a demographic density model that projected differential rates of population growth and emigration in different resource zones of the Near East, Flannery's BSR quickly became a global construct linking resource diversification and intensification to imbalances between population and environmental carrying capacity. In recent years the BSR has proven especially attractive to researchers working within an optimal foraging theory (OFT) framework in which diversification and intensification of subsistence only occurs within the context of resource depression, caused by either demographic pressure or environmental deterioration. This OFT perspective, that situates human societies in a one-way adaptive framework as they are forced to adapt to declining availability of optimal resources, however, is increasingly being called into question. Numerous examples of diversification and intensification are being documented in contexts of resource abundance shaped, in part, by deliberate human efforts at ecosystem engineering intended to promote resource productivity. An alternative approach, framed within a newer paradigm from evolutionary biology, niche construction theory (NCT), provides a more powerful explanatory framework for the BSR wherever it occurred.

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Introduction

In 1969 Kent Flannery identified a broadening in the subsistence base of Upper Paleolithic hunter–gatherers in the Near East that preceded, and set the stage, for plant and animal domestication and the emergence of agriculture (Flannery, 1969). Labeled the ‘Broad Spectrum Revolution’, the addition of a number of previously largely ignored invertebrates, fish, water fowl, and plant resources to the diet of Upper Paleolithic foragers was set within the context of a demographic density equilibrium model that involved the overflow of population from optimal resource zones into more marginal ones. Laid out in a concise two and a half pages of text, Flannery’s Broad Spectrum Revolution concept was itself revolutionary, and continues to influence research more than 40 years later.

At the time Flannery’s article appeared it was becoming clear that the Broad Spectrum Revolution was not limited to the Near East, but was a more widespread phenomenon among post-Pleistocene hunter–gatherers in many different areas of the world. The concepts of population growth and carrying capacity adjustment embedded in Flannery’s model also struck a responsive chord in an era when the impact of rapidly expanding world populations on finite resources was becoming widely recognized. As a result, in the 1970s and 1980s the Broad Spectrum Revolution became a general label for increasing diet diversity and resource intensification resulting from imbalances between population and environmental carrying capacity wherever it occurred.

In the late 1980s the Broad Spectrum Revolution was co-opted by researchers working within the tenets of optimal foraging theory, who, following OFT core principles, universally situated broad spectrum resource diversification within a context of resource depression – whether due to post-Pleistocene environmental change or human population growth. This OFT explanatory scenario for the BSR has endured into the 21st century. As more and more examples of the BSR are found in resource rich areas where no case can be made for an imbalance between population and available resources, however, it is becoming increasingly difficult to attribute diet diversity and resource intensification to resource depletion. Models that portray humans in a one-way adaptive framework in which they scramble to respond to the negative impact of deteriorating climate or unbridled population growth are being called into question as alternative perspectives emerge that portray humans as actively modifying environments to meet fundamental economic and social goals.

This paper explores the changing characterization of the Broad Spectrum Revolution over the past 40 years, tracing its journey from a nuanced regional model, to a covering law concept for imbalances between population and productivity on a global scale, to a cornerstone of optimal foraging applications anchored by assumptions of optimization and resource ranking. The shortcomings of these stress-based models are examined in light of recent counter examples of resource diversification in the context of plenty, and an alternative perspective derived from a more current evolutionary ecology paradigm, human niche construction, is proposed.

The genesis of the Broad Spectrum Revolution

Flannery’s original 1969 conceptualization of the Broad Spectrum Revolution was developed in response to a model proposed by Lewis Binford a year earlier (Binford, 1968). In this influential paper, Binford rejected explanations that attributed Mesolithic subsistence change across Europe and the Near East to human ingenuity and increasing familiarity with post-Pleistocene environments. Braidwood’s hypothesis (c.f. Braidwood, 1963; Braidwood and Willey, 1962) that agriculture was the product of human experimentation with wild resources in optimal environments was specifically targeted, characterized as an orthogenetic appeal to inherent capacities of human nature that had no explanatory power. Binford argued that changes in well-adapted Terminal Pleistocene economies could only come about if some forcing mechanism disrupted the equilibrium between human population levels on the one hand and the productive capacity of the environment and existing technology on the other. According to Binford, the late Ice Age rise in sea level resulted in increasing territorial circumscription, which forced post-Pleistocene populations to adopt more sedentary lifestyles supported by highly seasonal resources like anadromous fish and migratory waterfowl. These conditions, in turn, promoted marked heterogeneity in productivity, resulting in uneven rates of population growth in territories with different productive capacities. According to Binford, emigration of overflow population from territories of high productive potential into less productive territories raised population levels in these regions beyond their limited carrying capacity, selecting for innovations in the procurement, processing, and manipulation of resources to reestablish the equilibrium between population and productive capacity (Binford, 1968).

Focusing more specifically on the Near East, and in particular on the Taurus/Zagros arc where the majority of archaeological work on pre- and early agricultural societies had been conducted, Flannery dropped the element of sea level rise and resultant population circumscription featured in Binford’s reconstruction of events, emphasizing instead the dynamics of density equilibrium disturbance that formed the core of his model. Flannery argued that late and post-Pleistocene environments in the Near East consisted of a mosaic of more favorable “optimal” environments with higher inherent carrying capacities separated from one another by “less favorable” habitats with somewhat lower productive potential. These optimal habitats served as regional growth centers, with the periodic budding-off of daughter groups helping to keep population levels well below the region’s carrying capacity. Continued immigration into more marginal environments, however, disturbed the density equilibrium of resident groups in recipient areas, straining the region’s lower carrying capacity.

Evidence of mounting pressure on less productive areas, Flannery argued, could be seen in the increasing array of small game species (especially easily collected fish, crabs, turtles, molluscs, land snails, partridges, and migratory water fowl) found in some Upper Paleolithic assemblages beginning around 20,000 years

ago. Although botanical evidence was lacking at the time, Flannery proposed that the wider array of resources adopted in these marginal habitats also included a variety of nuts, wild cereals, and legumes. The addition of these species to the diet did not, however, signal a shift from large to small game focused hunting strategies; ungulates still provided more than 90% of the total meat supply. These newly utilized resources were, nevertheless, predictably and abundantly available, especially in certain seasons of the year, and they provided a nutritionally sound dietary supplement. Since women and children could collect many of these resources, their exploitation presented no scheduling challenges to the hunting of ungulates by men. Supplementing the more narrow range of resources utilized under low pressure conditions with this broader spectrum of small game and plants, eased imbalances between population and productivity in less favorable areas. In fact, these broader resource strategies proved so successful that they were eventually adopted even in more optimal habitats, paving the way, with their use of plant resources, ground stone tools, and storage facilities, for early cultivation.

Timing is everything

Flannery's Broad Spectrum Revolution found a very receptive audience. The impact of overpopulation on the earth's capacity to support human populations was very much on people's minds in 1969. Only a year earlier, the year Binford's density disequilibrium model appeared, biologist Paul Ehrlich published a controversial and widely read book, *The Population Bomb*, predicting mass starvation and near-term global social upheavals as the result of overpopulation (Ehrlich, 1968). Tracking the growth and impacts of human population over time, and assessing the connections between changes in subsistence and population became, in this larger context, a logical and clear-cut calling for many archaeologists. Flannery's linkage between resource diversification and demographic density, as captured in the Broad Spectrum Revolution concept, provided the field with an elegant and eminently testable way to explore the linkage between population, resource capacity, and the transition from foraging to farming.

Evidence for the BSR was subsequently sought and found in a number of different world areas. An increase in the use of marine resources in Late Upper Paleolithic Cantabria in northern Spain, for example, was seen as a classic illustration of the BSR, with resource diversification and intensification attributed to population growth in the context of unstable Late Pleistocene environments (Straus, 1977; see also Clark and Straus, 1986; Clark, 1987; Clark and Yi, 1983). Evidence of the BSR in the context of population growth was also linked to agricultural origins in Egypt (Clark, 1971; Wendorf and Schild, 1980), as well as to the broadening of subsistence economies in Late Prehistoric California without subsequent agricultural emergence (Jefferson, 1971).

While many of these attempts at documenting the connection between the BSR and population growth followed Flannery's lead by considering these processes at a regional scale of analysis, in his 1977 book *The Food Crisis in Prehistory* Mark Cohen elevated this connection to a global level (Cohen, 1977). Cohen argued that going back to earliest human origins the history of our species was marked by a recurrent cycle of population growth, territorial expansion and in-filling (Cohen, 1977, p. 85), with all areas of both the Old and New Worlds following a roughly synchronous trajectory culminating in the origin of agriculture. According to Cohen, this process began when, as a result of population induced resource pressure, humans were forced to spread out from the more optimal niches in which they first settled into less attractive habitats. Continued unbridled population growth and resultant resource pressure forced societies to adopt a broad-spectrum

consumption pattern that included aquatic resources, small game, and an increasing reliance on plants. Eventually even the most diversified broad spectrum strategies could not keep pace with population growth, and resultant resource pressure precipitated an overall decline in health that required the adoption of even more intensive practices of farming and herding.

Malthus, microeconomics, and macroevolution

In 1980 Timothy Earle developed a 'cost curve' model borrowed from microeconomic theory to provide an explanatory framework linking the BSR and population pressure (Earle, 1980). Based on projections of the unit costs of various subsistence items, the model was designed to measure the impact of the addition of new resources to the system, characterized as the costs of intensification (Earle, 1980, p. 8). The ratchet driving these cost curves and causing subsistence change was, in Earle's model, population density. Earle's cost curve model for predicting the costs and outputs was offered as a way of placing the BSR, now a "virtual worldwide phenomenon", into a systematic framework that accounted for the diversification and intensification of strategies that increased production (Earle, 1980, p. 21).

In the same edited volume in which Earle's paper appeared, Christenson, adopted a measure of food niche width derived from evolutionary ecology (c.f. Pianka, 1978) as a way of operationalizing Earle's cost-curve approach to tracking subsistence change (Christenson, 1980). Like Earle, Christenson embraced the assumption that population growth was the primary driver of increases in subsistence diversification and intensification (seen as a decrease in the efficiency of subsistence production), maintaining that "for much of human cultural evolution, population growth and declining subsistence efficiency are closely connected" (Christenson, 1980, p. 33). For Christenson, Flannery's BSR concept offered a way of characterizing these trends. He applied this approach to two case-study examples of agricultural origins – one in Mesoamerica and another in the North American Mid-west. In both cases he claimed there was a correlation between population growth and subsistence diversification and intensification.

In 1988 Richard Redding proposed a general model of subsistence change that, referencing principles featured in Earle's cost-curve and Christenson's niche width model, set Binford and Flannery's original density equilibrium model in a more explicit evolutionary ecology framework (Redding, 1988). Working once again on the general premise that changes in subsistence are correlated with population growth, he developed a predictive model for the different tactics hunter-gather groups might use to keep population levels below a region's carrying capacity: mobility, cultural practices that limit human reproduction, and the adoption of subsistence practices aimed at increasing resource productivity. Mobility was always the favored strategy. When mobility was no longer an option due to continued population growth, diversification and, later, the use of storage technology were adopted in environments where these more intensive subsistence strategies enhanced individual fitness to a greater degree than would limiting reproduction. When diversified strategies using storage were no longer sufficient to keep the wolf from the door, Redding argued that hunter-gathers basically had two options to choose from depending on the environments in which they lived. Individuals in environments with predictable yields of resources and less frequent, less severe fluctuations of annual yields, would opt for behaviors that kept human reproduction in check. Individuals in environments where yields were more susceptible to severe fluctuations, on the other hand, would not benefit from population limiting practices since there would be little way of predicting whether they were facing years of bounty when a greater number

of their offspring would survive long enough to have children of their own, or a period of scarcity that offspring might not be able to survive. In this case, continued pressure on the region's carrying capacity would make the investment in managing wild resources a more adaptive option since it would allow individuals to take advantage of good years while hedging their bets against the possibility of scarcity down the road.

Objecting to what he characterized as Redding's "selectionist" approach that set subsistence change within a gradual process of natural selection operating on the level of the individual, Michael Rosenberg instead opted for a macroevolutionary perspective that looked to a more hierarchical process of punctuated change to explain processes of resource diversification, intensification, and the origins of food production (Rosenberg, 1990; see also Zeder, 2009a, 2009b). Rosenberg's alternative "allocation model" drew loosely from an earlier paper on human territoriality by Dyson-Hudson and Smith (1978), which argued that territoriality in humans only becomes worthwhile under conditions of high resource density and predictability. Rosenberg added an element of population pressure not found in this original formulation as the primary engine of change. He argued that that in resource rich areas where the development of territoriality was favored, population growth and subsequent resource pressure would cause territorial boundaries and concepts of ownership of resources to become increasingly more strictly drawn and fiercely defended. These pressures, coupled with mounting competition with other adjacent territorially focused groups, would promote efforts at more fully and intensively utilizing resources within the territory, which, ultimately, resulted in food production. Rosenberg later used this model to examine the advent of sedentism and the process of resource diversification and intensification in the Taurus/Zagros arc where Flannery first documented the BSR and where Rosenberg himself had conducted considerable research (Rosenberg, 1998; Rosenberg and Davis, 1992; Rosenberg and Redding, 2000).

Flannery revisits the BSR

Flannery returned to the topic of post-Pleistocene resource diversification and the origins of agriculture in 1986 in a landmark book presenting the results of his work at Guila Naquitz in Oaxaca, Mexico (Flannery, 1986). Reviewing various single lever models for agricultural emergence in the Near East and Mesoamerica, Flannery once again discounted climate as a primary causal factor in this process. Instead of forcing people to adopt these strategies in order to counter climate-driven resource depression, Flannery continued to argue that the post-Pleistocene climate change and the accompanying geographical expansion of the progenitor species of later domesticates made agriculture possible.

Flannery did, however, take this opportunity to clarify and amend his position on the role of population pressure in the process of subsistence change and agricultural origins. Noting that Binford's original density equilibrium model had not found empirical support in the emerging record of agricultural origins in the two core areas of Mesoamerica and the Near East, he suggested that a more complicated and less directional approach to explaining post-Pleistocene subsistence change was called for. He was, in fact, highly critical of models that credited population pressure as a primary causal factor in agricultural origins, especially in highland Mexico where, *contra* Christenson, no credible claim could be made that pre-agricultural population levels were high enough to outstrip the environment's capacity to support them. He argued that instead of serving as a negative forcing factor driving behavioral change, population growth should be considered, as it is in biology, as an indication of species fitness, a sign that some "favorable evolutionary advance has already been made" (Flannery, 1986, p. 11).

Drawing on Hassan's study of human demographic trends (Hassan, 1981), he maintained that throughout human history environmental carrying capacity had kept well ahead of population as a "result of changes in foraging efficiency that preceded (and made possible) population growth" (Flannery, 1986, p. 12). Rather than being driven by population pressure, to Flannery the broad-spectrum diversification of the resource base seen in many areas of the world at the beginning of the Holocene was better characterized as an adaptation that had enhanced the overall fitness of post-Pleistocene foragers and made further population growth possible.

Population expansion does play a role in his revised model, however. While during most of the Pleistocene emigration was the easiest solution available to solve problems of periodic shortage or to resolve intra-group social conflicts, Flannery proposed that by about 12,000 years ago humans had spread so widely that options for further emigration were limited. Although not high enough to exceed, or even nudge, environmental carrying capacity as Cohen had projected, the density of human population across the landscape was high enough to make it "increasingly necessary for [human groups] to solve their problems on a local basis" (Flannery, 1986, p. 12; see also Hassan, 1981, pp. 206–207).

One of the primary problems people needed to deal with was uncertainty and unpredictability of the resource base, made all the more significant by the degree of environmental variation caused by Terminal Pleistocene climatic changes. The Broad Spectrum Revolution was, in this light, seen as a strategy for coping with unpredictable environmental variation in a world where mobility options were reduced due to societal barriers to emigration. Flannery's revised vision portrayed the BSR in much the same terms as Redding did 2 years later – as directed by goals of "resiliency, risk reduction, amelioration of environmental extremes, and an increase in resource predictability". But unlike Redding and others who saw the BSR as a response to resource depression caused by imbalances between population and carrying capacity, Flannery saw the conjoined goals of ameliorating uncertainty and enhancing predictability as shaping much of the record of subsistence change in prehistory "even at relatively low population densities and in relatively benign environments" (Flannery, 1986, p. 14).

Optimal foraging theory and the Broad Spectrum Revolution

Flannery's 1986 adjustments to his original conception of Broad Spectrum Revolution seem to have escaped the notice of anthropologists and archaeologists working within the framework of optimal foraging theory for whom the Broad Spectrum Revolution has become a prime example of optimal foraging in action. Originally developed in the framework of Behavioral Ecology to explain non-human foraging behavior (c.f. Emlen, 1966; MacArthur and Pianka, 1966; Pianka, 1978), the principles, core assumptions, and predictive modeling of optimal foraging theory were eagerly embraced in the early 1980s by anthropologists hoping to introduce an element of scientific rigor to their study of human foragers – both past and present (Bayham, 1979; Bettinger and Braumhoff, 1982; Hawkes et al., 1982; Hill and Hawkes, 1983; O'Connell and Hawkes, 1981; O'Connell et al., 1982; Perlman, 1980; Smith, 1983; Winterhalder, 1981, 1983a, 1983b). A core assumption of OFT is that "foragers will be selected to behave so as to maximize the net rate of return (of energy or nutrients) per unit foraging time" (Smith, 1983, p. 626); and the ultimate goal of OFT studies is identifying and documenting the cost–benefit considerations that frame the "decision rules" used by foragers and enhance the fitness of the efficient forager (Smith, 1983, p. 627).

Of special interest to anthropologists in their application of OFT to human resource diversification have been 'diet breadth' or 'prey choice' models, originally developed by MacArthur and Pianka

(1966) and Emlen (1966), that use cost–benefit principles to predict the choices a forager makes among a range of available prey types. The simplest of the various diet breadth models, and the one most commonly employed in the study resource diversification, is the ‘fine-grained’ diet breadth model. This model assumes that as a forager moves through an environment in which prey types are homogeneously distributed, prey items are encountered at random, and the decision as to whether or not to pursue a particular prey item is based on an assessment of its net return once capture and processing costs have been deducted from the resource’s overall yield. Energy (rather than nutrients) is the ‘currency’ most commonly used to measure returns in these applications. Items are added to the diet in descending rank order of net caloric return, but only if the net return of an item is higher than the average rate of return of higher-ranked items already in the diet (Hawkes and O’Connell, 1992, p. 94). Regardless of their abundance or their nutritional quality, lower ranked prey items that fall below this threshold will be ignored and only added to the diet if encounters with higher ranked items become less frequent (Hawkes et al., 1982, p. 394). Only then will it be worthwhile to invest in procuring and processing these items rather than continuing to search for the higher ranked prey (Hawkes and O’Connell, 1992; Smith, 1983). Shifts in diet breadth are, then, entirely attributable to the availability of higher ranked prey, which will always be pursued when encountered regardless of availability. When high ranking items become more abundant, diet breadth will narrow as lower ranked prey items are dropped from the diet and foraging efficiency is increased. If higher ranked prey become scarcer, on the other hand, previously ignored lower-ranked items are added, increasing diet breadth while decreasing foraging efficiency (Smith, 1983, p. 628).

The Broad Spectrum Revolution presented optimal foraging advocates an optimal target for the application of OFT models. Interestingly, Flannery’s 1986 clarifications about how goals of reducing risk and enhancing predictability could have resulted in a broadening of the resource base in the absence of resource pressure do not seem to have had much of an impression on OFT proponents eager to apply diet breadth models to the study of resource diversification, intensification, and agricultural origins. For them, the Broad Spectrum Revolution appeared to represent an excellent world-wide example of how principles of resource ranking and optimization had shaped the resource decisions of ancient foragers, resulting in sweeping transformations in subsistence strategies that would, in turn, have profound implications for the subsequent history of our species. OFT, and in particular diet-breadth models, were viewed as providing a coherent and already well-established framework in which the diversification of diet to include items like shellfish, snails, birds, nuts, and seeds (core components of Flannery’s Broad Spectrum Revolution) was, *by definition*, the result of reduced availability of higher ranked prey that lowered foraging efficiency. With such a ready-made explanation of the mechanisms driving resource diversification in hand, OFT proponents could turn to the remaining twin tasks of both documenting the downward movement through prey lists and identifying of the forces (environmental or demographic) responsible for setting these processes into motion.

