Chapter 5

Holocene Hunter–Gatherers

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1. INTRODUCTION

Because Holocene hunter–gatherers are the best known representatives of the original human lifeway, they are popularly viewed as representing the whole of that lifeway. The term *Holocene* should give pause here, however, for it roughly translates in Greek as "wholly modern," and, as we shall see, Holocene hunter–gatherers constitute but a very special case of the larger pattern. Holocene hunter–gatherers do share a good deal in common with Pleistocene hunter–gatherers, but outward similarities can be deceiving. Humans share 98% of their DNA in common with chimpanzees, for example, but humans make poor chimp analogs, just as chimps are poor analogs for much of what humans do.

In the familiar radiocarbon chronology that provides the temporal framework for this discussion, the date of the Pleistocene–Holocene boundary is well established at 10,000 years (in the convention used here, 10 kya equals 10,000 radiocarbon years ago). Radiocarbon years are only approximately equivalent to calendar years, however, because the concentration of atmospheric ^{14}C has varied through time. As a consequence, the radiocarbon chronology increasingly underestimates the "true age" of events as one proceeds further back in time (e.g., Fiedel, 1999; Stuiver et al., 1998). Thus, when calibrated for this secular variation, the Pleistocene-Holocene boundary of 10 kya (i.e., in radiocarbon years) corresponds to 11,600 "calendar" years (in the convention used here, 11,600 calB.P. equals calendar years before present). The distinction in the two temporal scales must be kept in mind because most of the paleoenvironmental evidence presented here is in calendar years (calB.P.), which is necessary for cross dating evidence dated by different methods (e.g., varve counting, lichenometry, etc.). Radiocarbon equivalents are given for the more important of these dates.

Whatever temporal scale is used, the differences in natural setting and hunter–gatherer behavior before and after the Pleistocene–Holocene boundary (10 kya = 11,600 calB.P.) are notable. Holocene hunter–gatherers fielded an array of complex technologies that most of their predecessors did without. The technical connection between Holocene hunter–gatherers and those of the latest Pleistocene is quite close but the boundary between these epochs marks important differences in natural, social, and economic settings. It has been evident for some time, and increasingly so as research has proceeded in the last two decades, that Pleistocene and Holocene climate and environments differed in ways that must have significantly affected the options open to hunter–gatherers, which accounts for the character and mix of strategies one sees.

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overall layout of designs on archaeological textiles. Cognitive archaeologists, however, have gone much further than Taylor, who made no suggestions about how such research should proceed. One fruitful line of investigation is a version of the direct historical approach (Heizer, 1941; Steward, 1942; Wedel, 1938) and uses ethnographic evidence to inform interpretations about the symbolic meaning of such traditionally problematic archaeological categories as ceremonial objects (Hall, 1977) and rock art (Lewis-Williams, 1982, 1988; Whitley, 1998).

Hunter–gatherers are naturally the focal point of hunter–gatherer research, but archaeologists and ethnographers are keenly aware that all recent and many prehistoric hunter–gatherers interacted closely with agriculturalists (Spielmann et al., 1991), pastoralists (Parkington et al., 1986), and colonial empires (Wilmsen, 1989) in ways that profoundly affected their behavior and organization. The extensive body of work dealing with such situations effectively dispels the stereotype that hunter–gatherer research speaks only to the past and has no place for hunter–gatherers "tainted" by the modern world. Rather, contact situations are seen as opportunities to gain important insights into the processes of adaptation and culture change (e.g., Kent, 1995). Thus, Winterhalder (1980) perceives the introduction of Western technology (rifles, fishhooks, nets, etc.) and consequent changes in foraging behavior among Cree-Ojibwa of Canada as providing a critical test case of theory, rather than as "noise" that interferes with our ability to see the "true" Cree-Ojibwa lifeway. The change in perspective is sometimes even more fundamental. It has been argued, for instance, that extensive trade relationships and contact with farmers does not distort our view of rainforest hunter–gatherers at all, because the symbiotic trade connection between the two permits both to thrive in an environment in which neither could survive alone (Bailey et al., 1989; Bailey and Headland, 1991; Headland and Reid, 1989). Farmer–forager interactions are an important focus of archaeological research as well (e.g., Spielmann and Eder, 1994), especially in connection with the spread of farming (Rowley-Conwy, 1998a; Zvelebil, 1996; Zvelebil and Rowley-Conwy, 1986a,b). All of this work underscores a point made earlier, that Holocene hunter–gatherers had to contend with agriculturalists and agropastoralists, so much so that in many settings this interaction became a basic component of hunter–gatherer adaptation.