OFT Applications to the Broad Spectrum Revolution

Since the early 1980s hundreds of papers have been published that apply OFT principles, especially those encapsulated in diet breadth models, to archaeological instances of resource diversification and intensification in a wide range of different environments around the globe. In the San Francisco Bay area, for example, Broughton attributed an increase in the representation of ‘lower ranking’ prey such as shellfish, sea otters, smaller fish, and acorns

in the diets of Late Holocene foragers to demographically driven declines in higher ranked resources like elk, white tailed deer and sturgeon (Broughton, 1994, 1997, 1999, 2002). Farther south along the California coast, diet breadth models have also been used to argue that human induced resource pressure on higher ranked seals and sea lions was responsible for the incorporation of more ‘expensive’ lower ranking sea otters and fish into the diets of Chumash foragers (Kennett, 2005; Porcasi et al., 2000). In a similar vein, the increased investment in maize agriculture and sedentism among Great Basin Fremont peoples at about A.D. 700–1100 was, following optimal foraging principles, attributed to decreasing yields of higher ranking wild game and plant resources (Barlow, 2002). In the Neotropics, Piperno and Pearsall (1998; see also Gremillion and Piperno, 2009, p. 616; Piperno, 2006, 2011) linked a diversification of the resource base of early Holocene foragers preceding the transition to food production in the region to post-Pleistocene climate change and the associated replacement of Pleistocene savanna environments by tropical forests dominated by smaller, solitary game and by plant communities having lower yields and high processing costs. In northern Spain, Arroyo Marin (2009) devised a simulation model based on OFT principles to demonstrate how demographically driven hunting pressure during the late glacial period caused the abandonment of more specialized and more highly mobile subsistence economies focusing on red deer and ibex in favor of more sedentary adaptations reliant on a diversified diet of lower ranked smaller bodied ungulates, birds, invertebrates, plants, fish, and shellfish. An optimal foraging take on the BSR has even made its way to Australia with the application of diet breadth principles to evaluate various hypotheses for the late appearance of seed plants and seed grinding technology in interior arid zones of the continent (Edwards and O’Connell, 1995). A similar approach has also been used to account for the shift from pinnipeds to lower ranking penguins, dogs, fish, and shags in coastal New Zealand (Nagaoka, 2002).

OFT applications in the Mediterranean Basin

The highest profile and most influential applications of foraging theory to the BSR were published in a brief span of 3 years by Mary Stiner and colleagues (Stiner, 2001; Stiner and Munro, 2002; Stiner et al., 1999, 2000). Earlier attempts at documenting the BSR in Near Eastern archaeological assemblages generated since Flannery published his influential 1969 paper had failed to detect a clear signal of broad spectrum resource diversification. Instead of a broadening of the resource base prior to agricultural emergence, one study found that pre-Neolithic diets in the Levant were uniformly broad from the Middle Paleolithic onward, with no increase in taxonomic diversity pre-staging the origins of agriculture (e.g., Edwards, 1989), while another concluded that diversity in diet actually decreased in the period leading up to agricultural emergence in the region (Horwitz, 1996). Stiner and her co-authors rejected these conclusions, maintaining that the use of Linnaean taxonomic categories to measure species richness and evenness had masked the significant impact that differences in pursuit, capture, and processing costs of various prey species could have on net energetic returns. Even prey items of roughly the same size and overall yield could have vastly different return rates when handling costs were taken into consideration. If handling costs (especially those related to the pursuit of small game) are factored in, they argued, clear signals of the Broad Spectrum Revolution and the demographic pressures behind it could be identified in the archaeological record.

Using Late Pleistocene assemblages in Italy, the southern Levant, and the Hatay coast of south central Turkey, Stiner and colleagues found that while overall taxonomic diversity remained constant, there were significant changes over time within the composition of the small game component of these assemblages –

changes which, they argued, could be directly tied to demographically driven resource pressure. In all three regions, a marked shift was detected away from slow moving game (tortoises and shell fish) in favor of fast moving game (various bird species, hares, and rabbits). Despite the roughly equivalent gross return rate of slow and fast moving small game of similar body size, following OFT principles, slower moving animals were seen as holding a higher rank in the prey list of foragers since they could be more easily and efficiently collected. Given the generally slow maturation rate of cold-blooded small game like tortoises and shell fish, these prey items are particularly susceptible to overharvesting, making high ranking, slow moving small game resources especially good proxies for demographically driven resource pressure. Capture of fast moving prey, in contrast, would be more difficult and probably could only be accomplished using special technology (i.e. bows and arrows, snares and nets) that carry higher energetic costs. Although the higher reproductive potential of warm-blooded fast prey like birds and lagomorphs made them much less vulnerable to overharvesting, the diet breadth principles Stiner and colleagues employed to interpret changes in prey diversity dictated that the shift to higher cost, less energetically efficient, fleeter small game could only occur in the context of reduced availability of more energetically efficient slow moving small game.

Thus, regardless of the quite limited contribution small game made to the overall diet, Stiner and colleagues held that shifts in the relative importance of slow vs. fast small game “serve as symptoms of threshold effects in predator–prey systems – like fume-sensitive canaries carried into coal shafts by, 19th century miners” (Stiner, 2001, p. 6995). Since these patterns seem to have occurred independently of global climate change, Stiner and colleagues further concluded that they were the outcome of “hunting pressure and demographic increase” (Stiner, 2001, p. 6995; Stiner et al., 1999, p. 192). Variations in the timing of changes in the proportions of slow and fast game were further argued to reveal not one but two revolutionary instances of demographically driven resource depression in the Mediterranean Basin – one that occurred during the Pleistocene/Holocene transition in the same time frame as Flannery’s original BSR conception, and a second, earlier shift that occurred at the beginning of the Upper Paleolithic (ca. 44,000 years ago). Like the Pleistocene/Holocene BSR, this earlier shift was also argued to be evidence of a human demographic pulse that coincided with the appearance of modern humans in the Mediterranean Basin, resulting in demographic packing and concomitant resource pressure.

Expanding on her early collaboration with Stiner, Natalie Munro has gone on to publish a remarkable series of high profile publications that track processes of resource diversification and intensification in the Epipaleolithic southern Levant (Bar-Oz and Munro, 2007; Munro, 2003, 2004a, 2004b, 2004c, 2009a, 2009b; Munro and Bar-Oz, 2005; Stutz et al., 2009). Also framed within the context of diet breadth models, Munro employed multiple indices to examine these processes as they play out on both a local and a regional scale. Ratios of slow and fast game were used to measure local scale site-occupation intensity, or degree of sedentism, with an increase in fleeter game taken as an indication of increased sedentism and more intensive exploitation of close-in resources having small home ranges. Larger game animals, distributed at much lower densities over much larger home ranges, were used to monitor regional-scale patterns of animal exploitation.

Over time both local and regional indices appeared to point to increasing resource pressure, with the strongest such indications coinciding with the establishment of Early Natufian sedentary communities during the Bølling–Allerød interstadial of peak warm and wet climatic conditions (around 14,500–13,000 years ago). This pattern was especially evident in measures of localized pressure, which showed a steady decrease in the proportion of slow game

relative to fast game peaking during the Early Natufian. The pattern of fast game prominence was reversed as tortoises once again dominate Late Natufian small game assemblages (around 13,000–11,500 years ago), coinciding with the brief pulse of cold and dry climate conditions that gripped the region during the Younger Dryas when people reverted to more mobile strategies. Munro detected another dramatic change in the composition of small game assemblages from fully sedentary Pre-Pottery Neolithic A communities established during a period of climate stabilization and a return of warmer, wetter conditions at the beginning of the Early Holocene (11,500–10,500 years ago). Assemblages from these larger, more permanent settlements yielded large quantities of small game that were comprised entirely of fast moving species, thus underscoring the sensitivity of small game exploitation to localized resource pressures induced by increases in site occupation intensity.

Though perhaps less clear-cut, Munro’s measures of regional resource pressure also seemed most strongly manifested during the Early Natufian. While large game species had been uniformly dominant in earlier Epipaleolithic assemblages, midden assemblages of Early Natufian sedentary communities were dominated by small game species. The reversal of this long standing pattern of large game dominance was considered to be an indication that reduced encounter rates with higher ranking large game had forced Early Natufian foragers to focus more intensively on smaller game animals found closer to home – evidence, it was argued, of “increased human predation pressure and associated decreases in human foraging efficiency on a regional scale” (Munro, 2004a, p. S11). The Early Natufian period also marked the nadir of a long period of decline in the proportion of larger bodied fallow deer relative to smaller bodied gazelle – another indication, Munro argued, of region-wide human induced pressure on higher ranking game that “produc[ed] a landscape dominated by gazelle and other small game species” (Munro, 2009a, p. 146). In addition, gazelle mortality patterns showed a jump in the proportion of very young juvenile animals in Early Natufian and Late Natufian assemblages (Munro, 2004a, 2009a, 2009b). Munro interpreted this as an additional sign of intensified predation on gazelle populations and an overall reduction in foraging efficiency that forced hunters to utilize less productive age classes of animals. Data on carcass butchery pointed to intensive processing of adult gazelles bones for marrow, and perhaps grease, which was also read as evidence for intensive resource utilization tied to regional scale resource pressure (Bar-Oz and Munro, 2007; Munro, 2004a; Munro and Bar-Oz, 2005).

Recent work by Stiner, Munro, and Starkovich took a similar approach to the analysis of periods of broad spectrum resource diversification in Mesolithic Greece (Starkovich, 2009; Starkovich and Stiner, 2011; Stiner and Munro, 2011). Here it was proposed that the encroachment of rising sea levels on the coastal plain, combined with human induced resource depression due to demographic packing and reduced mobility, forced occupants of Franchthi Cave to turn to less energetically efficient marine and terrestrial resources (plants, land snails, turtles, bustards, shell fish, and larger marine fishes such as bream and tunny). At the more inland site of Klissoura, which did not have ready access to coastal and marine resources, Mesolithic terrestrial resource depression in the context of demographic packing was identified on the basis of an increase in the importance of less energetically efficient small prey (e.g. hares).

Reconsidering optimal foraging theory and the Broad Spectrum Revolution

A large body of OFT inspired work now exists that invokes processes of optimization and resource ranking, triggered by either demographically or environmentally induced resource depression, to explain the adoption of broad spectrum diets and intensified

resource strategies, seemingly whenever and wherever they occurred. I will argue here, however, that it is premature to declare optimal foraging theory a “paragon of robustness” (Winterhalder, 1986, p. 372) or to demand that “archaeologists must incorporate [the] now standard approaches” of optimal foraging theory “to avoid a serious paradigm lag with modern biological principles and ensure that our theories can accommodate complex and learned human behaviors” (Piperno, 2006, p. 137). As I will show below, there are a steadily increasing number of examples of broad spectrum resource diversification that defy optimal foraging predictions and call for the consideration of alternative approaches to the explanation of subsistence change in human history.

Hallan Çemi – ground zero in the Broad Spectrum Revolution

The Taurus/Zagros arc of the Fertile Crescent provides an excellent setting in which to begin a critical reassessment of OFT explanations of the BSR, since it is here that Flannery originally recognized the Broad Spectrum Revolution. The Taurus/Zagros region has also recently drawn the attention of researchers who have played a central role the use of diet breadth foraging models to explain the BSR (Starkovich and Stiner, 2009). Excavated in the early 1990s by Michael Rosenberg, the site of Hallan Çemi, with its excellent preservation and careful recovery of faunal remains, provides an unparalleled case-study example of the BSR. A small site in the foothills of the Taurus Mountains of southeastern Turkey, Hallan Çemi was established at 11,700 years ago when the Younger Dryas climatic downturn was giving way to warmer, wetter and more stable Early Holocene conditions. Settlement survey in the region indicates that it was the first and, until it was abandoned, the only sedentary community in the drainage catchment consisting of a number of small streams that flow into the larger Batman river to the south (Peasnell, 2000). Over the course of its short, 200–300 year span of occupation, Hallan Çemi never consisted of more than 15–20 small round structures arrayed around a central activity areas that measured about 15 m in diameter. The approximately 2 tons of faunal remains recovered during Rosenberg's excavations have been under study for a number of years by Redding (Rosenberg et al., 1998; Redding, 2005), who has focused on the dense accumulation of remains excavated from the central open area of the site. More recently, Starkovich and Stiner (2009) analyzed a portion of a faunal assemblage recovered from multiple occupation levels of structures arrayed around this central area. I am currently analyzing a larger sample of the faunal assemblage previously sampled by Starkovich and Stiner.

Starkovich and Stiner straightforwardly acknowledge that the results of their analysis of the fauna from Hallan Çemi are not consistent with OFT expectations for a community of sedentary foragers (Starkovich and Stiner, 2009, p. 58). There is clear evidence, on the one hand, for the kind of resource diversification expected in a sedentary community such as at Hallan Çemi in terms of the wide range of taxa represented (e.g. seven large ungulate species, seven carnivore taxa ranging in size from large to small, four small mammal species, a number of large, medium, and small bird taxa, tortoises, lizards, fish, and shell fish). According to the core tenets of OFT, such a pattern of resource diversification only occurs when resource depression has reduced encounter rates with higher-ranking prey, both a predicted precursor for sedentarism in the OFT framework and an outcome of year round residence in a single location. Contrary to OFT expectations, however, large game predominate in the Hallan Çemi assemblage overall, and high ranking tortoises, rather than less energetically efficient fletcher small game, dominate within the small game fraction. Starkovich and Stiner also found no evidence for resource depression or intensification of animal exploitation in the mortality profiles for larger ungulate species, in the distribution of large prey skeletal elements, or in the

intensity of carcass processing. What they found instead of the expected pattern of diet diversification and intensification in the context of resource depression, is an “image of plenty... reminiscent of earlier Paleolithic conditions”, leading them to conclude that “though increasing sedentism often results in reduced supplies of large game resources, the occupants of Hallan Çemi were a small group of semi-sedentary foragers who enjoyed the luxury of high-return animal species” (Starkovich and Stiner, 2009, p. 58).

This failure of the Hallan Çemi faunal assemblage to conform to OFT expectations is made all the more interesting by the very substantial representation of plant resources and plant processing technology at the site. Large quantities of utilitarian ground stones tools were recovered at Hallan Çemi, which, given the low degree of bone fragmentation at the site, were most likely employed in plant processing rather than in marrow or grease extraction. At the same time, the site yielded a rich archaeobotanical assemblage that included a diverse array of legumes and, nuts, as well as a species of sea club rush utilized today for its oil rich seeds (Savard et al., 2006). The presence of these ‘lower rank’ plant species, especially small-seeded plants such as sea club-rush, while perhaps acceptable under OFT rules for sedentary settlements, should not be present in the absence of any evidence for resource stress in the faunal remains.

My ongoing analysis of a larger faunal sample from the same contexts at Hallan Çemi as those studied by Starkovich and Stiner support their earlier findings. There is some indication of an increase in fletcher hares and, especially, medium size bird taxa, over the course of occupation at the site – a pattern not unexpected after 200 years of sedentary affluence. Yet despite this observed increase in fletcher small game in later occupation levels, it appears that overharvesting did not cause a collapse in the local tortoise population or result in the depression of the availability of large ungulate game species. Throughout the occupation of the site, high-ranking tortoises remain a major resource in an animal economy that continues to be characterized by an emphasis on large game animals.

Starkovich and Stiner suggest that at least some of the signature of resource abundance seen among the large game component of the assemblage might be attributable to periodic feasting which provided a context for social display behaviors focusing on high utility portions of large game animals. They postulate that these practices (possibly exacerbated by demographic packing and resource depression) were separate from, and tend to mask, quotidian exploitation subsistence strategies based on “intensively processed plants and low-level ungulate exploitation” that they suggest may have been “the norm at Hallan Çemi” (Starkovich and Stiner, 2009, p. 58). This hypothesis is hard to support given that both the Starkovich and Stiner assemblage and the one I am currently studying come not from the central plaza, where feasting activities are hypothesized (Hayden, 1995; Rosenberg and Redding, 2000), but from the middens around small semi-subterranean houses at the site more likely to reflect the daily diet of Hallan Çemi residents.

In summary, the residents of Hallan Çemi do not fit the OFT scenario of a community that, due to demographic packing (or socially defined territorial circumscription) and resultant resource depression, have no other option other but to give up mobility, settle down, and adopt an increasingly less efficient reliance on a broadening array of lower return resources exploited in an increasingly intensive way. With only one small community in this drainage system and the apparent bounty of resources available to Hallan Çemi residents, there is simply no case to be made for demographically driven resource pressure at the site. What comes into clear focus instead is strong evidence for a group of people living in a sparsely occupied region who took advantage of increasing resource abundance caused by the stabilization of climate and a return of warmer and wetter conditions at the beginning of the

Early Holocene. Situating their settlement at the junction of multiple resource zones, they were able to develop and sustain a subsistence economy based on a wide range of plentiful and predictably available resources that were capable of supporting a sedentary, stable community for several hundred years. Clearly these people were operating well outside the OFT box and there is steadily increasing evidence that they were not the only ones to have done so.

An expanding list of examples that contradict diet breadth models

Hallan Çemi is not an isolated example of resource diversification that contradicts OFT expectations. An ever-growing number of case-study examples fail to conform to OFT diet breadth models, or to earlier cost/benefit approaches that cast the BSR in the context of imbalances between population and productivity. When considered together, these counter examples comprise a widespread and consistent pattern of evidence that indicates resource diversification in general occurs in the context of resource abundance, where the case for demographically, or environmentally, driven resource depression can either be categorically rejected or is ambiguous at best.

Levent Atici, for example, has recently documented another counter case among Epipaleolithic hunter-gatherers in the western Taurus Mountains. From 19,800 to 14,500 years ago, under cold and dry climatic conditions of the Terminal Pleistocene, highly mobile strategies were employed that narrowly targeted caprines and fallow deer (Atici, 2009). At about 13,900–13,700 years ago, coinciding with the increasingly warmer and wetter conditions of Bølling-Ållerød, Atici identifies a shift to more sedentary settlements coupled with a diversified subsistence strategy that combined a range of high yield, larger game animals along with a diverse array of smaller game (tortoises, hares, and a variety of bird taxa). In the absence of any evidence for population increase in this sparsely inhabited region, and under increasingly improving environmental conditions, Atici maintains that it was the “pull of more favourable conditions” and the increased “availability, accessibility, predictability, and abundance of both high- and low-yield taxa” that “foster[ed] prolonged site occupation and multi-seasonal site use in the productive Western Taurus Mountains during the later part of the Epipaleolithic” (Atici, 2009, pp. 12–13).

Moving to the western end of the Mediterranean Basin, recent research by a number of scholars has resulted in clear and compelling case studies that directly contradict the expectations of diet breadth models. Geoff Bailey, for example, has been a vocal critic for more than two decades of demographically driven models of resource intensification in northern Spain, arguing that shifting climatic conditions and fluctuations in sea level had more to do with the restructuring of the subsistence economy of Late Pleistocene foragers in this region than the dynamics of demographic disequilibria (Bailey, 1978, 1983). In a review of evidence from the Asturian shell middens, Bailey and co-author Alan Craighead (2003, 2004) contend that each of the indices used to buttress earlier arguments for declining foraging efficiency in the face of demographically driven resource pressure during the Late Pleistocene/Early Holocene transition (i.e. changes in limpet size and mortality profiles, as well as in the proportions of different limpet taxa) can be more convincingly linked to the responses of molluscan communities to dynamic climatic oscillations and habitat change as a result of sea level rise (Clark, 1971; Clark and Straus, 1983; Ortea, 1986; Straus, 1979, 1986; Straus and Clark, 1986; see replies to Bailey and Craighead in Gutiérrez-Zugasti (2011) and Straus (2004)). Far from being marginal “cultural cul-de-sacs” occupied only under conditions of resource pressure, Bailey concludes that coastal environments offered a diverse and highly productive array of abundant resources capable of supporting large and stable

human populations – not only during the Pleistocene/Holocene transition, but also for earlier foragers who exploited these resources on coastlines now submerged by sea level rise (Bailey, 2004a, 2004b; Bailey and Milner, 2002).

Recent evidence from the Iberian Peninsula that pushes the utilization of coastal and marine resources back to at least 30,000 to about 40,000 years ago supports this argument, rendering traditional models for “demographic pressure on resources forcing a dietary shift to include marine resources”, it is argued, “completely obsolete” (Bicho and Haws, 2008). In fact, it appears increasingly likely that diversified diets that included an array of coastal, marine, and terrestrial small game (i.e. rabbits) and plant resources were utilized in the Iberian Peninsula throughout the Upper Paleolithic (Barton et al., 1999; Bicho and Haws, 2008; Blasco, 2008; Blasco and Fernández Peris, 2009; Hockett and Hawes, 2009; Manne and Bicho, 2009), and quite possibly far back into the Middle Paleolithic (Aura et al., 2009; Cortés-Sánchez et al., 2011).

Similarly, Jones (2006, 2007, 2009) has recently presented evidence that calls into question scenarios that set Late Pleistocene diet diversification in the Dordogne region of southern France as a response to either environmentally (Simek and Snyder, 1988) or demographically driven (Straus, 2000) resource stress. Earlier models saw the increase in rabbit exploitation during the Pleistocene–Holocene transition as an indication of reduced foraging efficiency caused by the depletion of higher-ranking ungulate species. Jones, however, offers several lines of evidence that point to the mass-collection of rabbits – strategies targeting dense warrens of rabbits which can be relatively easily captured in quantity. Her innovative approach in effect calls for a substantial reconsideration of the OFT profile of rabbits as being a high coast/low return resource (Jones, 2006). Instead of a sign of lowered foraging efficiency in the face of resource depression, Jones sees the increase in the exploitation of rabbits, and other supposedly ‘low ranked’ resources like birds and plants, as a response to a broadening of resource availability and predictability coincident with a oscillating and eventually warming climate during the Pleistocene–Holocene transition (Jones, 2007, p. 350, 2009).

Turning to Northeast Asia, Gyoung-Ah Lee has shown that inhabitants of the Korean Peninsula adopted a stable sedentary subsistence economy based on the exploitation of diverse marine and terrestrial resources (likely including cultivated millet and legumes) within the context of increased resource abundance during the Middle Holocene (Lee, 2011). Lee’s documentation of the existence of such a broad spectrum food producing economy directly contradicts two previous models that placed the transition to agriculture 2000 years later in time, and assigned a causal role in this transition to either demographically induced resource pressure (Norton, 2000), or to environmentally driven migration and territorial circumscription (Kim, 2003, 2006). To the contrary, this and other recent research in the Korean Peninsula (Lim, 2009) clearly point to the embrace of a broad spectrum subsistence economy that included managed/domesticated plants among a wide array of wild resources during the Middle Holocene when no case can be made for resource stress due to either high population density or environmental degradation (Lee, 2011, p. S323).

A similar developmental context has been described for resource diversification in China during the Early Holocene and in Japan during the Middle Holocene (Crawford, 1992, 2011a, 2011b). In both cases, climate stabilization and increased warming coincide with the adoption of increasingly sedentary subsistence economies that utilized a wide array of nuts, fleshy fruits, annual plants (including grasses and gourds) and tubers, as well as a similarly diverse range of terrestrial and aquatic animal resources. In China, with its greater degree of habitat variation and its wider array of potentially domesticable resources, this broad spectrum resource strategy led relatively quickly to the adoption of

agricultural economies based on millet in the north and rice in the south (Crawford, 2011a, 2011b). In Japan, broad-based 'low level food production' that combined a wide array of domesticated, managed, and wild plant and animal resources, set within a context of resource abundance, persisted for millennia before intensive rice agriculture was introduced to Japan. In neither China nor Japan can these developments be linked to "a food crisis or population pressure on resources", but are instead better characterized as the result of people taking advantage of late and post-Pleistocene environmental changes by "actively changing the environment in which they were living" to produce stable and sustainable subsistence economies (Crawford, 2011a, p. S442).

Low level food producing economies of Jomon age Japan find an excellent parallel in Mid-Holocene Late Archaic populations in the eastern North America (Smith, 1986, 2006, 2009a, 2011a; Smith and Yarnell, 2009). Earlier models had set the diversification of subsistence economies and the origins of food production in this region as a response to population pressure (Christenson, 1980), as a function of pre-historic supply-side economics (Keegan and Butler, 1987), or as a means of dealing with environmental unpredictability and social stress (Jefferies, 1996). Smith has countered these external push, stress-based models with an alternative explanatory framework that links the establishment of small semi-sedentary Late Archaic communities to preceding mid-Holocene climatic and environmental changes, which in mid-latitude oak-savannah and oak-hickory forest zones "resulted in the development of meandering river valley regimes and an associated enrichment of floodplain environments" (Zeder and Smith, 2009, p. 686). Although the number of river valley settlements increases during the following Late Archaic Period, and there is associated evidence for an increased semi-permanent to permanent commitment to newly emerging resource rich valley environments, extensive settlement survey in the region finds "no compelling evidence that landscape packing of river valley corridors, demographic pressure, or resource imbalance occurred in advance of, or along with, the initial domestication of plants and the initial formation of a crop complex" (Zeder and Smith, 2009, p. 686; see also Smith and Yarnell, 2009; Smith, 2011a, 2011b, p. S482). The Riverton site in the lower Wabash River valley in southeast Illinois provides a clear example of the early development of food production economies in the absence of any evidence for population pressure or resource depression. Spaced at 10 mile intervals along the Wabash, Riverton and the two other Late Archaic "base camps" identified by Winters (1969) would each have had resource catchment zones of 500 square miles or more. Consisting of perhaps a dozen small habitation structures, Riverton yielded evidence for the cultivation of four domesticated seed crops as part of a broad-spectrum diet including a variety of nuts, fish, small prey, and white-tailed deer (Smith and Yarnell, 2009).

Finding no evidence for landscape packing, demographic pressure, or resource imbalance along the lower Wabash or other similar resource rich flood plain habitats in the region, Smith concludes that much like Early Holocene residents of Hallan Çemi in southeastern Anatolia, Late Archaic foragers in eastern North America took advantage of the abundance and diversity of resources in these environments to frame stable, increasingly sedentary subsistence economies that combined predictable and seasonally abundant nuts (hickory, walnuts, and acorns) that could be gathered and stored with little effort, with a lesser use of small seeded annuals (chenopodium, squash, sunflower and marshelder) that thrive in disturbed flood-plains. This diverse range of plant resources was complimented by an animal economy focusing on white tailed deer supplemented by a wide range of terrestrial and aquatic species (rabbits, squirrels, raccoons, turkeys, waterfowl, fish, and bivalves). According to Smith, it is these resource rich environments (marked by both high biotic-diversity and the

abundance of species with high biotic potential) that "provided the greatest opportunity for human societies to expand and enrich their overall integrated resource-management strategies" (Zeder and Smith, 2009, p. 687) – a process of 'niche construction' or 'environmental engineering' that provided the setting for the domestication of a number of indigenous plant species and the development of stable, sustainable low-level food producing economies that persisted in this region for several millennia (Smith, 2011a, 2011b; see also Brown (1985) for a similar argument against demographically driven resource pressure being a catalyst for subsistence change in Eastern North America).

Another look at the Mediterranean Basin

The many examples of alternative pathways to resource diversification discussed above make it possible to reassess the OFT-based explanation for resource diversification in the Mediterranean Basin. Adopting Munro's more restrained use of fluctuations in small game animals as a measure of localized resource pressure, the changes in the relative abundance of slow and fast small game seen among early Upper Paleolithic and Late Pleistocene/Early Holocene assemblages can alternatively be interpreted as reflecting localized changes in the intensity of site occupation in the Mediterranean Basin, and not a signal of region wide "demographic pulses" and population packing. Similarly, Bailey, Bicho, and others' recent model that attributes the restructuring of Late Pleistocene/Early Holocene resource economies in the Iberian Peninsula to environmentally driven changes in resource abundance rather than to imbalances between population and productivity can also be applied to the eastern end of the Mediterranean Basin, providing an alternative to the OFT resource depression scenario proposed by Stiner, Starkovich, and Munro to explain shifts in Mesolithic faunal assemblages in the Peloponnese Peninsula.

Munro's indices of regional resource pressure in the Late Epipaleolithic southern Levant are also open to reinterpretation. Rather than stemming from reduced encounter rates with high-ranking prey, the observed increase in the proportion of small game relative to large game that peaks in the Early Natufian period might instead be an artifact of decreased hunter-gatherer mobility. While large game would be expected to dominate in assemblages from hunting stations or short term base camps, the residential middens of sedentary foragers are more likely to be "artificially" enriched by the remains of smaller prey animals collected closer to home by women and children (Lupo, 2007, p. 174). Similarly, the shift in the relative abundance of medium sized fallow deer vs. small bodied gazelle might also be, at least in part, attributable to transport considerations; fewer skeletal elements of larger game may have been brought back to long term residential base camps than was the case with smaller ungulates more easily brought back to camp for processing as whole carcasses. Moreover, the warming of climates that Munro sees as encouraging growth in deer populations would also have been favorable for gazelle (Rosen and Rivera-Collazo, 2012), and differences in the behavior, distribution, and density of deer and gazelle, especially under conditions of reduced hunter-gatherer mobility, could well have encouraged a shift toward gazelle despite their smaller size. And while human predation can result in a downward shift in the age profile of prey populations, as Munro notes, lower age profiles are also a signature of a growing population freed from "the constraints of carrying capacity" (Munro, 2009b). Given the high biotic potential of gazelle, they may, like white-tailed deer populations in eastern North America (Smith, 2009a) have sustained population levels in the face of high human harvest levels. Finally, the absence of evidence for the relative intensity of carcass processing in earlier periods of low human population density and the absence of variation in this processing signature across the entire 8000 year span of the

Epipaleolithic (Bar-Oz and Munro, 2007; Munro and Bar-Oz, 2005), makes it impossible to determine whether carcass processing practices are indicative of resource pressure or simply the standard approach used to process gazelle carcasses in both “good” and “bad” times (see Burger et al., 2005, p. 1155).

Thus Munro's elegant, multi-pronged argument for resource depression induced dietary diversification among Late Epipaleolithic foragers in the southern Levant is open to an alternative explanation. Instead of a response to population packing and resultant resource depression, all of the patterns detected in this impressive body of work might be explained, as argued by Atici for contemporary foragers in the western Taurus, as a response to increasing resource abundance coincident with post-glacial climatic amelioration. Following this alternative interpretive path, rather than being forced by demographically induced resource pressure to adopt sedentary, broad based subsistence strategies, residents of both Early Natufian communities and the larger, longer lived Early Holocene villages established after the intervening Younger Dryas/Late Natufian climatic downturn, can be seen as hunter-gatherer groups taking advantage of an increased diversity and abundance of densely distributed predictable resources to construct diverse, stable subsistence economies capable of supporting larger aggregations of people for longer periods of time.

OFT adjustments

When the theoretical expectations of optimal foraging theory are directly contradicted by real world empirical examples, like those briefly described above, OFT modelers characteristically respond by adjusting their expectations. This expectation adjustment is considered appropriate because of the very nature of OFT models that “offer an opportunity to ‘translate’ . . . aspects of orthodox cultural ecology into a more rigorous format, making them susceptible to both logical scrutiny and empirical test” (Smith, 1983, p. 626). Models framed within the OFT paradigm “strive to be as simple as possible” so that they might “capture the essential features of an adaptive problem, and neglect . . . the myriad ancillary variables of concern in the more particularist tradition of anthropology” (Winterhalder and Smith, 2000, p. 52). While this intentionally reductionist approach may not capture the complexity of the real world, OFT models are often characterized as providing “useful starting points for hypothesis development” with “[d]eviations from model predictions [opening] up new areas of inquiry by identifying unanticipated relationships between variables” Gremillion, 1998, p. 149; see also Piperno, 2011, p. S465).

Such a ‘useful starting point’ perspective opens the door to any number of adjustments or modifications that can be invoked when empirical reality (e.g. BSR archaeological assemblages) does not conform with the core conceptual principles or central assumptions of simple diet breadth models, all the while staying safely within the overall optimization umbrella that defines the paradigm (see Winterhalder and Kennett, 2006). Accommodations made to bring OFT principles into better alignment with real world BSR examples have ranged from adjusting diet breadth model central assumptions to replacing this basic model with other models framed within the OFT rubric.

Abundance of lower ranked resources

An important core assumption of diet breadth OFT models is that the abundance of lower ranked resources plays no role in foraging decisions and that the addition of these resources to the diet depends entirely on the relative availability of higher ranked items (Bird and O'Connell, 2006, p. 147; Hawkes et al., 1982, p. 388; Hawkes and O'Connell, 1992, p. 63; Smith, 1983, p. 628;

Winterhalder and Goland, 1997, p. 128; Winterhalder and Kennett, 2006, p. 15). As amply demonstrated by the case studies described above, however, there is growing evidence that the BSR takes place in the context of increased abundance of ‘low ranking’ resources with either equivocal or no evidence for depression of higher ranking resources stemming from either population packing or environmental deterioration. Such clear and compelling contradiction of a central principle or assumption of the diet breadth model, however, has been conveniently addressed by a caveat that allows for the addition of low ranked resources into the diet without a prerequisite decline in the availability of higher ranking prey items: “any change that increases the pursuit and handling efficiency of an unharvested resource above the marginal foraging efficiency will move that item into the optimal set” (Winterhalder and Goland, 1997, pp. 128–131).

Changes that might elevate a low ranked resource into this optimal set include new harvesting or processing techniques that increase the yield of the resource per capture episode – mass-collection of densely distributed resources, for example, (i.e. Jones, 2006; Madsen and Kirkman, 1988; Madsen and Schmitt, 1998) or improved milling or cooking technologies that remove inedible or toxic components in plant resources (Winterhalder and Goland, 1997, p. 148). Morphological or physiological responses to climate change, anthropogenic disturbance, or human manipulation (both intentional or unintentional) that result in higher yields per capita or reduced processing costs also qualify as elevating factors (Gremillion and Piperno, 2009, p. 618; Piperno, 2011; Winterhalder and Goland, 1997, p. 148). The higher ‘opportunity costs’ of stopping to collect abundant lower ranking items and, in so doing, suspend the search for more profitable resources may also be offset by storage technology or scheduling practices that defer the processing of lower rank items to times of day or seasons of the year when it is not possible to engage in other foraging activities (Gremillion, 2004; Hill et al., 1987, pp. 30–31; Lupo, 2007, p. 155; Metcalfe and Barlow, 1992; Winterhalder and Goland, 1997, p. 148). Even though the abundance of low ranked resources is held to have no impact on foraging decisions, it seems that changes that result in greater spatial aggregation of lower ranked resources (i.e. increased density or abundance) may decrease search costs to the extent that previously ignored low ranking resources become an energetically worthwhile investment (Gremillion, 1998, p. 151, 2004; Gremillion and Piperno, 2009, p. 616; Layton et al., 1991, p. 258; Piperno, 2006, p. 141; Pyke, 1984, p. 531; Winterhalder and Goland, 1997, p. 148).

Currencies

Most diet breadth applications assume that energy in the form of kilocalories is the primary currency of optimization (c.f. Hawkes et al., 1982; Piperno, 2006; Smith, 1983; Stiner, 2001; Winterhalder and Kennett, 2006, p. 13; Winterhalder and Smith, 2001, p. 54). Very different expectations or predictions follow, however, if any number of different currencies are used in the cost accounting of foraging subsistence decisions (Lupo, 2007, pp. 173–174; Smith, 1983, p. 638; Winterhalder and Kennett, 2006, pp. 17–18). Hockett and Haws, for example, argue that rather than confining currency computations to net caloric returns, foragers actually take into account a wider array of nutrients important in maintaining human health when making decisions about which resources to include in their diet (Hockett and Haws, 2003, 2009). Following their ‘nutritional ecology’ paradigm, the adoption of a broad dietary mix of terrestrial, marine, and plant resources by Late Pleistocene foragers can be interpreted not as a response to demographically induced resource pressure, but rather as a highly adaptive behavior that, under conditions of climatic variability, gave foragers with a

diversified diet a competitive advantage over foragers specializing on a limited array of high energy yielding species.

Models that substitute risk avoidance for net energy return as the optimization currency also offer the potential of bringing OFT principles into closer agreement with the empirical record of broad spectrum diet diversification. Placing risk avoidance at the center of foraging decisions would also seem more in line with Flannery's 1986 BSR update that emphasizes the role of risk in resource diversification. Though recognizing the potential role of risk in shaping foraging decisions (Hill et al., 1987, pp. 23–24), early OFT applications tended to downplay the importance of risk and uncertainty, claiming that decisions shaped by risk minimizing behaviors tend to mimic those directed by goals of energy maximization (Smith, 1983, pp. 638–639; Winterhalder, 1986). The importance of risk as a currency guiding foraging decisions has, however, received greater attention in recent years (Winterhalder and Kennett, 2006, pp. 18–19, 2009, p. 646, see also Marston, 2011).

Gremillion (1996), for example, has shown that diet breadth models driven by goals of risk minimization would predict very different dietary outcomes than diet breadth models in which energy maximization is the primary currency. Using energy maximization as the currency shaping foraging decisions, foragers living in resource rich environments would, as we have seen, be predicted to opt for a relatively narrow diet, only replacing old dietary items with newer ones if the newer item offers a greater net return. Risk minimizing foragers in the same environments, in contrast, would gain more by adding novel items to the diet, hedging their bets by maintaining a broader dietary base. Conversely, while energy maximization rules dictate that foragers in resource poor environments broaden their diets to include food items of increasingly lower quality, foragers following risk minimization rules in these same resource poor environments would, Gremillion maintains, benefit most from a narrow diet composed of high ranking items, ignoring new resources unless they are highly profitable. Thus depending on the currency, broad spectrum resource diversification may happen under conditions of either "scarcity or abundance" (Gremillion, 1996, p. 189), substantially minimizing the risk that OFT principles will fail to account for the BSR under any set of circumstances.

Patches choice and central place models

Another core assumption of diet breadth models is that foragers randomly and sequentially encounter and consume prey items that are found in "the same relative proportions throughout the foraging area" (Smith, 1983, p. 628). Once again, this assumption is hard to reconcile with the empirical record of diet diversification and the BSR, which involves human foragers exploiting multiple heterogeneously distributed resource rich patches accessed from centrally located base camps that were occupied for much if not all of the year.

There are, however, two other OFT models – patch choice and central place models, that appear to offer ways of rationalizing the mismatch between diet breadth model predictions and empirical reality (Burger et al., 2005; Smith, 1983; Winterhalder and Kennett, 2006). Patch choice models predict how much time will be spent collecting and processing an array of resources that co-occur in unevenly distributed resource patches, using cost–benefit principles of marginal valuation to determine how and when foragers decide to suspend foraging in one patch and move onto another (Smith, 1983, pp. 630–633; Winterhalder and Kennett, 2006, pp. 15–16). Central place foraging models, also grounded in optimizing principles, focus on forager decisions regarding whether or not to bring resources back to a habitation site. Fall-off cost curves are employed to predict how far from home a forager is willing to go for a particular resource, and how much, or what parts, of the resource will be carried back to the home base and deposited in base camp

middens (Barlow and Heck, 2002; Cannon, 2003; Gremillion, 2006; Lupo, 2007, pp. 151–153). When applied to examples of broad spectrum resource diversification these models have helped OFT practitioners reconcile apparently contradictory patterning in the archaeological record with OFT principles.

Considerations of patchiness of resources and transport cost–benefit decisions, for example, have been used to demonstrate how acorns, despite their virtual absence from Natufian archaeological assemblages, can be used to explain plant-based resource decisions, settlement patterns, and the movements of Early Natufian foragers in the southern Levant that may at first seem to contradict OFT principles if a simple diet breadth model is employed (Barlow and Heck, 2002; Olszewski, 1993). Patch choice and central place models also have allowed for a great deal of latitude in the interpretation of base camp middens. One set of transport expectations, for example, predicts that low utility elements of large game killed some distance from a base camp will be left behind at a processing site. Under this model, base camp middens dominated by high utility elements of large game species are interpreted as indicating hunters had to travel farther from base camps due to reduced encounter rates with higher ranked resources – a sign of resource depression (see Cannon, 2003; Speth, 1991). An alternative transport model, however, predicts that high utility parts of animals encountered far from base camps are stripped of meat and left behind at processing sites (Bartram, 1993; O'Connell et al., 1988, 1990). According to the assumptions of this alternative model, a base camp midden dominated by high utility elements of large game would be taken as a sign that large game is widely available closer to camp – an indication of plenty (as seen in Starkovich and Stiner, 2009). Thus the same pattern of abundant high utility elements in a settlement midden can indicate that large game is either sparse or abundant.