Many contemporary and prehistoric hunter–gatherers were organized in simple, egalitarian bands (Fried, 1967), but this is no longer viewed as the quintessential hunter–gatherer organization, merely one of a series of possibilities. Increasing attention has been given to understanding the nature and emergence of more complex, nonegalitarian hunter–gatherer social formations (Bean and King, 1974; Hayden, 1992, 1995a,b; Ingold, 1988; Price and Brown, 1985; Woodburn, 1980). In a similar way, research has revealed a substantial range of more subtle organizational variability at the simpler end of the spectrum, as the result of dynamic, rather than static, social processes occurring there (Hayden et al., 1986; Ives, 1993).

The preceding brief survey clearly fails to convey the full breadth of issues in play in contemporary hunter–gatherer research. It is enough, however, to establish that the modern view sees hunter–gatherer behavior arising from the active interplay between hunter–gatherer individuals and groups and the material and social circumstances around them. Within that perspective, it sees the Holocene as presenting hunter–gatherers with a variety of conditions, including but not limited to the rise of agriculture, that caused them to differ in important ways from their Pleistocene counterparts.

2.1. Cultural Ecology

The roots of this understanding are diverse and difficult to trace, but the works of Julian Steward and his method of *cultural ecology* were unquestionably seminal (e.g., Steward, 1938). The strength of Steward's intellect was such that, with surprisingly few data and still less mentor support, he was able to intuit a materialist logic of human adaptation that was especially well suited to hunter–gatherers (Steward, 1936, 1937, 1938). The problem Steward undertook was to understand social institutions in terms of their economic and ecological context rather than culture areas and diffusion, which was then common (Steward, 1955:78-97). The method of cultural ecology develops this materialist context from two independent givens: environment and technology. In this, it contrasts with *environmental determinism*, in which technology is dependent on (i.e., a function of) environment. The difference is significant because, for Steward, technology and environment together determine what amounts to the *effective environment*. This comprises the edible foods, places of habitation, and so forth, that are *actually* available to humans with a given technology in a given environment, as opposed to the much broader range of options that are conceivable when technological constraints are not assumed.

For Steward, effective environment and technology together determined the nature of labor (patterns of work) required for resource acquisition—its intensity, seasonal and spatial distribution, work group composition, and so forth. In turn, social and economic organization and various other elements of culture are shaped to suit the demands of the work process and other sorts of connections between technology and effective environment, the whole of this nexus comprising what Steward termed the "culture core." In his classic Great Basin example, for instance, Steward argued that the combination of sparse, patchy, and unreliable resources, on the one hand, and simple extractive technology and foot travel, on the other, had discouraged the ownership and defense of territories and the development of extensive social ties, leading to the formation of small, highly mobile, autonomous social units centering on the nuclear family. He further showed how, where bison were available, the introduction of new technology in the form of horsepower in historic times had greatly improved resource access, transforming the effective environment and patterns of work, and resulting in the formation of larger, more closely knit groups.

Cultural ecology provided hunter–gatherer studies an analytical framework that was robust, parsimonious, and, best of all, plausible. The framework, together with Steward's specific expositions, provided what Giere (1988:34–35) would term the *exemplars* (solutions that can be used to model other solutions in the same field) that were the foundation of modern hunter–gatherer studies. The theoretical landscape has changed since Steward's time, of course, but less than is widely asserted. Surely the most noticeable difference is the modern emphasis on neo-Darwinian theory. As I note from time to time in my examination of many such applications later, however, the practical differences between Steward's and these are seldom great, and the behavioral expectations are frequently identical or nearly so. Indeed, it is only in two respects—population and social relationships—that Steward's account of the cultural ecology of hunter–gatherers seems truly dated.

2.1.1. Population

Insofar as hunter–gatherers were concerned, Steward gave only passing attention to population, which he was inclined to interpret as a dependent variable, rising and falling with technological and environmental change. This is likely a function of his subject matter, which was primarily ethnographic, and hence synchronic. By contrast, population growth plays a key role in his historical scenario for the development of clans in the agricultural American Southwest, which he developed using archaeological evidence. In any event, population emerged as an important independent variable in hunter–gatherer studies in the late 1960s in connection with explanations for the origins of agriculture. In Binford's (1968) account, population growth was stimulated by late Pleistocene–early Holocene environmental changes permitting sedentism in certain favored environments. This removed natural checks on population previously imposed by residential mobility that necessitated wide birth spacing and infanticide. Population pressure grew in more marginal environments occupied by the excess population, which resulted in subsistence innovations culminating in agriculture. This narrow account was quickly incorporated in a more general hypothesis postulating a much longer trajectory of growth-induced subsistence change known as the broad-spectrum revolution, beginning well back in the Pleistocene (Flannery, 1971). The elegance of this argument, and thus the importance of population size as an independent determinant of subsistence patterns, was immeasurably enhanced by the injection of optimal foraging theory (OFT) in the 1980s (Bettinger, 1980; MacArthur and Pianka, 1966). Specifically, two models borrowed by anthropologists from evolutionary ecology—diet breadth and patch choice—were pivotal in formalizing the population argument. The motivation for this borrowing was not to embrace neo-Darwinian theory (the logic and math of OFT came from microeconomics), but a growing interest in the development of predictive models widely applicable to hunter–gatherers (e.g., Jochim, 1976).