Gender differences

Crediting men and women with different foraging goals is another way that the OFT paradigm can accommodate patterning in the archaeological record of broad spectrum resource diversification that contradicts predictions of an unmodified, gender-neutral diet breadth model (Alvard and Gillespie, 2004; Bird and O'Connell, 2006; Hawkes, 1993; Hawkes et al., 1991, 2001; Hill et al., 1987; Smith, 2004; Winterhalder and Kennett, 2006, p. 18; Winterhalder and Smith, 2000, p. 59). Studies among modern day foragers in Amazonia, East and South Africa, Indonesia, and Melanesia have been used to argue that while women are likely to follow simple energy maximization principles in foraging decisions geared toward provisioning their family, men are more likely to engage in foraging behaviors that garner prestige and social recognition with the ultimate goal of enhancing their mating prospects. Pursuit of this goal results in male hunting strategies that subscribe to neither energy maximization nor risk minimization goals, as men pass-up the higher net energy yields that might be gained from collecting more abundant and reliably encountered small game and higher yield plant resources in favor of pursuing large game that, due to their rareness or difficulty of capture, are likely to result in a lower net energy yield (Hawkes, 1993; Hawkes et al., 2001). It is unclear whether this higher risk strategy still serves group-level provisioning goals through collective sharing of prey (Bliege Bird, 1999; Cashdan, 1992; Hawkes et al., 1991; Kaplan et al., 2000; Lancaster and Lancaster, 1983; Marlowe, 1999), or whether this behavior has little to do with family or collective provisioning and everything to do with mating success (Hawkes, 1993; Hawkes et al., 1995; O'Connell et al., 1999, 2002), or whether male hunting strategies shift easily between these goals (Alvard and Gillespie, 2004; Smith, 2004). Regardless, differentiating between the foraging behavior of men and women offers

archaeologists an additional way of accounting for the divergence between diets that continue to emphasize high ranking game species, while also broadening their subsistence base to include an array of smaller prey and plant resources.

Kuhn and Stiner (2006), for example, reference this model when they attribute Upper Paleolithic diet diversification to the origin of gendered divisions of labor among *Homo sapiens* – a strategy that provided colonizing modern humans with a demographic advantage over indigenous Neanderthal populations which, they hypothesize, had yet to discover gender based differentiation in subsistence activities. This gendered approach has also been invoked to account for the failure of diversified diets to show the expected resource depression predicted by a uni-sex diet breadth model (Hildebrandt and McGuire, 2002; McGuire and Hildebrandt, 2005). As discussed earlier, Starkovich and Stiner (2009) also reference this line of argument to account for the unexpectedly high proportions of large game and high utility elements in the faunal assemblage from Early Holocene Hallan Çemi.

Hypothesis testing

The impressive flexibility of OFT approaches, and the rich array of addenda adjustments, modifications, and alternatives that are variously invoked when a model fails to account for empirical observations of foraging behavior, rather than being a strength, reflects instead a basic and debilitating resistance to look beyond the OFT family of models for more appropriate explanatory frameworks. Rarely, if ever, do OFT practitioners make an effort to consider various alternative perspectives that might more accurately capture the underlying rules of foraging behavior. Are foraging decisions shaped by nutrients, risk, or energy maximization goals, and how might one detect whether one or more of these currencies is in play? Should simple diet breadth models be abandoned in favor of patch-choice or central place models that more realistically match the way human foragers behave? How do the gender specific foraging goals of men and women come together in framing subsistence economies and how can the impact of these shaping goals be detected in the range of foods that make up that economy – especially when using archaeological assemblages? Rather than addressing these issues, OFT modeling modification efforts appear more focused on demonstrating the chameleon nature of foraging theory: that it is capable of addressing any discrepancy between observed and predicted results without ever violating the central assumption of optimality that lies at its core. If all else fails, one can always blame the data for not being up to the rigorous standards of optimal foraging models designed to predict the individual decisions of individual foragers at particular moments in time as they weigh the energetic returns of an array of possible prey items. This is a particularly attractive and frequently employed rationalization for the failings of OFT predictions to match observations when using time averaged archaeological data which represents the decisions of hundreds of foragers over hundreds of years or more (Bettinger, 1983, p. 640; Smith, 2006; Winterhalder and Smith, 2000, p. 57).

Early applications of foraging theory to human foragers emphasized the need to rigorously test OFT models and the assumptions behind them.

... it is important to keep in mind that foraging theory is not a finished product or dogma, but very much an evolving entity: foraging theorists are continually testing and revising their models and hypotheses and are generally well aware of the problems inherent in any analysis of complex, dynamic phenomena in terms of simplified and abstract models. ... It is also important to remember that until simple models of foraging strategy have been empirically tested, we really don't know to

what extent they might succeed in accounting for observed patterns – regardless of any dogmatic statements to the contrary. (Smith, 1983, pp. 637–638)

Over the past two decades, however, this characterization of OFT has changed dramatically, so that by 2006 we learn that:

Models themselves are never tested. It is the situation-specific assumptions (hypotheses) that applications require that are at risk in any analysis. ... Modeled as a series of contingent relationships, these assumptions enable an analyst to generate predictions about behavior under the circumstances so stipulated. Mismatches between predicated and observed (or archaeologically inferred) behavior imply either that one or more of the specific hypotheses about goals, decision variables trade-off, currencies, and constraints are wrong and in need of reassessment, or that the model itself is in some way inappropriate to the behavioral question being addressed. (Bird and O'Connell, 2006, p. 146)

Thus over time, and regardless of protestations to the contrary (Piperno, 2011, p. S465), OFT models have been transformed from a 'starting point' to established principles that are inviolate and immune to testing. As a result, those working within the paradigm see no need to consider that an alternative explanatory framework outside of the general optimizing umbrella might actually provide a better fit with observed reality.

This reluctance to consider alternatives to an OFT perspective was recognized in biology nearly three decades ago. In a critical review of optimal foraging theory written in the 1980s, Pyke notes a tendency toward the "tautological" within OFT applications such that:

...when predictions and observations do not agree, it is not clear which assumptions are at fault. ... Authors have tended to rationalize such discrepancies between observed and predicated results by attributing them to faulty assumptions regarding constraints or the currency of fitness rather than those assumptions about the heritability of behavior. ... If the most realistic currency and constraints assumptions and the most careful development of theory do not lead to reasonably close agreement between observed and predicted results a reasonable fraction of the time, then optimal foraging theory should properly be judged as not very useful. ... (Pyke, 1984, pp. 525–526).

Particularly troubling to Pyke at the time was the view held by some biologists working with an OFT framework that:

... there are already so many studies supporting ... [optimal foraging theory's] predictions that it can be regarded as well-established and verified: hence there is no need for further development and tests of its predictions. However, the large and growing number of studies in which some discrepancy has been found between the predictions of optimal foraging theory and observations... mitigates strongly against this view." (Pyke, 1984, p. 527)

It seems, then, that more than 20 years before Piperno declared OFT a "largely unquestioned premise in nonhuman animal studies" (Piperno, 2011, p. S465), biologists were, in fact, harshly critical both of the failure of OFT principles to account for nonhuman foraging behaviors and of the resistance of OFT practitioners to even consider the possibility that optimality may not direct these behaviors.

While proponents of OFT claim that their approach is testable, ... the allegation that optimality is an unfalsifiable article of faith is perhaps the most persistent criticism leveled at the

optimality approach (see Gould and Lewontin, 1979; Lewontin, 1979a, 1979b; Brady, 1982; Mazur, 1983). The problem arises whenever there is a discrepancy between the predictions made by a specific model and observations. In this situation it is difficult to know whether the approach is fundamentally wrong or whether a more specific assumption is inaccurate. Since an endless number of highly plausible *ad hoc* modifications are possible the hypothesis of optimality need never be rejected. (Gray, 1987, p. 81)

Just as with non-human foragers, then, there is a real need for those studying human foraging behavior to consider that factors other than optimality may be driving these behaviors (Blundell, 1983, p. 642). There are, in fact, several key features of the Broad Spectrum Revolution that simply cannot be reconciled with foraging theory, and that speak to the need to consider alternative explanatory frameworks that lay outside of optimality principles at the core of the OFT paradigm.

Fundamental flaws in optimal foraging explanations of the Broad Spectrum Revolution

As flexible as OFT may be, there are five core aspects of the BSR that cannot be accounted for by the download of any of the various available OFT patches. In each case foraging theory carries initial assumptions or principles that predetermine explanations for these five basic features of the BSR. If these initial OFT assumptions are accepted, then the BSR must occur in the context of resource depression and lowered foraging efficiency resulting from an imbalance between carrying capacity and population. If these assumptions are shown not to be viable, then the basic utility of foraging theory as providing an explanatory framework for the BSR is called into question.

Mobility

Within the OFT paradigm mobility is a fundamental adaptive feature of foraging economies. Mobility is sacrificed only as a last resort, when movement is no longer an option – usually due to population packing and a resultant depression of preferred high ranking resources (Stiner et al., 1999, p. 193, 2000, p. 58; Stutz et al., 2009, p. 302). Once this initial assumption regarding mobility is adopted, it logically follows that any reduction in mobility, and in particular sedentism – the occupation of central places or base camps through a significant portion of an annual cycle, involves considerable costs in terms of reduced foraging efficiency as foragers intensify resource strategies that focus on less profitable, more costly resources (Munro, 2004, p. S20; Stiner et al., 1999, p. 193). Since broad spectrum diet diversification almost always coincides with a reduction in residential mobility, the OFT linkage between loss of mobility and lowered foraging efficiency automatically situates the BSR within a context of resource stress.

This perspective on mobility appears to originate with Lewis Binford (1980). Binford argued that mobility is a critical strategy used by hunter-gatherers to gather information about resource availability used as a hedge against scarcity arising from seasonal or year-to-year fluctuations. While the size of the territories and the nature of forager movements vary in different environments, Binford maintained that even in richer resource areas where camps are moved less frequently, mobility will be given up only when foragers no longer have room to move – a projected “packing threshold” of 9.098 people per 100 km² (Binford, 1999, 2001).

Robert Kelly (1995) is also often cited in support of the linkage between reduced mobility, population packing, and resource depression (e.g. Stutz et al., 2009, p. 302). Although Kelly questions the value of mobility in information gathering where resources are

constant and reliable (Kelly, 1995, p. 15), he still maintains that mobility is required to keep daily return rates as high as possible.

...in an environment of homogeneously distributed resources, the only apparent reason hunter-gatherers would not move is if there is no place to move to – that is, if population density rises to the saturation point, packing foraging groups into the region. (Kelly, 1995, p. 151)

Kelly goes on to stipulate, however, that in environments where resources are not homogeneously distributed, but are instead concentrated in resource rich patches, the higher costs of moving camp between distant patches might encourage foragers to reduce mobility and engage more in logistical forays from a residential base that is occupied for a longer period of time. In this way: “sedentism can be the product of local abundance in the context of regional scarcity” (Kelly, 1995, p. 152).

A landmark paper by Dyson-Hudson and Smith (1978) looks more deeply at the impact of resource density and predictability on residential mobility and territoriality among human foragers, and provides a compelling alternative to the OFT perspective that sees reduced mobility as an indication of population packing and resource stress. Borrowing from studies of animal territoriality (e.g. Hamilton et al., 1976; Wilson, 1975; Wolf and Hainsworth, 1971), Dyson-Hudson and Smith argue that regions of unpredictable resource availability are most efficiently exploited by foraging strategies that emphasize mobility. Communal sharing of information is expected when resources are unpredictable but densely distributed, while a high degree of forager dispersion can be anticipated when resources are both unpredictable and scarce. Regions where resources are scarce but predictable, according to this model, are best exploited by groups living at low population densities that travel over relatively large home ranges with some degree of overlap between the ranges of different groups within the region. However, where resources are both predictable (in terms of location and timing) and abundant (over a broad area, within patches, or seasonally) the most efficient foraging strategy is to limit mobility and to defend the territories in which these resources can be found.

Following the Dyson-Hudson Smith model, mobility, distances traveled, and dispersion of forager populations all increase with resource scarcity and unpredictability. It is significant to note in this regard that most modern mobile foragers live within environments that fall into Dyson-Hudson and Smith's first three categories: where resources are scarce and unpredictable; abundant but unpredictable; or scarce but predictable. Rather than any of these three categories, however, it is the last situation in the Dyson-Hudson and Smith model, where resources are both abundant and predictable and where more sedentary territorial defense strategies are predicted, that best describes the conditions under which the broad spectrum resource diversification emerged, whether among Late Pleistocene foragers of the Mediterranean Basin, Mid-Holocene populations of eastern North America or northeast Asia, or among the foragers living in large stable villages in resource rich areas in coastal California and the northwest coast of North America up into modern times. The Dyson-Hudson and Smith model (co-authored by Eric Smith one of the first to apply foraging theory to human foragers) offers an alternative to more recent OFT approaches that attribute the reduction of mobility that coincides with broad spectrum resource diversification to population packing and stress. It provides a framework for understanding how reduced mobility can come about within the context of resource abundance and predictability in the absence of population pressure. And while such resource rich areas encourage population aggregation and growth, it is the abundance of resources and, above all, their predictability, not demographic dynamics, that is key in the establishment of more sedentary populations supported

by broad spectrum subsistence economies within these regions (Smith, in press-a).

Intensification

OFT explanations of the Broad Spectrum Revolution are also based on initial faulty assumptions regarding the nature and costs of resource intensification. When the BSR is viewed through an OFT lens, resource diversification is equated with resource intensification, which in turn is seen as an indication of lowered foraging efficiency.

Diversification of the human ... diet is ... an effective measure of intensification. (Munro and Atici, 2009, p. 2)

Intensification... generally refers to a decrease in the cost/benefit ratio invested in human procurement... (Munro and Atici, 2009, p. 2)

There are several problems with this $D = I = E$ linkage between diversification, intensification, and reduced foraging efficiency.

First, a simple increase in the number of taxa utilized need not automatically be seen as an indication of intensification, especially if the species added to the diet are of the same general rank as prey already exploited (Broughton and Grayson, 1993). Similar amounts of energy might be extracted with no increase in time spent pursuing or processing this broader array of prey species, and with no loss of foraging efficiency. Moreover, as Grayson and Cannon (1999) have noted, increasing exploitation of low-ranking prey does not necessarily provide clear cut evidence of resource depression, intensification, or reduced foraging efficiency, especially if the encounter rate of higher ranked prey remains the same. Conversely, it is entirely possible to have intensification without diet diversification. In fact, a specialized subsistence economy focused on the exploitation of a narrow range of species might be even more likely to show a greater level of intensification in resource procurement and processing than a broadly based one (Munro and Atici, 2009, p. 2).

But perhaps more troubling, and even more open to question, is the OFT definitional equation that links intensification with reduced foraging efficiency. Lupo, for example, defines intensification as a: “process whereby total productivity per unit of land is increased, but at increasing costs to the individual resulting in a decline in foraging efficiency” (Lupo, 2007, p. 160). Butler and Campbell similarly equate intensification with decreasing foraging efficiency: “wherein the total productivity of a unit of land is increased but individuals work harder (spend more energy, per unit time) in the process” (Butler and Campbell, 2004, p. 336). Munro holds that intensification, defined as “an increase in the amount of energy extracted from a given environment per unit time”, is “synonymous with a reduction in foraging efficiency – more energy invested for each unit of energy returned” (Munro, 2009a, p. 141, Munro, 2009b, p. 2).

Once reduced foraging efficiency is imbedded in the definition of intensification, any evidence of intensification must be seen as an indication of lowered foraging efficiency. Following this synonymy, any procurement strategy or new technology designed to increase yield, either in terms of the capture/collection of resources or in their processing, automatically carries with it the assumption that these strategies incur a significant increase in costs. And while these costs might eventually be recouped by the higher yields they afford, their adoption is nonetheless taken as an indication of lowered cost/benefit ratios that is “associated with declines in subsistence efficiency” (Bird and O’Connell, 2006, p. 153, original emphasis, see also Bettinger et al., 2006; Bright et al., 2002; Elston and Brantingham, 2002; Kuhn and Stiner, 2001; Lupo and Schmitt, 2002; Munro, 2009, p. 147; Stiner, 2001, p. 6993; Ugan et al., 2003).

There is, however, no reason to assume that resource intensification automatically entails a net decline in energy yield relative to energy input, or even that it involves a greater investment in time per unit of energy extracted. A less prejudicial and more accurate definition would characterize intensification as an effort to increase the amount of energy extracted from a resource item or from a group of items found in a unit area. Whether or not the strategies (or technologies) employed to this end succeed in producing more (or less) energy than is devoted to procurement and processing depends on how effective these strategies are; it should not be presumed that these strategies will, by definition, result in a net reduction in return compared to less intensive strategies. Nor can it be assumed that intensification automatically entails a lowering in the ratio of energy yield per unit of time. The amount of time dedicated to strategies directed at enhancing yield per resource item or area is, once again, an aspect of resource intensification that is open to empirical observation. It may be that the energy to time ratio will move in the direction of lowered efficiency. But it may also be that the yields afforded in the time devoted to intensified extraction and processing techniques are more favorable when compared to time spent pursuing more extensive strategies that may fail to yield as high returns. Imbedding these concepts into the definition of resource intensification means that intensification can only occur within the context of declining foraging efficiency associated with resource depression. Freeing this concept from these burdensome assumptions allows us to consider the resource intensification that often accompanies broad spectrum resource diversification from a very different perspective.

Resource depression

OFT diet breadth, patch-choice, and central-place models used to account for the BSR are all based on optimizing mandates in which diet breadth is controlled by the availability of higher ranked resources (Hawkes and O’Connell, 1992; Hawkes et al., 1982; Smith, 1983, Winterhalder and Kennett, 2006). A broadening of the diet to include purportedly low ranked food items like small game, invertebrates, and small seeded plants like cereals and pulses (core constituents of broad spectrum subsistence economies) can, under this mandate, only occur in the context of reduced encounter rates with higher ranked food items. In this way a broad spectrum diet, resource depression, and a decrease in foraging efficiency are all inextricably linked together, imbedded within the foundational assumptions of the OFT world view. And even though, as discussed above, OFT practitioners afford themselves some wiggle room by the application of various caveats and addenda to these core prescriptive assumptions, virtually all applications of optimal foraging theory to broad spectrum diet diversification take for granted that the BSR occurred within the context of some form of pressure on higher ranked resources that forced people to turn to previously ignored lower yield resources, resulting in an overall lowering of foraging efficiency. Following the same $D=I=E$ reasoning that equates diet diversification with intensification with reduced efficiency, an increase in diet breadth to include smaller prey items and high processing cost plants is *ipso facto* evidence for reduced encounter rates with higher ranking resources caused by some form of resource depression. What remains to be demonstrated is the cause or causes of resource depression.

The most commonly identified cause in OFT resource depression scenarios is an imbalance between population and a region’s carrying capacity caused by demographic expansion and population packing. In seeking evidence for population pressure OFT practitioners tend to fall back on the same tautological approach that uses diversification as proxy evidence for both intensification and resource depression. Loss of mobility, intensification of subsistence

practices, and diversification of diet are all held to be proxy indicators of population pressure which, to complete the circle, is held to cause loss of mobility, intensification, and diversification (c.f. Binford, 2001; Rosenberg, 1998, p. 663; Stiner et al., 1999). Tidy yes, but logically flawed.

It is admittedly difficult to directly measure either population density or regional productive capacity with archaeological and paleo-environmental data. But before population pressure can be invoked as a cause of resource depression and resultant diet diversification, some measure of population is needed that is independent of the very things population pressure is hypothesized to cause. Using more appropriate, though admittedly limited, population proxies (e.g. the number, size, and distribution of sites and the density and duration of their occupation), it is becoming increasingly difficult to make a case for population packing in a number of the case study examples of the BSR. This is certainly true of the Eastern Taurus/Zagros arc, Eastern North America, and the Korean Peninsula examples of broad spectrum diet diversification where population densities were clearly low and where there is categorically no evidence of population packing. And while there is some evidence that diet diversification coincided with increasing population in the southern Levant during the Late Pleistocene Early Natufian and especially during the Early Holocene PPNA, in both periods improved environmental conditions would have raised regional carrying capacity, making it hard to convincingly argue for a region-wide imbalance between population and productivity.