The diet breadth and patch choice models represent a special form of OFT in which decisions are determined by momentary rates of energetic return (energy divided by time). In both cases, but at different scales, food getting is envisioned as consisting partly of time devoted to food getting proper and partly of the search or travel time required to move to locations where food getting can occur. In the diet breadth model, for instance, the time needed to spot a deer or a promising deer trail (termed *search time*) is distinguished from the amount of time subsequently required to catch, clean, cook, and consume the deer (termed *handling time*). Similarly, in the patch choice model, the time needed to travel to a place where one could hunt (termed *travel time*) is distinguished from the time actually spent hunting at that place (termed *foraging time*). To determine an optimal solution, resources (diet breadth model) or patches (patch choice model) are ranked by energetic return per unit of food-getting time, that is, excluding search or travel. The highest ranked resource or patch is always used but may be so rare that higher overall return rates can be obtained by adding lower ranked resources/patches, thus reducing search and travel. In fact, a lower ranked resource will increase overall return rates any time it produces more energy per unit of food-getting time than higher ranked resources produced overall (i.e., counting both moving and food getting). Thus use of lower ranked resources is more likely if their energetic return on food-getting time is relatively large or if high ranked resources are relatively rare. Further, the use of a lower ranked resource is independent of its abundance (how often it is encountered) and depends only on its food-getting rate relative to the food getting rate *and encounter rate* (abundance) of the higher ranked resources.

The diet breadth model explained in formal terms the role of population in the broad-spectrum and agricultural revolutions. As the abundance of larger, more profitable resources was diminished by growing populations in the late Pleistocene and early Holocene, diet had first expanded to include smaller, less profitable but frequently abundant wild resources (e.g., nuts, shellfish), and then to include domesticates that required costly tending. Equally important, the model implied that, because they were abundant, once in the diet these lower ranked resources would sustain population growth (Layton et al., 1991; Winterhalder and Goland, 1993) beyond the levels that had prompted their use initially (compare Hawkes and O'Connell, 1992). The patch choice model similarly implied that, as population growth diminished overall environmental productivity (because there were more consumers per resource), travel between widely spaced rich patches would become less profitable than foraging more intensively within fewer patches. This sedentism opened the door for additional growth directly (land use at higher density) and indirectly (decreased mobility-related infanticide). This explanation proved so successful that what had started as an explanation for a special case (Pleistocene/Holocene adaptive change) rapidly became a basic property of hunter–gatherers that was altogether beyond the vision of Steward: intrinsic capacity for population growth sufficient to cause resource stress leading to subsistence change and, potentially, technological and social change. As a result, adaptive change resulting from growth-induced resource stress, in a word, *intensification*, is the cornerstone of most modern discussions of Holocene hunter–gatherers.

The merits of such demographic explanations have been questioned from several quarters (Cowgill, 1975). As we shall see, there is good reason to question the role of population growth and resource depletion in the so-called "broad-spectrum revolution." More immediately, it is clear from recent simulation studies that the demographic relationship between hunter–gatherers and their resources is more complex than Steward and others envisioned. Both Winterhalder (Winterhalder et al., 1988) and Belovsky (1988) have suggested that hunter-gathers and their resources must oscillate inversely in what are called "stable limit cycles" that begin with few people and many resources; as the population rises, resources diminish gradually until that population is affected and begins to drop, at which point resources begin to rise, and so on. Belovsky showed that cycle magnitude and frequency are greatest with high and low resource abundance, whereas at median values they disappear almost altogether. Belovsky and Winterhalder note that these cycles create alternating periods of resource abundance and scarcity that would cause diet breadth to expand and contract. From this vantage, it is clear that, although populations and resources are connected, the relationship is complex and dynamic.