As in the southern Levant, most examples of broad spectrum diet diversification took place in the context of generally improving climate and associated increases in regional biotic diversity and potential, which is likely why environmental variables are rarely invoked in most OFT explanatory scenarios for the BSR. Since by definition the BSR represents a lowering of foraging efficiency, there can, in the OFT mind set, be no causal connection between environmental conditions that result in an increase of a region's carrying capacity and resource strategies indicative of resource depression. Some other factor must at play (i.e. population pressure) to account for the resource depression evidenced by diet diversification. Climate warming and associated sea level rise are, it is true, are sometimes held to have contributed to broad spectrum diets, as in OFT based explanatory scenarios for the BSR in both the western and eastern Mediterranean Basin (Clark and Straus, 1986; Starkovich, 2009; Starkovich and Stiner, 2011; Stiner and Munro, 2011) and in southern France (Simek and Snyder, 1988). But in these as in most other OFT explanatory scenarios, environmental factors, if considered relevant at all, are generally held to be secondary to population growth and packing as proximate causes of resource depression and associated diet diversification.

The most prominent exception to the general exclusion of environment as a driver of the BSR can be found in OFT grounded explanations of broad spectrum diet diversification in the Early Holocene Neotropics, where the sparse and ephemeral distribution human settlement over vast areas makes "human demographic pressure on resources an improbable factor in economic change" (Piperno, 2006, p. 148). The shift from the cold and dry glacial conditions of the Late and Terminal Pleistocene to the warmer and wetter Early Holocene climates, which in other areas of the world is thought to have enhanced carrying capacity, is held in the Neotropics to have resulted in an overall lowering of biotic potential. Based on paleo-ecological data (Burbridge et al., 2004; Piperno et al., 2007), Piperno and Pearsall have hypothesized that many parts of the Neotropics during the late glacial period were covered by a savanna/thorny scrub vegetation, that "probably contained dense associations of dry-land cacti and legumes" of "high-quality and low cost edible biomass, with little processing costs" (Piperno, 2006, p. 151; emphasis added). These open savanna environments are furthermore posited to have served as home

for a number of "big, herbivorous game animals roaming in some abundance" (Piperno and Pearsall, 1998, p. 100). With warmer temperatures and increased rainfall in the Early Holocene, according to this scenario, these open savanna environments were replaced by expanding tropical forests dominated by smaller, more dispersed, often arboreal, fauna and by plants with both lower yields and higher processing costs – a shift in environments hypothesized to "immediately force subsistence options in the direction of lower ranked resources, and substantially broaden the diet breadth" (Piperno, 2006, p. 152; see also Gremillion and Piperno, 2009, p. 616; Piperno, 2011, p. S465; Piperno and Pearsall, 1998). Lacking archaeological data that would allow for a comparison of Late and Terminal Pleistocene Neotropical subsistence strategies with those of the ensuing Early Holocene, it is difficult to directly assess the validity of this hypothetical scenario. At the same time, ethnographic data from the Neotropics and elsewhere seriously undercuts the Piperno model in that it indicates an inverse relationship between prey size and success rates (Hawkes et al., 2001) and documents foraging strategies based on small game and other gathered Neotropical resources that are, in effect, more efficient than those based on large prey (Hawkes, 1993; Hill et al., 1987).

Whether environment or population packing is featured as the primary driver of resource depression in these scenarios, they are all based on an axiomatic assumption that a broad spectrum diet which includes purportedly lower ranking resources is a less optimal strategy than a diet more narrowly focused on higher ranking resources and that an increase in diet breadth will only be adopted in the face of declining availability of preferred higher rank resources. An alternative view that questions whether broad spectrum diet diversification does in fact represent a reduction in efficiency and, perhaps more significantly, that questions whether considerations of cost and optimization of returns really do drive foraging decisions allows us to look at the BSR in a whole new light.

Optimality

Fundamental to an optimal foraging approach is the assumption that foraging decisions (in both human and non-human foragers) are directed toward an optimal outcome that "yields the greatest possible benefit for the individual forager's survival and reproductive success" (Smith, 1983, p. 626). As we have seen, most applications of foraging theory to the study of broad spectrum resource diversification assume that foraging decisions are targeted at maximizing energy yields. In making these decisions foragers are considered to take into account not only the cost/benefit outcomes of their choice of whether or not to pursue and capture a prey item, but that they also make optimizing decisions about how far they are willing to go to obtain the item, what bits of the item they are willing to transport back to a home base, and the tools and techniques they will use to procure and process the item. Any choice that fails to conform to this strict accountant mentality – that fails to realize some theoretical maximum energy return – must be seen as an indication that there is some impediment preventing the forager from making the optimal choice. Following this optimality principle, foragers will only add small game or small seeded plants to their diet if alternative resources with greater net yields are either no longer available or, at least, not as plentiful. As noted above, there is no consensus that energy is the appropriate currency for analyzing optimizing behaviors among OFT practitioners. Indeed, very different outcomes attain when foraging models use different currencies – some of which seem a better match with various case study examples of the BSR. But regardless of the choice of currency, foraging theory rests on the principle that foragers will optimize for something (energy, nutrients, sex, status), and that they

will not settle for a sub-optimal return unless compelled to do so by some obstacle that prevents them from making a more optimal choice.

The assumption of optimization has long been recognized as problematic by biologists evaluating the efficacy of optimal foraging theory in explaining the behavior of non-human foragers. Russell Gray, for example, questions the central assumption that “the maximization of ‘fitness’ will result in the maximization of foraging efficiency” (Gray, 1987, p. 72), pointing to numerous empirical examples in the study of non-human foragers where this core principle did not hold (i.e. Sih, 1982; Porter et al., 1983). The linkage between fitness and optimizing behaviors is even more tenuous in humans, which may be why it is rarely directly addressed (only simply assumed) in OFT applications to human foraging behavior.

When this linkage between fitness and optimizing behaviors is considered, OFT theorists offer a wide range of often conflicting arguments to explain how broad spectrum strategies based on lower ranking small prey and plants provided a competitive advantage to groups that embrace these strategies over those who focused in a more specialized way on high ranking resources. Hawkes and O’Connell, for example, argue that since “foragers who maximize nutrient returns enjoy greater reproductive success than those who do not”, increases in diet breadth that “result from reduced foraging return rates” (like those predicted for broad spectrum subsistence strategies) should “lead to declines in population growth rates” (Hawkes and O’Connell, 1992, p. 64, emphasis original). From this perspective higher growth rates can only be realized through increases in handling efficiency that come about as that come about as a response to the diminished returns of a broader diet. Winterhalder and Goland (1997), on the other hand, disagree, maintaining that increases in resource density and recovery potential or sustainability are key factors in promoting population growth thereby conferring adaptive advantage on groups that focus on these resources over those who do not. Kuhn and Stiner take a different approach by arguing that a broadening of diet in which the hunting of large mammals by men was supplemented with lower-ranked animal and plant resources by women and children gave modern humans the evolutionary edge that allowed for their dispersal out of Africa and across Eurasia (Kuhn and Stiner, 2006). Unlike Hockett and Haws (2003) who credit this advantage to the superior nutrient balance of this broader diet, to Stiner there is something about the greater “access to primary production in ecosystems” afforded by a focus on larger seed plants that, despite the lowered efficiency of the subsistence economies based on their utilization, “may support humans at higher population densities” (Stiner, 2001, p. 6995). Others highlight the reproductive benefits that accrue to successful hunter for their linkage between optimizing behavior and fitness (e.g. Alvard and Gillespie, 2004; Smith, 2004). If success in hunting is indeed the missing link between optimizing strategies and fitness, however, it is hard to understand why, over time and as a result of the selective advantages conferred by the higher reproductive success enjoyed by successful hunters, there are any men left in hunter-gather societies who do not hunt. It is even harder to explain, following this line of reasoning, how agricultural societies in which the role of hunting and hunters is much diminished have proven so successful relative to hunting societies (although Aldenderfer (2006) uses this line of argument to explain the origin of llama herding in the Andes).

Quite apart from the problematic (frequently *ad hoc*) linkage between optimizing behaviors and fitness, it is also unclear whether foraging decisions actually follow the strict optimizing rules laid out in optimal foraging theory. In fact, tests of the predictive power of OFT models have been shown to come up short in predicting the foraging behavior of non-human foragers. In an examination of 134

applications of Optimal Diet Theory (another name for diet breadth models) to non-human foragers, Sih and Cristensen (2001) found that while the ODT model did a reasonably good job in predicting the behavior of foragers feeding on immobile prey, it performed poorly in predicting the diets of foraging animals exploiting mobile prey (especially prey which exhibit active anti-predator escape or defense behaviors), concluding that “[o]ne might argue that ODT was never meant to be applied to foragers on mobile prey” (Sih and Cristensen, 2001, p. 387).

Gray (1987) reports even more damaging results in his evaluation of 87 different tests of optimal diet theory, finding only moderate support for the weakest ODT predictions (that foragers are likely to select profitable prey) and no support for other more robust optimizing principles (that foragers ignore prey outside the optimal set regardless of their abundance). Even so-called ‘second generation’ OFT models that allow for choices between prey types rather than prey sizes, for multiple alternative choices rather than simply binary ones, or that are based on field studies instead of controlled laboratory experiments, failed to perform well in making predictions that matched actual behavior, leading Gray to conclude that “much of the evidence that has been asserted to strongly support OFT simply evaporates when the tests are examined in a detailed, systematic way”, suggesting that “it is the basic approach that is at fault” (Gray, 1987, pp. 78–79).

These evaluations of the ability of OFT to predict the behavior of non-human foragers strongly suggest, then, that it is not the “specific hypothesis about goals, decisions variables trade-offs, currencies, [or] constraints” (Bird and O’Connell, 2006, p. 146) generated by foraging theory that needs adjustment; but rather it is the central optimizing assumption at the heart of the theory that fails to account for the way foragers behave. And if OFT fares so poorly in rigorous tests of foraging behavior in non-human foragers, it seems unlikely that it would be any more effective in predicting the behavior of humans, which may be why those seeking to do so have never really subjected human foraging case study applications of OFT to this kind of scrutiny.

This is not to say that humans (or other species) do not engage in goal directed behaviors – they clearly do. But it is questionable whether these behaviors are shaped by an optimizing goal of maximizing return, regardless of which of many different currencies of optimization is selected (e.g., energy, vitamin B, risk avoidance, or mating opportunities). Foraging decisions are in all likelihood shaped by a range of much more loosely defined overlapping goals, with general subsistence strategies designed to meet these more reasonably attainable goals rather than some optimal outcome. Instead of basing decisions on precise categorizations of prey items and quantitative cost/benefit assessments directed at assuring optimal returns, it is far more plausible that ancient foragers swept up in the Broad Spectrum Revolution took a “fuzzier” approach to constructing their subsistence economies, drawing on a deep body of collective knowledge of the environment passed down from generation to generation and continually refreshed by the addition of new information (Berkes, 2008, pp. 197–200), that they then used to make subsistence choices that generally and in a more holistic sense address these overlapping goals. Foraging strategies did not need not yield optimal results, they just had to be good enough to generally satisfy a cluster of interrelated goals.

Adaptation

Researchers applying foraging theory to humans often highlight OFT’s grounding in neo-Darwinianism as a way of buttressing the theory’s credentials as a branch of evolutionary biology (Winterhalder and Smith, 2000, p. 51; Winterhalder and Kennett, 2006, p. 20). As discussed above, this heritage is clearly evident in the linkage between optimization and fitness often invoked at the outset of

OFT-grounded studies of human foraging behavior (e.g. Alvard, 1993, p. 357; Bird and O'Connell, 2006, p. 146; Gremillion, 1996, p. 184; Hill et al., 1987, p. 2; Smith, 1983, p. 626; Winterhalder and Kennett, 2006, p. 11). Optimizing behavior is seen by OFT advocates as a product of natural selection that confers selective advantage on individuals who practice these behaviors over those who do not (Hill et al., 1987, p. 2; Kaplan and Hill, 1992; Smith, 1983, p. 626). This neo-Darwinian approach is itself based on an atomistic world-view that reduces complex phenomena to their simplest component parts, focusing on how each of these parts is shaped by natural selection in a way that maximizes fitness. Adaptation in this perspective is a one-way street in which "organisms adapt to their environment, never vice versa" (Williams, 1992, p. 484). This 'adaptationist' viewpoint has come under considerable fire from both biologists and anthropologists for obscuring, or worse ignoring or denying, the more hierarchical and interactive evolutionary processes in which organisms both respond to and shape their environments (Gould and Lewontin, 1979; Gray, 1987; Laland and Brown, 2006, p. 95; Laland and O'Brien, 2010; Laland et al., 2011; Lewontin, 1979a, 1979b, 1982, 1983, p. 276; Odling-Smee et al., 2003, pp. 15–17; Rosenberg, 1994; Smith, 2009a, 2009b, in press-a; Spencer, 1997; Zeder, 2009a, 2009b). And it is this underlying asymmetrical view of adaptation that results in the, largely tacit, OFT embrace of "unidirectional 'environments change, humans adapt' explanations to subsistence change" (Smith, in press-a; see also O'Brien and Laland, in press) that represents the final of the five fundamental flaws in optimal foraging explanations of the BSR.

OFT explanations of subsistence change occasionally do allow for feed-back between humans and their environments that can shape foraging decisions. The morphological and physiological responses plants make to human manipulation is, as mentioned above, seen as one of the processes which can elevate a previously ignored low ranking plant resource into the optimal set of exploited dietary resources (Gremillion and Piperno, 2009, p. 618; Piperno, 2011; Winterhalder and Goland, 1997, p. 148). The impact of anthropogenic fire on shaping biodiversity and its impact on foraging decisions has also been explored in ground breaking work by Rebecca Bliege Bird and colleagues (Bird et al., 2005; Bliege Bird et al., 2008). More explicit attempts to recognize the active role humans play in shaping environments can also be found in both Smith and Wishnie (2000) and Broughton et al. (2010) that discuss the role of humans in 'eco-system engineering' and 'niche construction'. These last efforts, however, are cast within a context of responses to environmental change stemming from unintentional human-induced disturbance that results in an overall reduction in foraging efficiency as humans are forced to broaden their resource base to include lower ranking prey due to the depression of higher yield prey (Broughton et al., 2010, p. 377; Smith and Wishnie, 2000, p. 499).

Once again, foundational OFT assumptions play a prescriptive role in determining how those operating with the paradigm view long-term investments in environmental engineering. Investment in modifying environments for some future benefit is "contrary to the assumptions of foraging theory, which argues that hunters will do whatever is required... to maximize returns in the short-term" (Alvard, 1993, p. 358), with 'short-term' defined as "over the course of one or several foraging bouts" (Alvard, 1993, p. 368, citing Stephens and Krebs, 1986, p. 16). Under this short-term resource maximization axiom, any effort at enhancing an environment's long-term biotic potential requires discounting the value of the "opportunity costs" of not engaging in an alternative activity with immediate returns (see also Alvard and Kunzner, 2001; Tucker, 2006; Winterhalder and Kennett, 2006, p. 12). By this logic, then, long-term investment in enhancing biotic potential of an environment can only happen under circumstances in which the short-term pay-off alternative is no longer as attractive (i.e. through resource depression) or when something occurs that

elevates the value of the delayed returns of the investment over that to be had from foraging activities that yield more immediate returns (i.e. increases in density or returns from resources either as a result of manipulation or some technological advance that enhances the long-term return). This core assumption of short-term maximization precludes those working within the OFT framework from acknowledging the active and purposeful role that humans (and other non-human animals) play in modifying their environments for their own benefit regardless of considerations the loss of short-term returns. As a result they fail to recognize the profound impact of niche-constructing activities on the evolutionary trajectory of organisms that engage in them, as well as on that of other organisms living within the niches they construct.

The OFT paradigm's limitations in realizing the role of humans in shaping their environments is brought into clearer focus by the emergence of a new paradigm in evolutionary biology that explicitly acknowledges a reciprocal dynamic between organisms and their environment as a major driver of evolution. Niche construction theory (Odling-Smee et al., 2003) is grounded in a "macro-evolutionary" approach that recognizes complex hierarchical processes and views "organisms and their environments as co-determined rather than as separate entities with independent properties" (Gray, 1987, p. 90). Niche construction is defined as "the process whereby organisms, through their metabolism, their activities, and their choices, modify their own and/or each other's niches" (Odling-Smee et al., 2003, p. 419), and in so doing act "as co-directors of their own and other species' evolution" (Laland and O'Brien, 2010, p. 314; O'Brien and Laland, in press). It is argued, in fact, that niche construction is a universal behavior, widely exhibited across a broad range of species and that it should, along with natural selection, be recognized as a major driver of evolution (Odling-Smee et al., 2003, p. 18) – a driver that has resulted in demonstrable, directional genetic change in organisms practicing the behavior, including humans (O'Brien and Laland, in press; Laland et al., 2000, 2010).

And while many species engage in this practice, humans, with their ability to spontaneously create new behaviors and broadly transmit these behaviors through social learning, are seen as "the ultimate niche constructors" (Odling-Smee et al., 2003, p. 28; Laland and Brown, 2006, p. 96; Smith, 2007a, 2007b, 2012). In small-scale societies like those involved in the Broad Spectrum Revolution, knowledge acquired about the environment and the ways in which it can be shaped to enhance its biotic potential are passed down from generation to generation in the form of "Traditional Ecological Knowledge" (Berkes, 2008, p. 7). This multi-layered and continually updated knowledge base allows small-scale human societies to "bequeath to the next generation landscapes that have already been modified and shaped in a variety of ways, and over many generations" (Smith, in press-a). And it is the sustained, multi-generational transmission of large bodies of environmental information that makes humans such proficient niche constructors, an ability that confers a tremendous evolutionary advantage to our species (Boyd and Richerson, 1985; Laland and O'Brien, 2010; Richerson and Boyd, 2005; Smith, 2007a, 2007b, 2009a, 2011b, 2012).

Studies of modern small-scale societies document the many ways in which humans modify their environment to increase the relative abundance and predictability of plant and animal resources within their resource catchment areas – burning to change the successional plant communities, transplanting, coppicing, and pruning plants of interest, constructing artificial beaches to grow clams and other molluscs (Anderson, 2005; Duer and Turner, 2005; Smith, 2007a, 2007b, 2009b, 2011b, in press-a). These activities are not confined to modern day small-scale societies, but likely have considerable depth, stretching as far back as 50,000 years or more into human history (Smith, 2007a, p. 1797).

To be clear, human niche construction should not be confused with some form of conservation, either “altruistic” or “selfish” (Alvard, 1993, p. 258), geared at preventing “resource depletion, species extirpation, or habitat degradation” (Smith and Wishnie, 2000, p. 501, see Smith, 2011c). Instead, it should be viewed as a purposeful activity that seeks to shape the environment in ways that directly and in the long-term promote the viability of the groups that practice this behavior. The extent to which these behaviors succeed in conserving species and protecting habitats is secondary to the overarching goals of ensuring the long-term sustainability of resource extraction practices. More often than not, these behaviors result in profound modification of environments and associated biota as humans use their deep, multi-generational knowledge of the environment to manage and shape it in ways that their own needs and not some esoteric ideal of a pristine environment.

Niche construction theory (NCT) thus provides a compelling alternative approach to that of optimal foraging theory in developing an explanatory framework for the BSR. Given OFT’s restrictive central definitional assumptions and its static, one-way conceptualization of human/environmental interaction, it dictates that the BSR can only be interpreted as a response to either environmentally or demographically driven resource pressure. A niche construction perspective, in contrast, allows humans to be viewed not as passive and reactive in the face of external stress, but as active instigators of the BSR through their efforts at constructing their local environments to meet a variety of overarching goals. And it is to this alternative explanatory approach that we will now turn.

An alternative NCT explanatory framework for the Broad Spectrum Revolution

The foregoing critical evaluation of the central assumptions or principles of OFT explanations of the Broad Spectrum Revolution concerning mobility, intensification, optimality, resource depression, and adaptation provides a solid introduction to consideration of an alternative niche construction theory explanatory framework for the emergence of broad spectrum resource diversification in different regions of the world. Importantly, there are a number of critical test implications or predictions that allow for a straightforward comparison of how well these two alternative explanatory perspectives appear to account for the archaeological signature of the BSR. From a NCT perspective, for example, broad spectrum resource diversification is not likely to occur in marginal environments or in regions where (as a result of environmental change or demographic growth) human groups are pushing up against regional carrying capacity. Rather the BSR is more likely to take root in highly productive ‘resource rich’ ecosystems where there is an abundance of densely distributed and highly predictable resources of potential economic value. In particular, environments having a mosaic of eco-zones that support diverse arrays of abundant and seasonally predictable resources can be recognized as providing high probability settings for the BSR. This combination of abundance and predictability, following Dyson-Hudson and Smith, makes it possible for human groups to reduce mobility, or give up residential mobility altogether, usually settling in logistical locations at the confluence of multiple eco-zones where different members of the group (men, women, and children) can access different sets of resources at different times of the year. The broadening of the resource base seen among BSR economies is, then, not a response to resource depression, but rather the result of people taking advantage of environmental opportunity.

This ‘rich environment’ critical test implication clearly favors NCT in many different world areas. During the height of the Last Glacial Maximum in the southern Levant, for example, the base camp of Ohalo II was established on the shores of the Sea of Galilee

in a resource rich refugia for a wide range of plant and animal resources. Residents of this semi-sedentary settlement exploited a broad array of small and large seeded grasses, acorns, and berries along with a wide range of large and small prey animals (Nadel, 1995, 2004, 2006; Weiss et al., 2004) – providing a clear foreshadowing of the Broad Spectrum Revolution that was to sweep across the region. The more fully sedentary Early Natufian era communities documented in both in the southern Levant and in Central Anatolia at the height of the late-glacial Bølling–Ållerød warming period were similarly located in resource rich areas at the confluence of multiple eco-zones, and were supported by a classic broad spectrum diet of large and small game and plant resources. The explosion of the PPNA communities across the entire Fertile Crescent region that followed the Younger Dryas climatic downturn can, in this light, be seen as taking advantage of the return of warmer and wetter conditions at the onset of the Early Holocene, with the rise in ambient CO₂ and the stabilization of climate setting the stage for a concentration of annual plants (especially cereals and legumes) that made them more profitable and reliable than during the Late Pleistocene. Similar broad spectrum diet diversification elsewhere in the Mediterranean Basin can also be seen as the result of people taking advantage of environments where an array of densely distributed and predictable resources supported larger aggregations of people for longer periods of time. This was also the setting for BSR adaptations in resource rich environments of the Mid-Holocene eastern North America and northeastern Asia. In all of these settings it is hard to make the case that demographically driven resource depression, and not greater resource abundance and predictability, was the principle driver of the BSR, either because of a demonstrable lack of evidence for population increase or an absence of compelling evidence that any increases in population that did occur surpassed or even nudged the enhanced carrying capacity of the resource rich environment.

This confluence of resource abundance and predictability within a concentrated region, once again following the Dyson-Hudson and Smith model, promotes the development of concepts of ‘ownership’ of both specific resources and the locations in which they can be found (Smith, *in press-a*). Where resources are densely aggregated within a mosaic of overlapping adjacent eco-zones, this concept of ownership may extend to the group’s entire catchment area. In such circumstances it becomes profitable to defend these owned territories through social negotiation with other groups and, if necessary, by the physical repulsion of interlopers (Dyson-Hudson and Smith, 1978, p. 25; Kelly, 1995, p. 202; Smith, *in press-a*). A system in which a group establishes a territory around a bounded set of defensible resources creates the kind of societal barriers to movement that Flannery described in his revised model of the Broad Spectrum Revolution (Flannery, 1986), as well as the regionalism Braidwood (1960) noted much earlier as coinciding with the BSR in the Taurus/Zagros arc; it is the same kind of territorial system Rosenberg (elaborating on the Dyson-Hudson and Smith model) hypothesized as a precursor to the establishment of more sedentary, broad spectrum economies that gave rise to plant and animal domestication and agricultural emergence (Rosenberg, 1990, 1998). But unlike OFT based models in which sedentism and the development of territorial systems are caused by population packing, or even those like Flannery’s where a much thinner spread of people across the landscape serves as a barrier to emigration, in this alternative view this kind of system may develop solely as a response to the spatial concentration of resources capable of supporting year-round settlements within well defined catchment areas where the returns are sufficiently abundant and reliable to make it worth investing in and defending from encroachment by outsiders (Smith, *in press-a*). Demography is not a negligible factor here, for it can be argued that such a system is only feasible when there are enough people to ensure that

groups focusing on these well-defined resource zones are able to develop social ties with other groups as buffers against localized shortages and to maintain viable mating networks. But in this view, population size is, like environment, a factor that makes the reduction of mobility and the year-round focus on these resource rich regions possible; it does not force it to happen.

Efforts at enhancing the productivity of economically valuable target species, practiced to some degree by all foragers, take on a special significance in these resource rich settings for several reasons. Both the diversity and density of plants and animals in such environments offer humans abundant opportunities for experimentation with different productivity enhancing exploitation techniques. The greater permanence of human presence here also opens up new opportunities for plants and animals to move into new anthropogenic environments and develop a range of relationships with humans (from commensalism to domestication) that work to their own evolutionary advantage (see papers in Dean, 2010 and also Zeder, 2012a, *in press*). Perhaps more importantly, the concept of ownership and the growing commitment to maintaining a group's investment in the territory serves as an additional incentive to engage in niche construction activities. In fact, increased investment in eco-system engineering is another likely response, along with reduced mobility and territorial defense, to environments with abundant and predictable resources.

It is also likely that both reduced mobility and subsequent growth of populations located in these resource rich areas will put some strain on the capacity of the environment to support these communities – another factor that might serve as an inducement to invest in new strategies and invent new technologies that enhance productivity. To say that greater site occupation intensity has a localized impact a community's catchment area, as Munro's important work clearly shows, is not to concede that population packing and region-wide resource depression are responsible for loss of mobility, resource diversification and intensification as OFT modelers would have it. Far from driving this process, in this alternative perspective, the threat of localized resource depletion due to increased sedentism takes a secondary role in motivating efforts at enhancing productivity. Instead this perspective sees the increased engagement in niche-construction activities in these resource rich environments as motivated primarily by a commitment to community and an interest in continuing to reap the rewards of past generations' investment in modifying and shaping the environment that has sustained it.

While these NCT strategies are aimed at enhancing the abundance and reliability of resources within the group's catchment area, it is unlikely that they were based on a small and tightly defined goal set predicated on the high-bar standards of achieving the optimal return of either energy, predictability, or any other currency of return. Rather they were more likely structured toward a much larger and more loosely defined target zone defined in terms of satisfying more generally dawn goals of providing communities with a secure and reliable resource base capable of preserving and perpetuating their commitment to and control over their resource territory now and in the future. While it might not have a more optimal energetic pay-off than an alternative mobile strategy in a less territorially conscripted situation, this investment in local resource productivity has real adaptive value in preserving community as the nexus for the transmission of information about the environment, each other, and the larger world. This accounts for why, along with intensification of subsistence strategies, there is an associated parallel elaboration of social and ritual behaviors in Broad Spectrum communities best read as mechanisms for preserving social cohesion and damping down social and economic tensions that may arise among sedentary people supported by a territorially conscripted resource base (Zeder, 2011; 2012b).

Conclusion

Since Kent Flannery first coined the term more than 40 years ago, the Broad Spectrum Revolution has served as a primary focus of the work of hundreds of researchers examining BSR developments on essentially every continent colonized by our distant ancestors. Much of this work has been predicated on the assumption that the BSR was set in a context of an imbalance between productivity and population, most commonly projected to be the result of unbridled population growth, though sometimes seen as the negative impact of climate change on regional resource availability. Although Flannery's original conception of the BSR was based on a demographic equilibrium model, subsequent researchers who have co-opted this concept have emphasized the role of demographically driven resource pressure to a far greater degree than Flannery proposed in either his original presentation of the BSR concept in 1969 or in his later fine-tuning of the BSR in 1986. This emphasis on the central role of resource imbalance in broad spectrum resource diversification has proven the perfect vehicle for the promulgation of OFT's cost accounting approach to human history.

Here I've presented an alternative view that does not situate the BSR in marginal or degraded environments, or in the context of threatened or real resource depression that forced hunter-gathering groups to give up mobility and more profitable subsistence practices and settle down to a diminished lifestyle based on sub-optimal resources that they had to work harder to procure and to process. Instead, this alternative view sets the BSR within a context of environmental opportunity where people were able to use their singular knowledge of the environment and their ingenuity in manipulating that environment to their benefit. This is not to say that the BSR had no down side. Environmental manipulation by humans, even if it served to enhance productivity and reliability, clearly had long-term implications that may not have been so positive – for the environments that were manipulated or for the human manipulators themselves (Laland and Brown, 2006, p. 99). But there can be no question that the broad spectrum economies developed in these optimal resource zones, and the agricultural economies that grew out of them, have, provided, for good or ill, a major engine for the growth and dispersion of humans around the globe.

There are aspects of the alternative explanatory framework proposed here that resonate with Robert Braidwood's (1963) "settling in" hypothesis, which was the consensus interpretation prior to Flannery's BSR model – an explanatory approach to the establishment of broad spectrum resource strategies that Binford (1968) dismissed as teleological. In contrast to Braidwood's hypothesis, which was rooted in the opaque realm of human nature, the explanatory framework presented here is firmly grounded in an emerging paradigm within evolutionary biology – niche construction theory. Unlike optimal foraging theory, niche construction theory recognizes the complex hierarchical interactions that shape both biological and cultural evolution. NCT not only acknowledges but intentionally spotlights the active and adaptive role humans play in shaping their environments, and demonstrates how niche-construction behavior plays a catalytic role in evolutionary process. This interesting new paradigm, I argue, shows great promise as an explanatory framework for the Broad Spectrum Revolution wherever it occurred.

Some might take my critique of the failings of OFT to account for the Broad Spectrum Revolution as a general condemnation of Human Behavioral Ecology (HBE). To the extent that HBE remains essentially synonymous with OFT this may be true. But I do not think this has to be the case, and believe that HBE enthusiasts would be well advised to look to its progenitor discipline of Behavioral Ecology (BE) as an example of the direction in which

HBE should evolve. In recent years BE has become increasingly decoupled from an earlier almost exclusive association with optimal foraging theory to include other theoretical perspectives (e.g. game theory, network theory) not grounded in restrictive optimizing axioms at the core of OFT. HBE, on the other hand, has yet to grow in this direction. Following this example, Human Behavioral Ecology is well poised to broaden its reach to include other theoretical perspectives outside of OFT as they apply to the study of the evolutionary and ecological basis for human behaviors. And while, as discussed above, NCT has its roots in branch of evolutionary biology framed largely in opposition to the adaptationalist program of Neo-Darwinian theory that gave rise of OFT, BE, and HBE, I believe that NCT could easily be included within a broader, reimagined HBE released from the bondage of its now almost exclusionary linkage with OFT (see Smith, in press-b).

Obviously, this alternative NCT perspective needs to be subjected to rigorous evaluation against the empirical record. And along with rich vs. marginal environmental setting and the lack of evidence for population packing and resource depression discussed above, there are a number of additional test implications or predictions that should allow for a close comparison and evaluation of the relative strength of NCT and OFT in explaining the BSR (Smith, in press-a). Such a careful and critical comparison of the relative value of the two competing interpretive frameworks will ensure that Flannery's Broad Spectrum Revolution remains at the forefront of archaeological inquiry for years to come. Clearly there is considerable life after 40 for the Broad Spectrum Revolution, and if the niche construction alternative proposed here does indeed fulfill its considerable promise, archaeologists studying this important juncture in human history may no longer have to count calories while doing so.

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References

- Aldenderfer, M., 2006. Costly signaling, the sexual division of labor, and animal domestication in the Andean Highlands. In: Kennett, D.J., Winterhalder, B. (Eds.), *Behavioral Ecology and the Transition to Agriculture*. University of California Press, Berkeley, pp. 167–196.
- Alvard, M.S., 1993. Testing the "Ecologically Noble Savage" hypothesis: interspecific prey choice by Piro hunters of Amazonian Peru. *Human Ecology* 21, 355–387.
- Alvard, M.S., Gillespie, A., 2004. Good Lamalera whale hunters accrue reproductive benefits. *Research in Economic Anthropology* 23, 223–245.
- Alvard, M.S., Kunzner, L., 2001. Deferred harvests: the transition from hunting to animal husbandry. *American Anthropologist* 103, 295–311.
- Anderson, M.K., 2005. *Tending the Wild: Native American Knowledge and the Management of California's Natural Resources*. University of California Press, Berkeley.
- Arroyo Marin, A.B., 2009. Economic adaptations during the Late Glacial in northern Spain: a simulation approach. *Before Farming: The Archaeology of Old World Hunter–Gatherers*, 2009/2 (article 3).
- Atici, L., 2009. Specialisation and diversification: animal exploitation strategies in the Terminal Pleistocene, Mediterranean Turkey. *Before Farming: The Archaeology of Old World Hunter–Gatherers*, 2009/3 (article 1).
- Aura, J.E., Jordá, J.F., Morales J.V., Pérez, M., Villalba M.-P., Alcover, J.A., 2009. Economic transitions in finis terra: the western Mediterranean of Iberia, 15–7 ka BP. *Before Farming: The Archaeology of Old World Hunter–Gatherers* 2009/2 (article 4).
- Bailey, G.N., 1978. Shell middens as indicators of postglacial economies: a territorial perspective. In: Mellars, P.A. (Ed.), *The Early Postglacial Settlement of Northern Europe*. Duckworth, London, pp. 37–63.
- Bailey, G.N., 1983. "Economy change in Late Pleistocene Cantabria. In: Bailey, G.N. (Ed.), *Hunter–Gatherer Economy in Prehistory*. Cambridge University Press, Cambridge, pp. 149–165.
- Bailey, G.N., 2004a. World prehistory from the margins: the role of coastlines in human evolution. *Journal of Interdisciplinary Studies in History and Archaeology* 1, 39–50.
- Bailey, G.N., 2004b. The wider significance of submerged archaeological sites and their relevance to world prehistory. In: Flemming, N.C. (Ed.), *Submarine Prehistoric Archaeology of the North Sea: Research Priorities and Collaboration with Industry*. English Heritage and Council for British Archaeology, New York, pp. 3–10.
- Bailey, G.N., Craighead, A.S., 2003. Late Pleistocene and Holocene palaeoeconomies: a reconsideration of the molluscan evidence from Northern Spain. *Geoarchaeology* 18, 175–204.
- Bailey, G.N., Craighead, A.S., 2004. Coastal palaeoeconomies and palaeoenvironmental trends: Austrian and Australian middens compare. In: González Morales, M., Clark, G.A. (Eds.), *The Mesolithic of the Atlantic Façade*. Proceedings of the Santander Symposium, Anthropological Research Papers No. 55. Arizona State University, Tempe, pp. 181–204.
- Bailey, G.N., Nicky Milner, 2002. Coastal hunter–gatherers and social evolution: marginal or central? *Before Farming: The Archaeology of Old World Hunter–Gatherers* 3–4 (article 1).
- Barlow, K.R., 2002. Predicting maize agriculture among the Fremont: an economic comparison of farming and foraging in the American Southwest. *American Antiquity* 67, 65–88.
- Barlow, K.R., Heck, M., 2002. More on acorn eating during the Natufian: expected patterning in diet and the archaeological record of subsistence. In: Mason, S.L.R., Hather, J.G. (Eds.), *Hunter–Gatherer Archaeobotany: Perspectives from the Northern Temperate Zone*. Institute of Archaeology, London, pp. 128–145.
- Bar-Oz, G., Munro, N.D., 2007. Gazelle bone marrow yields and Epipalaeolithic carcass exploitation strategies in the southern Levant. *Journal of Archaeological Science* 34, 946–956.
- Barton, R.N.E., Currant, A., Fernandez-Jalvo, Y., Finlayson, J.C., Goldberg, P., Macphail, R., Pettit, P., Stringer, C., 1999. Gibraltar Neanderthals and results of recent excavations in Gorham's, Van-guard and Ibex caves. *Antiquity* 73, 13–24.
- Bartram Jr., L.E., 1993. Perspectives on skeletal part profiles and utility curves from eastern Kalahari ethnoarchaeology. In: Hudson, J. (Ed.), *From Bones to Behavior: Ethnoarchaeological and Experimental Contributions to the Interpretation of Faunal Remains*. Center for Archaeological Investigations Occasional Papers 21. Center for Archaeological Investigations, Carbondale, pp. 115–137.
- Bayham, F.E., 1979. Factors influencing the Archaic pattern of animal exploitation. *Kiva* 44, 219–235.
- Berkes, F., 2008. *Sacred Ecology*, second ed. Routledge, New York.
- Bettinger, R.L., 1983. Comment on Smith, Eric, anthropological applications of optimal foraging theory: a critical review. *Current Anthropology* 24, 625–651.
- Bettinger, R.L., Braumhoff, M.A., 1982. The Numic spread: Great Basin Cultures in competition. *American Antiquity* 47, 485–503.
- Bettinger, R.L., Winterhalder, B., McElreath, R., 2006. A simple model of technological intensification. *Journal of Archaeological Science* 33, 538–545.
- Bicho, N., Haws, J., 2008. At the land's end: marine resources and the importance of fluctuations in the coastline in the prehistoric hunter–gatherer economy of Portugal. *Quaternary Science Reviews* 27, 2166–2175.
- Binford, L.R., 1968. Post-Pleistocene adaptations. In: Binford, S.R., Binford, L.R. (Eds.), *New Perspectives in Archaeology*. Aldine, Chicago, pp. 313–341.
- Binford, L.R., 1980. Willow smoke and dogs' tails: hunter–gatherer settlement systems and archaeological site formation. *American Antiquity* 45, 4–20.
- Binford, L.R., 1999. Time as a clue to cause. *Proceedings of the British Academy* 101, 1–35.
- Binford, L.R., 2001. Constructing Frames of Reference. An Analytical Method for Archaeological Theory Building Using Ethnographic and Environmental Data Sets. University of California Press, Berkeley.
- Bird, D.W., O'Connell, J.F., 2006. Behavioral ecology and archaeology. *Journal of Archaeological Research* 14, 143–188.
- Bird, D.W., Bliege Bird, R., Parker, C.H., 2005. Aboriginal burning regimes and hunting strategies in Australia's Western Desert. *Human Ecology* 33, 443–464.
- Blasco, R., 2008. Human consumption of tortoises at Level IV of Bolomor Cave (Valencia Spain). *Journal of Archaeological Science* 35, 2839–2848.
- Blasco, R., Fernández Peris, J., 2009. Middle Pleistocene bird consumption at Level XI of Bolomor Cave. *Journal of Archaeological Science* 36, 2213–2223.
- Bliege Bird, R., 1999. Cooperation and conflict: the behavioral ecology of the sexual division of labor. *Evolutionary Anthropology* 8, 65–75.
- Bliege Bird, R., Bird, D.W., Codding, B.F., Parker, C., Holland Jones, J., 2008. The fire-stick farming hypothesis: anthropogenic fire mosaics, biodiversity and Australian Aboriginal foraging strategies. *Proceedings of the National Academy of Sciences* 105, 14796–14801.
- Blundell, V., 1983. Comment on Smith, Eric, Anthropological applications of optimal foraging theory: a critical review. *Current Anthropology* 24, 625–651.
- Boyd, R., Richerson, P.J., 1985. *Culture and Evolutionary Process*. University of Chicago Press, Chicago.
- Brady, R.H., 1982. Dogma and doubt. *Biological Journal of the Linnean Society* 17, 79–96.
- Braidwood, R.J., 1960. The agricultural revolution. *Scientific American* 203, 30–141.
- Braidwood, R.J., 1963. *Prehistoric Men*, sixth ed., Popular Series. Anthropology No. 37. Chicago Museum of Natural History, Chicago.
- Braidwood, R.J., Willey, G., 1962. Conclusions and afterthoughts. In: Braidwood, J.R., Willey, G. (Eds.), *Courses Toward Urban Life*. Aldine Press, Chicago, pp. 132–146.

- Bright, J., Ugan, A., Hunsaker, L., 2002. The effect of handling time on subsistence technology. *World Archaeology* 34, 164–181.
- Broughton, J.M., 1994. Declines in mammalian foraging efficiency during the Late Holocene, San Francisco Bay, California. *Journal of Anthropological Archaeology* 13, 371–401.
- Broughton, J.M., 1997. Widening diet breadth, declining foraging efficiency, and prehistoric harvest pressure: Ichthyofaunal evidence from the Emeryville Shellmound, California. *Antiquity* 71, 845–862.
- Broughton, J.M., 1999. Resource Depression and Intensification during the Late Holocene, San Francisco Bay: Evidence from the Emeryville Shellmound Vertebrate Fauna. University of California Anthropological Records 32, Berkeley, University of California.
- Broughton, J.M., 2002. Prey spatial structure and behavior affect archaeological tests of optimal foraging models: examples from the Emeryville Shellmound vertebrate fauna. *World Archaeology* 34, 60–83.
- Broughton, J.M., Grayson, D.K., 1993. Diet breadth, Numic expansion, and the White Mountains faunas. *Journal of Archaeological Science* 20, 331–336.
- Broughton, J.M., Cannon, M.D., Barelinsk, E.J., 2010. Evolutionary ecology, resource depression, and niche construction theory: applications to central California hunter-gatherers and Mimbres-Mogollon Agriculturalists. *Journal of Archaeological Method and Theory* 17, 317–421.
- Brown, J.A., 1985. Long-term trends in sedentism and the emergence of complexity in the American Midwest. In: Price, T.D., Brown, J.A. (Eds.), *Prehistoric Hunter-Gatherers*. Academic Press, Orlando, pp. 201–234.
- Burbridge, R.E., Mayle, F.E., Killeen, T.J., 2004. Fifty-thousand-year vegetation and climate history of Noel Kempff Mercado National Park, Bolivian Amazon. *Quaternary Research* 61, 215–230.
- Burger, O., Hamilton, M.J., Walker, R., 2005. The prey as patch model: optimal handling of resources with diminishing returns. *Journal of Archaeological Science* 32, 1147–1158.
- Butler, V.L., Campbell, S.K., 2004. Resource intensification and resource depression in the Pacific Northwest of North America: a zooarchaeological review. *Journal of World Prehistory* 18, 327–405.
- Cannon, M.D., 2003. A model of Central Place forager prey choice and an application to faunal remains from the Mimbres Valley, New Mexico. *Journal of Anthropological Archaeology* 22, 1–25.
- Cashdan, E., 1992. Attracting mates: effects of paternal investment on mate attraction strategies. *Ethnology and Sociobiology* 14, 1–24.
- Christenson, A.L., 1980. Change in the human food niche in response to population growth. In: Earle, T.K., Christenson, A.L. (Eds.), *Modeling Change in Prehistoric Subsistence Economies*. Academic Press, New York, pp. 31–72.
- Clark, G.A., 1971. A reexamination of the archaeological evidence for agricultural origins in the Nile Valley. *Proceedings of the Prehistoric Society* 37, 34–79.
- Clark, G.A., 1987. From the Mousterian to the Metal Ages: long-term change in the human diet of northern Spain. In: Soffer, O. (Ed.), *The Pleistocene Old World: Regional Perspectives*. Plenum Publishing, New York, pp. 293–316.
- Clark, G.A., Straus, L.G., 1983. Late Pleistocene hunter-gatherer adaptations in Cantabrian Spain. In: Bailey, G.N. (Ed.), *Hunter-Gatherer Economy in Prehistory*. Cambridge University Press, Cambridge, pp. 131–147.
- Clark, G.A., Straus, L.G., 1986. Synthesis and conclusions – Part I: Upper Palaeolithic and Mesolithic hunter-gatherer subsistence in Northern Spain. In: Straus, L.G., Clark, G.A. (Eds.), *La Riera Cave: Stone Age Hunter-Gatherer Adaptations in Northern Spain*. Arizona State University Anthropological Research Papers, 36. Arizona State University Press, Tempe, pp. 351–366.
- Clark, G.A., Yi, S., 1983. Niche-width variation in Cantabrian archaeofaunas: a diachronic study. In: Clutton-Brock, J., Grigson, C. (Eds.), *Animals and Archaeology*. Vol. 1. Hunters and their Prey. BAR International Series 163. British Archaeological Reports, Oxford, pp. 183–208.
- Cohen, M.N., 1977. *The Food Crisis in Prehistory*. Yale University Press, New Haven.
- Cortés-Sánchez, M., Morales-Muniz, A., Simón-Vallejo, M.D., Lozano-Francisco, M., Vera-Peláez, J.L., Finlayson, C., Rodríguez-Vidal, J., Delgado-Huertas, A., Jiménez-Espejo, F.J., Martínez-Ruiz, F., Martínez-Aguirre, M.A., Pascual-Granged, A.J., Bergadá-Zapata, M., Gibaja-Bao, J.F., Riqueime-Cantal, J.A., López-Sáez, J.A., Rodrigo-Gámiz, M., Sakai, S., Sugisaki, S., Finlayson, G., Fa, D.A., Bicho, N.F., 2011. Earliest known use of marine resources by Neanderthals. *Plos One* 6/9, e24026.
- Crawford, G.W., 1992. The transitions to agriculture in Japan. In: Gebauer, A.B., Price, T.D. (Eds.), *Transitions to Agriculture in Prehistory*. Monographs in World Archaeology, No. 4. Prehistory Press, Madison, WI, pp. 117–132.
- Crawford, G.W., 2011a. Advances in understanding early agriculture in Japan. *Current Anthropology* 52 (S4), S331–S345.
- Crawford, G.W., 2011b. Early rice exploitation in the lower Yangzi valley: what are we missing? *The Holocene*. <http://dx.doi.org/10.1177/0959683611424177>.
- Dean, R. (Ed.), 2010. *The Archaeology of Anthropogenic Environments*. Center for Archaeological Investigations Occasional Paper No. 37, Carbondale, IL, Southern Illinois University, Carbondale.
- Duer, D., Turner, N.J. (Eds.), 2005. *Keeping it Living: Traditions of Plant Use and Cultivation on the Northwest Coast of North America*. University California Press, Berkeley.
- Dyson-Hudson, R., Smith, E.A., 1978. Human territoriality: an ecological reassessment. *American Anthropologist* 80, 21–41.
- Earle, T.K., 1980. A model of subsistence change. In: Earle, T.K., Christenson, A.L. (Eds.), *Modeling Change in Prehistoric Subsistence Economies*. Academic Press, New York, pp. 1–29.
- Edwards, P.C., 1989. Revising the Broad Spectrum Revolution: and its rôle in the origins of Southwest Asian food production. *Antiquity* 63, 225–246.
- Edwards, D.A., O'Connell, J.F., 1995. Broad spectrum diets in arid Australia. *Antiquity* 69, 769–783.
- Ehrlich, P.G., 1968. *The Population Bomb*. Buccaneer Books, Inc., Cutchogue.
- Elston, R.G., Brantingham, P.G., 2002. Microlithic technology in northern Asia: a risk-minimizing strategy of the late Paleolithic and early Holocene. In: Elston, R.G., Kuhn, S.L. (Eds.), *Thinking Small: Perspectives on Microlithization*. Archaeological Papers No. 12. American Anthropological Association, Washington, pp. 104–117.
- Emlen, J., 1966. The role of time and energy in food preference. *American Naturalist* 100, 611–617.
- Flannery, K.V., 1969. Origins and ecological effects of early domestication in Iran and the Near East. In: Ucko, P.J., Dimbleby, G.W. (Eds.), *The Domestication and Exploitation of Plants and Animals*. Duckworth, London, pp. 73–100.
- Flannery, K.V., 1986. *Guila Naquitz: Archaic Foraging and Early Agriculture in Oaxaca, Mexico*. Academic Press, New York.
- Gould, S.J., Lewontin, R.C., 1979. The spandrels of San Marco and the Panglossian paradigm: a critique of the adaptationalist programme. *Proceedings of the Royal Society London Series B* 205, 581–598.
- Gray, R.D., 1987. Faith and foraging: a critique of the 'paradigm argument from design'. In: Kamil, A.C., Krebs, J.R., Pulliam, H.R. (Eds.), *Foraging Behavior*. Plenum Press, New York, pp. 69–140.
- Grayson, D.K., Cannon, M.D., 1999. Human paleoecology and foraging theory in the Great Basin. In: Beck, C. (Ed.), *Models for the Millennium: Great Basin Anthropology Today*. University of Utah Press, Salt Lake City, pp. 141–150.
- Gremillion, K.J., 1996. Diffusion and adoption of crops in evolutionary perspective. *Journal of Anthropological Archaeology* 15, 183–204.
- Gremillion, K.J., 1998. Changing roles of wild and cultivated plant resources among early farmers of eastern Kentucky. *Southeast Archaeology* 17, 140–157.
- Gremillion, K.J., 2004. Seed processing and the origins of food production in Eastern North America. *American Antiquity* 69, 215–233.
- Gremillion, K.J., 2006. Centralplace foraging and food production on the Cumberland Plateau, eastern Kentucky. In: Kennett, D.J., Winterhalder, B. (Eds.), *Behavioral Ecology and the Transition to Agriculture*. University of California Press, Berkeley, pp. 41–62.
- Gremillion, K.J., Piperno, D.R., 2009. Human Behavioral Ecology, phenotypic (developmental) plasticity, and agricultural origins: insights from the emerging evolutionary synthesis. *Current Anthropology* 50, 615–619.
- Gutiérrez-Zugasti, E.I., 2011. Changes in mollusc exploitation patterns during the Late Pleistocene and Early Holocene in eastern Cantabria (Northern Spain). In: Bicho, N.F., Haws, J., Davis, L. (Eds.), *Trekking the Shore: Changing Coastlines and the Antiquity of Coastal Settlements*. Interdisciplinary Contribution to Archaeology. Springer, New York, pp. 101–179.
- Hamilton III, W.J., Buskirk, R.F., Buskirk, W.H., 1976. Defense of space and resources by Chacma (*Papio ursinus*) Baboon Troops in an African Desert and Swamp. *Ecology* 57, 1264–1272.
- Hassan, F.A., 1981. *Demographic Archaeology*. Academic Press, New York.
- Hawkes, K., 1993. Why hunter-gatherers work. *Current Anthropology* 34, 341–361.
- Hawkes, K., O'Connell, J.F., 1992. On optimal foraging models and subsistence transitions. *Current Anthropology* 33, 63–65.
- Hawkes, K., Hill, K., O'Connell, J.F., 1982. Why hunters gather: optimal foraging and the Aché of eastern Paraguay. *American Ethnologist* 9, 379–398.
- Hawkes, K., O'Connell, J.F., Blurton Jones, N.G., 1991. Hunting income patterns among the Hadza: big game, common goods, foraging goals and the evolution of the human diet. *Philosophical Transactions of the Royal Society of London Series B* 334, 243–251.
- Hawkes, K., Rogers, R., Charnov, E., 1995. The male's dilemma: increased offspring production is more paternity to steal. *Evolutionary Ecology* 9, 662–677.
- Hawkes, K., O'Connell, J.F., Blurton Jones, N.G., 2001. Hunting and nuclear families: some lessons from the Hadza and men's work. *Current Anthropology* 42, 681–709.
- Hayden, B., 1995. A new overview of domestication. In: Price, T.D., Gebauer, A.-B. (Eds.), *Lat Hunters, First Farmers: New Perspectives on the Transition to Agriculture*. School of American Research Press, Santa Fe, pp. 273–300.
- Hildebrandt, W.R., McGuire, K.R., 2002. The ascendance of hunting during the California Middle Archaic: an evolutionary perspective. *American Antiquity* 67, 231–256.
- Hill, K., Hawkes, K., 1983. Neotropical hunting among the Aché of eastern Paraguay. In: Hames, B., Vickers, W.T. (Eds.), *Adaptive Responses of Native Amazonians*. Academic Press, New York, pp. 139–188.
- Hill, K., Kaplan, H., Hawkes, K., Hurtado, M., 1987. Foraging decisions among Aché hunter-gatherers: new data and implications for optimal foraging models. *Ethnology and Sociobiology* 8, 1–36.
- Hockett, B.S., Haws, J.A., 2003. Nutritional ecology and diachronic trends in Paleolithic diet and health. *Evolutionary Anthropology* 12, 211–216.
- Hockett, B., Haws, J., 2009. Continuity in animal resource diversity in the Late Pleistocene human diet of Central Portugal. *Before Farming: The Archaeology of Old World Hunter-Gatherers*, 2009/2 (article 2).
- Horwitz, L.K., 1996. The impact of animal domestication on species richness: a pilot study from the Neolithic of the southern Levant. *Archaeozoologia* 8, 53–70.
- Jefferies, R.W., 1996. The emergence of long distance trade networks in the southeastern United States. In: Sassaman, K., Anderson, D. (Eds.), *Archaeology of the Mid-Holocene Southeast*. University Press of Florida, Gainesville, pp. 222–234.
- Jefferson, G.T., 1971. A model of adaptive change in late prehistoric southeastern California. *UCLA Archaeological Survey Annual Report* 13, 167–172.

- Jones, E.L., 2006. Prey choice, mass collecting, and the wild European rabbit (*Oryctolagus cuniculus*). *Journal of Anthropological Archaeology* 25, 275–289.
- Jones, E.L., 2007. Subsistence change, landscape use, and changing site elevation at the Pleistocene–Holocene transition in the Dordogne of southwestern France. *Journal of Archaeological Science* 34, 344–353.
- Jones, E.L., 2009. Climate change, patch choice, and intensification at Pont d'Ambon (Dordogne, France) during the Younger Dryas. *Quaternary Research* 72, 371–376.
- Kaplan, H., Hill, K., 1992. The evolutionary ecology of food acquisition. In: Smith, E.A., Winterhalder, B. (Eds.), *Evolutionary Ecology and S. Aldine de Gruyter*, New York, pp. 167–202.
- Kaplan, H., Hill, K., Lancaster, J., Hurtado, A., 2000. A theory of human life history evolution: diet, intelligence, and longevity. *Evolutionary Anthropology* 9, 156–158.
- Keegan, W.F., Butler, B., 1987. The microeconomic logic of horticultural intensification in the Eastern Woodlands. In: Keegan, W.F. (Ed.), *Emergent Horticultural Economies of the Eastern Woodlands. Occasional Papers No. 7, Center for Archaeological Investigations. Center for Archaeological Investigations, Carbondale*, pp. 109–127.
- Kelly, R.L., 1995. *The Foraging Spectrum: Diversity in Hunter–Gatherer Lifeways*. Smithsonian Institution Press, Washington.
- Kennett, D.J., 2005. *The Island Chumash: Behavioral Ecology of a Maritime Society*. University of California Press, Berkeley.
- Kim, J., 2003. Land-use conflicts and the rate of the transition to agricultural economy: A comparative study of southern Scandinavia and central-western Korea. *Journal of Archaeological Method and Theory* 10, 277–321.
- Kim, J., 2006. Resource patch sharing among foragers: lack of territoriality or strategic choice? In: Grier, C., Kim, J., Uchiyama, J. (Eds.), *Beyond Affluent Foragers: Rethinking Hunter–Gather Complexity*. Oxbow, Oxford, pp. 168–191.
- Kuhn, S.L., Stiner, M.C., 2001. The antiquity of hunter–gatherers. In: Panter-Brick, C., Layton, R.H., Rowley-Conwy, P. (Eds.), *Hunter–Gatherers: An Interdisciplinary Perspective*. Cambridge University Press, Cambridge, pp. 99–142.
- Kuhn, S.L., Stiner, M.C., 2006. What's a mother to do? The division of labor among Neanderthals and modern Humans in Eurasia. *Current Anthropology* 47, 953–980.
- Laland, K.N., Brown, G.R., 2006. Niche construction, human behavior, and the adaptive-lag hypothesis. *Evolutionary Anthropology* 15, 95–104.
- Laland, K.N., O'Brien, M.J., 2010. Niche construction theory and archaeology. *Journal of Archaeological Method and Theory* 17, 303–322.
- Laland, K.N., Odling-Smee, F.J., Feldman, M.W., 2000. Niche construction, biological evolution, and cultural change. *Behavioral and Brain Sciences* 23, 131–175.
- Laland, K.N., Odling-Smee, F.J., Myles, S., 2010. How culture shaped the human genome: bringing genetics and the human sciences together. *Nature Reviews Genetics* 11, 137–148.
- Laland, K.N., Sterelny, K., Odling-Smee, J., Hoppitt, W., Uller, T., 2011. Cause and effect in biology revisited: is Mayr's proximate–ultimate dichotomy still useful? *Science* 334, 1512–1516.
- Lancaster, J., Lancaster, C., 1983. Parental investment: the hominid adaptation. In: Ortner, D. (Ed.), *How Humans Adapt*. Smithsonian Institution Press, Washington, DC, pp. 33–69.
- Layton, R.H., Foley, R.A., Williams, E., 1991. The transition between hunting and gathering and the specialized husbandry of resources. *Current Anthropology* 32, 255–274.
- Lee, G.-A., 2011. The transition from foraging to farming in prehistoric Korea. *Current Anthropology* 52 (S4), S307–S329.
- Lewontin, R.C., 1979a. Sociobiology as an adaptationist program. *Behavioral Science* 24, 5–14.
- Lewontin, R.C., 1979b. Fitness, survival, and optimality. In: Horn, D.H., Mitchell, R., Stairs, G.R. (Eds.), *Analysis of Ecological Systems*. Ohio State University Press, Columbus, pp. 3–21.
- Lewontin, R.C., 1982. Organism and environment. In: Plotkin, H.C. (Ed.), *Learning, Development, and Culture: Essays in Evolutionary Epistemology*. John Wiley and Sons, Chichester, pp. 151–170.
- Lewontin, R.C., 1983. Gene, organism, and environment. In: Bendall, D.D. (Ed.), *Evolution from Molecules to Men*. Cambridge University Press, Cambridge, pp. 273–285.
- Lim, S., 2009. The adoption process of agriculture and socioeconomic changes during the Chulmun period in the Southern Korean Peninsula. In: Ahn, S.-M., Lee, J.-J. (Eds.), *New Approaches to Prehistoric Agriculture*. Sahoi Pyoungnon, Seoul, pp. 144–171 (in Korean).
- Lupo, K.D., 2007. Evolutionary foraging models in zooarchaeological analysis: recent applications and future challenges. *Journal of Archaeological Research* 15, 143–189.
- Lupo, K.D., Schmitt, D.N., 2002. Upper Paleolithic net-hunting, small prey exploitation and women's work effort: a view from the ethnographic and ethnoarchaeological record of the Congo Basin. *Journal of Archaeological Method and Theory* 9, 147–179.
- MacArthur, R.H., Pianka, E.R., 1966. On optimal use of a patchy environment. *American Naturalist* 100, 603–609.
- Madsen, D.B., Kirkman, J.M., 1988. Hunting hoppers. *American Antiquity* 53, 593–604.
- Madsen, D.B., Schmitt, D.N., 1998. Mass collecting and the diet breadth model: a great basin example. *Journal of Archaeological Science* 25, 445–455.
- Manne, T., Bicho, N.F., 2009. Vale Boi: rendering new understandings of resource intensification & diversification in southwestern Iberia. *Before Farming: The Archaeology of Old World Hunter–Gatherers*, 2009/2 (article 1).
- Marlowe, F., 1999. Male care and mating effort among Hadza forager. *Behavioral Ecology and Sociobiology* 46, 57–64.
- Marston, J.M., 2011. Archaeological markers of agricultural risk management. *Journal of Anthropological Archaeology* 30, 190–205.
- Mazur, J.E., 1983. Reply to Staddon and Hinson. *Science* 221, 977.
- McGuire, K.R., Hildebrandt, W.R., 2005. Re-thinking Great Basin foragers: Prestige hunting and costly signaling during the Middle Archaic period. *American Antiquity* 70, 695–712.
- Metcalfe, D., Barlow, R.K., 1992. A model for exploring the optimal trade-off between field processing and transport. *American Anthropologist* 94, 340–359.
- Munro, N.D., 2003. Small game, the Younger Dryas, and the transition to agriculture in the southern Levant. *Mitteilungen der Gesellschaft für Urgeschichte* 12, 47–71.
- Munro, N.D., 2004a. Zooarchaeological measures of hunting pressure and occupation intensity in the Natufian. Implications for agricultural origins. *Current Anthropology* 45, S5–S33.
- Munro, N.D., 2004b. Small game and the transition to agriculture in the southern Levant. In: Delage, C. (Ed.), *Last Hunter–Gatherer Societies in the Near East. BAR Series 1320. John and Erica Hedges, Oxford*, pp. 169–188.
- Munro, N.D., 2004c. Small game indicators of human foraging efficiency and early herd management at the transition to agriculture in south-west Asia. In: Brugal, J.-P., Desse, J. (Eds.), *Petits Animaux et Société Humaines. du Complément Alimentaire aux Ressources Utilitaires. XXIV^e reconstrues international d'archéologie et d'histoire d'Antibes*. Editions APDA, Antibes, pp. 515–531.
- Munro, N.D., 2009a. Epipaleolithic subsistence intensification in the southern Levant: the faunal evidence. In: Hublin, J.-J., Richards, M.J. (Eds.), *Integrating Approaches to the Study of Paleolithic Subsistence*. Springer, Netherlands, pp. 141–155.
- Munro, N.D., 2009b. Integrating inter- & intra-site analyses of Epipaleolithic faunal assemblages from Israel. *Before Farming: The Archaeology of Old World Hunter–Gatherers*, 2009/1 (article 4).
- Munro, N.D., Atici, L., 2009. Human subsistence change in the Late Pleistocene Mediterranean Basin: the status of research on faunal intensification, diversification, and specialization. *Before Farming: The Archaeology of Old World Hunter–Gatherers*, 2009/1 (article 1).
- Munro, N.D., Bar-Oz, G., 2005. Gazelle bone fat processing in the Levantine Epipaleolithic. *Journal of Archaeological Science* 32, 223–239.
- Nadel, D., 1995. The visibility of prehistoric burials in the southern Levant: How rare are the Upper Paleolithic/Early Epipaleolithic graves? In: *The Archaeology of Death in the Ancient Near East*. In: Campbell, S., Green, A. (Eds.), . Oxbow Monograph, vol. 51. Oxbow, Oxford, pp. 1–5.
- Nadel, D., 2004. Wild barley harvesting, fishing, and year-round occupation at Ohalo II (19.5 KY, Jordan Valley, Israel). In: *Le Secrétariat du Congrès (Ed.), Section 6: The Upper Paleolithic (General Sessions and Posters)*, Acts of the XIVth UISSP Congress, University of Liege (September, 2001). *British Archaeological Reports International Series No. 1240*. Archaeopress, Oxford, pp. 135–143.
- Nadel, D., 2006. "Residence ownership and continuity: From the Early Epipaleolithic unto the Neolithic. In: Banning, E.B., Chazan, M. (Eds.) *Domesticating Space. Construction, Community, and Cosmology in the Late Prehistoric Near East, Studies in Early Near Eastern production, subsistence and environment*. Berlin, 6, Ex Oriente, pp. 25–34.
- Nagaoka, L., 2002. The effects of resource depression on foraging efficiency, diet breadth, and patch use in southern New Zealand. *Journal of Anthropological Archaeology* 21, 419–442.
- Norton, C.J., 2000. Subsistence change at Konam-ri: implications of the advent of rice agriculture in Korea. *Journal of Anthropological Research* 56, 325–348.
- O'Brien, M.J., Laland, K.N., in press. Genes, culture, and agriculture: an example of human niche construction. *Current Anthropology*.
- O'Connell, J.F., Hawkes, K., 1981. Alyawara plant use and optimal foraging theory. In: Winterhalder, B., Smith, E.A. (Eds.), *Hunter–Gatherer Foraging Strategies: Ethnographic and Archaeological Analyses*. University of Chicago Press, Chicago, pp. 99–125.
- O'Connell, J.F., Jones, K.T., Simms, S.R., 1982. Some thoughts on prehistoric archaeology in the Great Basin. In: Madsen, D.B., O'Connell, J.F. (Eds.), *Man and Environment in the Great Basin*. Society for American Archaeology Papers 2, pp. 227–240.
- O'Connell, J.F., Hawkes, K., Blurton Jones, N.G., 1988. Hadza hunting, butchering and bone transport and their archaeological implications. *Journal of Anthropological Research* 44, 113–161.
- O'Connell, J.F., Hawkes, K., Blurton Jones, N.G., 1990. Reanalysis of large animal body part transport among the Hadza. *Journal of Archaeological Science* 17, 301–316.
- O'Connell, J.F., Hawkes, K., Blurton-Jones, N., 1999. Grandmothering and the evolution of *Homo erectus*. *Journal of Human Evolution* 36, 461S–485S.
- O'Connell, J., Hawkes, K., Lupo, K., Blurton-Jones, N., 2002. Mate strategies and Plio-Pleistocene archaeology. *Journal of Human Evolution* 43, 831–872.
- Odling-Smee, F.J., Laland, K.N., Feldman, W., 2003. *Niche Construction. Monographs in Population Biology*, vol. 37. Princeton University Press, Princeton.
- Olshewski, D., 1993. Subsistence ecology in the Mediterranean forest: implications for the origins of cultivation in the Epipaleolithic southern Levant. *American Anthropologist* 95, 420–435.
- Ortega, J., 1986. The malacology of La Riera Cave. In: Straus, L.G., Clark, G.A. (Eds.), *La Riera Cave, Stone Age Hunter–Gatherer Adaptations in Northern Spain*. Anthropological Research Papers No. 36. Arizona State University Press, Tempe, pp. 289–298.
- Peasnell, B.L., 2000. The Round-House Horizon along the Taurus/Zagros Arc: A Synthesis of Recent Excavations of Late Epipaleolithic and Early Aceramic Sites

- in Southeastern Anatolia and Northern Iraq. PhD Dissertation, University of Pennsylvania.
- Pierlan, S.M., 1980. An optimum diet model, costal variability, and hunter-gatherer behavior. *Advances in Archaeological Method and Theory* 3, 257–310.
- Pianka, E.R., 1978. *Evolutionary Ecology*, second ed. Harper and Row, New York.
- Piperno, D.R., 2006. The origins of plant cultivation and domestication in the Neotropics: a behavioral ecological approach. In: Kennett, D., Winterhalder, B. (Eds.), *Behavioral Ecology and the Transition to Agriculture*. University of California Press, Berkeley, pp. 137–166.
- Piperno, D.R., 2011. The origins of plant cultivation and domestication in the New World Tropics. *Current Anthropology* 52 (S4), 453–470.
- Piperno, D.R., Pearsall, D.M., 1998. *The Origins of Agriculture in the Lowland Neotropics*. Academic Press, San Diego.
- Piperno, D.R., Moreno, J.E., Holst, I., Lachniet, M., Jones, J.G., Ranere, A.J., Castanzo, R., 2007. Late Pleistocene and Holocene environmental history of the Iguala Valley, central Balsas watershed of Mexico. *Proceedings of the National Academy of Sciences of the USA* 104, 11874–11881.
- Porcasi, J.F., Jones, T.L., Raab, L.M., 2000. Trans-Holocene marine mammal exploitation on San Clemente Island, California: a tragedy of the commons revisited. *Journal of Anthropological Archaeology* 19, 200–220.
- Porter, K.G., Orcutt, J.D., Gerritsen, J., 1983. Functional response and fitness in a generalist filter feeder, *Daphnia Magna* (Cladocera: Crustacea). *Ecology* 64, 735–742.
- Pyke, G.H., 1984. Optimal foraging theory: a critical review. *Annual Review of Ecology and Systematics* 15, 523–575.
- Redding, R.W., 1988. A general explanation of subsistence change: from hunting and gathering to food production. *Journal of Anthropological Archaeology* 7, 56–97.
- Redding, R.W., 2005. Breaking the mold, a consideration of variation in the evolution of animal domestication. In: Vigne, J.-D., Peters, J., Helmer, D. (Eds.), *The First Steps of Animal Domestication*. Oxbow Books, Oxford, pp. 41–48.
- Richerson, P.J., Boyd, R., 2005. *Not by Genes Alone: How Culture Transformed Human Evolution*. University of Chicago Press, Chicago.
- Rosen, A., Rivera-Collazo, I., 2012. Climate change, adaptive cycles, and persistence of foraging economies during the late Pleistocene/Holocene transition in the Levant. *Proceedings of the National Academy of Sciences USA* 109, 3640–3645.
- Rosenberg, M., 1990. The mother of invention: evolutionary theory, territoriality, and the origins of agriculture. *American Anthropologist* 92, 399–415.
- Rosenberg, M., 1994. Pattern, process, and hierarchy in the evolution of culture. *Journal of Anthropological Archaeology* 13, 307–340.
- Rosenberg, M., 1998. Cheating at musical chairs: territoriality and sedentism in an evolutionary context. *Current Anthropology* 39, 653–684.
- Rosenberg, M., Davis, M., 1992. Hallan Çemi Tepesi, and Early Aceramic Neolithic site in eastern Anatolia: some preliminary observations concerning material culture. *Anatolica* 18, 1–18.
- Rosenberg, M., Redding, R.W., 2000. Hallan Çemi and early village organization in eastern Anatolia. In: Kuijt, I. (Ed.), *Life in Neolithic Farming Communities: Social Organization, Identity, and Differentiation*. Kluwer Academic /Plenum Press, New York, pp. 39–62.
- Rosenberg, M., Nesbitt, M., Redding, R.W., Peasnell, B.L., 1998. Hallan Çemi. Pig husbandry, and post-Pleistocene adaptations along the Taurus–Zagros arc (Turkey). *Paléorient* 24 (1), 25–41.
- Savard, M., Nesbitt, M., Jones, M.K., 2006. The role of wild grasses in subsistence and sedentism: new evidence from the northern Fertile Crescent. *World Archaeology* 38, 179–196.
- Sih, Andrew., 1982. Optimal patch use: variation in selective pressure for efficient foraging. *American Naturalist* 120, 666–685.
- Sih, A., Cristensen, B., 2001. Optimal diet theory: when does it work, and when and why does it fail. *Animal Behaviour* 61, 379–390.
- Simek, J.F., Snyder, L.M., 1988. Changing assemblage diversity in Périgord archaeofaunas. In: Dibble, H.L., Montet-White, A. (Eds.), *Upper Pleistocene Prehistory of Western Eurasia*. The University Museum, University of Pennsylvania, Philadelphia, pp. 321–332.
- Smith, E.A., 1983. Anthropological applications of optimal foraging theory: a critical review. *Current Anthropology* 24, 625–651.
- Smith, B.D., 1986. The archaeology of the southeastern United States: from Dalton to de Soto, 10,500–500 B.P. In: Wendorf, F., Close, A. (Eds.), *Advances in World Archaeology*, vol. 5. Academic Press, Orlando, pp. 1–92.
- Smith, E.A., 2004. Why do good hunters have higher reproductive success? *Human Nature* 15, 343–364.
- Smith, B.D., 2006. Eastern North America as an independent center of plant domestication. *Proceedings of the National Academy of Sciences, USA* 103, 12223–12228.
- Smith, B.D., 2007a. Niche construction and the behavioral context of plant and animal domestication. *Evolutionary Anthropology* 16, 188–199.
- Smith, B.D., 2007b. The ultimate ecosystem engineers. *Science* 315, 1797–1798.
- Smith, B.D., 2009a. Resource resilience, human niche construction, and the long-term sustainability of pre-Columbian subsistence economies in the Mississippi River Valley corridor. *Ethnobiology* 29, 167–183.
- Smith, B.D., 2009b. Core conceptual flaws in Human Behavioral Ecology. *Communicative and Integrative Biology* 2, 533–534.
- Smith, B.D., 2011a. The cultural context of plant domestication in eastern North America. *Current Anthropology* 52 (S4), S471–S484.
- Smith, B.D., 2011b. General patterns of niche construction and the management of ‘wild’ plant and animal resources by small-scale pre-industrial societies. *Philosophical Transactions of the Royal Society B* 366, 836–848.
- Smith, B.D., 2011c. Shaping the natural world: patterns of human niche construction by small scale societies in North America. In: Smith, B.D. (Ed.), *The Subsistence Economies of Indigenous North American Societies*. Smithsonian Institution Scholarly Press, Washington, DC, pp. 593–610.
- Smith, B.D., in press-a. A cultural niche construction theory of initial domestication. *Biological Theory*.
- Smith, B.D., in press-b. BE → HBE/NCT → HNCT/BE ≫ OFT/HBE ≫ OFT/HNCT ≠ OFT/TRM = HNCT/ETC. *Current Anthropology*.
- Smith, E.A., Wishnie, M., 2000. Conservation and subsistence in small-scale societies. *Annual Review of Anthropology* 29, 493–524.
- Smith, B.D., Yarnell, R.A., 2009. Initial formation of an indigenous crop complex in eastern North America at 3800 BP. *Proceedings of the National Academy of Sciences, USA* 106, 6561–6566.
- Spencer, C.S., 1997. Evolutionary approaches in archaeology. *Journal of Archaeological Research* 5, 209–264.
- Speth, J.D., 1991. Some unexplored aspects of mutualistic Plains–Pueblo food exchange. In: Spielmann, K. (Ed.), *Farmers, Hunters, and Colonists: Interaction between the Southwest and Southern Plains*. University of Arizona Press, Tucson, pp. 18–35.
- Starkovich, B.M., 2009. Dietary Changes during the Upper Palaeolithic at Klissoura cave 1 (Prosymni), Peloponnese, Greece. *Before Farming: The Archaeology of Old World Hunter–Gatherers*, 2009/3 (Article 4).
- Starkovich, B.M., Stiner, M.C., 2009. Hallan Çemi Tepesi: high ranked game exploitation alongside intensive seed processing at the Epipaleolithic Neolithic transition in southeastern Turkey. *Anthropozoologica* 44, 41–61.
- Starkovich, B.M., Stiner, M.C., 2011. Upper Paleolithic animal exploitation at Klissoura Cave 1 in southern Greece: dietary trends and mammal taphonomy. *Eurasian Prehistory* 7, 107–132.
- Stephens, D.W., Krebs, J.R., 1986. *Foraging Theory*. Princeton University Press, Princeton.
- Stiner, M.C., 2001. Thirty years on the “Broad Spectrum Revolution” and Palaeolithic demography. *Proceeding of the National Academy of Sciences, USA* 13, 6993–6996.
- Stiner, M.C., Munro, N.D., 2002. Approaches to prehistoric diet breadth, demography and prey ranking systems in time and space. *Journal of Archaeological Method and Theory* 9, 181–214.
- Stiner, M.C., Munro, N.D., 2011. On the evolution of diet and landscape during the Upper Paleolithic through Mesolithic at Franchthi Cave (Peloponnese, Greece). *Journal of Human Evolution* 60, 618–636.
- Stiner, M.C., Munro, N.D., Surovell, T.A., Tchernov, E., Bar-Yosef, O., 1999. Paleolithic population growth pulses evidenced by small animal exploitation. *Science* 283, 190–194.
- Stiner, Mary C., Munro, N.D., Surovell, Todd A., 2000. The tortoise and the hare: small-game use, the broad-spectrum revolution, and Paleolithic demography. *Current Anthropology* 41, 39–73.
- Straus, L.G., 1977. Of deerslayers and mountain men: Paleolithic faunal exploitation in Cantabrian Spain. In: Binford, L.R. (Ed.), *For Theory Building in Archaeology*. Academic Press, New York, pp. 41–76.
- Straus, L.G., 1979. Mesolithic adaptations along the northern coast of Spain. *Quaternaria* 21, 305–327.
- Straus L.G., 1986. An overview of the La Riera chronology. In: Straus, L.G., Clark, G.A. (Eds.), *La Riera Cave: Stone Age Hunter–Gatherer Adaptations in Northern Spain*. Anthropological Research Papers No. 36. Arizona State University Press, Tempe, pp. 19–23.
- Straus, L.G., 2000. Coming out from the cold: Western Europe in Dryas I and beyond. In: Peterkin, G.L., Price, H.A. (Eds.), *Regional Approaches to Adaptation in Late Pleistocene Western Europe*. British Archaeological Reports International Series 896. Archaeopress, Oxford, pp. 191–204.
- Straus, L.G., 2004. Transitions: into and out of Mesolithic adaptations along the Atlantic façade of Europe and beyond. In: González Morales, M., Clark, G.A. (Eds.), *The Mesolithic of the Atlantic Façade*. Proceedings of the Santander Symposium, Anthropological Research Papers No. 55. Arizona State University, Tempe, pp. 249–260.
- Straus, L.G., Clark, G.A. (Eds.), 1986. *La Riera Cave: Stone Age Hunter–Gatherer Adaptations in Northern Spain*. Anthropological Research Papers No. 36. Arizona State University Press, Tempe.
- Stutz, A.J., Munro, N.D., Bar-Oz, G., 2009. On increasing the resolution of the Broad Spectrum Revolution in the Southern Levantine Epipaleolithic (19–12 ka). *Journal of Human Evolution* 56, 294–306.
- Tucker, B., 2006. A future discounting explanation for the persistence of a mixed foraging–horticulture strategy among Mikea of Madagascar. In: Kennett, D.J., Winterhalder, B. (Eds.), *Behavioral Ecology and the Transition to Agriculture*. University of California Press, Berkeley, pp. 22–40.
- Ugan, A., Bright, J., Rogers, A., 2003. When is technology worth the trouble? *Journal of Archaeological Science* 30, 1315–1329.
- Wendorf, F., Schild, R., 1980. *Prehistory of the Eastern Sahara*. Academic Press, New York.
- Wiess, E., Wetterstrom, W., Nadel, D., Bar-Yosef, O., 2004. The broad spectrum revisited: evidence from plant remains. *Proceedings of the National Academy of Sciences, USA* 101, 9551–9555.
- Williams, G.C., 1992. Gaia, nature worship, and biocentric fallacies. *Quarterly Review of Biology* 67, 479–486.
- Wilson, E.O., 1975. *Sociobiology: The New Synthesis*. Harvard University Press, Cambridge.
- Winterhalder, B., 1981. “Foraging strategies in the boreal forest: an analysis of Cree hunting and gathering. In: Winterhalder, B., Smith, E.A. (Eds.), *Hunter–Gatherer*

- Foraging Strategies: Ethnographic and Archaeological Analyses. University of Chicago Press, Chicago, pp. 66–98.
- Winterhalder, B., 1983a. Opportunity cost foraging models for stationary and mobile predators. *American Naturalist* 122, 73–84.
- Winterhalder, B., 1983b. The boreal forest, Cree–Ojibwa foraging, and adaptive management. In: Wein, R.W., Riewe, R.R., Methven, I.R. (Eds.), *Resources and Dynamics of the Boreal Zone*. Association of Canadian Universities for Northern Studies, Ottawa, pp. 331–345.
- Winterhalder, B., 1986. Diet choice, risk, and food sharing in a stochastic environment. *Journal of Anthropological Archaeology* 5, 369–392.
- Winterhalder, B., Goland, C., 1997. An evolutionary ecology perspective on diet choice, risk, and plant domestication. In: Gremillion, K. (Ed.), *Plants, People, and Landscapes: Studies in Paleoethnobotany*. University of Alabama Press, Tuscaloosa, pp. 123–160.
- Winterhalder, B., Kennett, D.J., 2006. Behavioral ecology and the transition from hunting and gathering to agriculture. In: Kennett, D.J., Winterhalder, B. (Eds.), *Behavioral Ecology and the Transition to Agriculture*. University of California Press, Berkeley, pp. 1–21.
- Winterhalder, B., Smith, E.A., 2000. Analyzing adaptive strategies: Human Behavioral Ecology at twenty-five. *Evolutionary Anthropology* 9, 51–72.
- Winters, H., 1969. *The Riverton Culture*. Illinois State Museum, Springfield, IL.
- Wolf, L.L., Hainsworth, F.R., 1971. Time and energy budgets of territorial humming birds. *Ecology* 52, 980–988.
- Zeder, M.A., 2009a. The Neolithic macro-(r)evolution: macroevolutionary theory and the study of culture change. *Journal of Archaeological Research* 17, 1–63.
- Zeder, M.A., 2009b. Evolutionary biology and the emergence of agriculture: the value of co-opted models of evolution in the study of culture change. In: Prentiss, A., Kuijt, I., Chatters, J. (Eds.), *Evolutionary Theory and Processual Archaeology*. Springer, New York, pp. 157–210.
- Zeder, M.A., 2011. The origins of agriculture in the Near East. *Current Anthropology* 54 (S4), S221–S235.
- Zeder, M.A., 2012a. Pathways to animal domestication. In: Gepts, P., Famula, T.R., Bettinger, R.L., Brush, S.B., Damania, A.B., McGuire, P.E., Qualset, C.O. (Eds.), *Biodiversity in Agriculture: Domestication, Evolution and Sustainability*. Cambridge University Press, Cambridge, pp. 227–259.
- Zeder, M.A., 2012b. Religion and the revolution: the legacy of Jacques Cauvin. *Paléorient* 37 (1), 39–60.
- Zeder, M.A., in press. The domestication of animals. *Journal of Anthropological Research*.
- Zeder, M.A., Smith, B.D., 2009. A conversation on agriculture: talking past each other in a crowded room. *Current Anthropology* 50, 681–691.