2.1.2. Social Relations

The second difference between the hunter–gatherers of Steward and the hunter–gatherers of contemporary theory is in social relationships. In a nutshell, whereas social relationships were relatively unproblematic for Steward, who saw them as responding to material conditions, the current view portrays them as a sphere of action independent of those conditions. The central issue here revolves around the logic of collective action and the potential conflicts of interest among individuals and between individuals and groups. As many have noted, until recently, anthropological accounts of human behavior often treated individual and group interests as though they were the same, that is, the individual was viewed as the group writ small, and the group as the individual writ large. The costs and benefits of given practices were tallied collectively, that is, in terms of the bottom line it produced for groups or cultures as a whole, which was used to explain the behavior of their individual constituents. Thus individual hunter–gatherers limit their take of game or their capacity to produce fledgling hunter–gatherers, because doing that maintains maximal levels of resources for them and consequently for the group as a whole.

Such accounts could be questioned from at least two theoretical perspectives, one originating with Marx, the other with Darwin. Marx, it is remembered, had noted the frequent discrepancy between benefits that individuals generated and those they actually enjoyed, and, more than that, the differences between the motives and behaviors of individuals depending on their social position (usually class) and perception of payoff structures. Thus Marxists might have been expected to question the altruism pervasive in collectivist accounts of hunter–gatherers in which homogeneous individual interests coincided with group interests. Further, one might have expected them to question the claim that, in denying their immediate self-interests, individual hunter–gatherers were generating benefits they later reaped in full as members of the group as a whole. In the event, that did not happen; at least Marxists were not the source of the challenge. The Marxist portrayal of hunting and gathering as an evolutionary stage of primitive communism prevented this. To be sure, Marxists, the structural Marxists in particular, made critical contributions to hunter–gatherer studies (e.g., Woodburn, 1980, 1982), but many were largely overlooked by archaeologists who have attended to them only recently and mostly as points of historical interest (e.g., Godelier, 1973, 1975; Meillassoux, 1973; Rey, 1979). Rather, the more effective challenge to collectivist theorizing came from neo-Darwinian evolutionary ecology. And this time the motivation was explicitly theoretical rather than merely methodological, as had been the case with OFT.

Certainly, one of the lasting achievements of evolutionary theory in the last half of the twentieth century has been in understanding the nature of cooperation and the logic of collective action. This inquiry was partly set in motion by a book by Wynne-Edwards (1962)—influential well beyond the confines of biology (e.g., Binford, 1968:326; Flannery, 1971:53)—proposing that selection between groups rather than between individuals (the default unit of Darwinian selection) accounted for a wide variety of animal behaviors that functioned to maintain population levels below carrying capacity. Anthropology was openly sympathetic to this argument, which was wholly in keeping with its tradition of functional collectivist interpretation. Combining group selection with the feedback logic of general systems theory, anthropologists and archaeologists proceeded to develop a peculiar form of explanation, termed neofunctionalism, in which cultural behaviors that outwardly seemed irrational (e.g., fanatic gift giving, divination) or disruptive (e.g., stock raiding) performed latent, group-beneficial functions. A critical premise was that the cultural logic of these behaviors, that is, the payoff structure said to motivate individuals, was largely or entirely divorced from (or at least perversely connected to) the system of material relationships—the flow of resources—that actually made the system viable. For example, the motive of Kwakiutl potlatching was prestige, whereas its material result was resource redistribution. For neofunctionalists, then, the role of culture was to conceal the true nature of payoffs (i.e., resource flow) to prevent its subversion by self-interested individuals (e.g., Rappaport, 1971:32). Thus culture, in the quest for status, deceives the Kwakiutl chief into thinking that bestowing resources on others in return for prestige is solely in his own self-interest, when the material reality is that this serves the interests of others at his expense (though he, too, benefits as a member of a functioning group). This function-concealing emphasis of neofunctionalism approximates the Marxism concept of mystification, except that for neofunctionalists cultural mystification benefits the group as a whole and leads to equilibrium, whereas for Marxists it does not, benefiting only powerful special interests, leading eventually to system collapse.

The neofunctionalists, of course, had good reason to think that unchecked individual self-interest might often prevent the development of behaviors beneficial to groups. Indeed, it is doubtful they could have made their case that culture provided that check without evidence that group selection was acting in nature, which suggested the presence of analogous checking forces there. Unfortunately, while they labored to restructure anthropology under the mandate of group selection (e.g., Vayda and Rappaport, 1968), the concept rapidly lost ground in natural sciences against more parsimonious explanations arising from simple selection acting on individuals (e.g., Williams, 1966) or on groups of closely related individuals, that is, through kin selection (Hamilton, 1964; Maynard Smith, 1982, 1991). Then, entering through the door that the neofunctionalists had conveniently opened from the other side, the evolutionary biologists argued that these same individual-level processes predominated in the human sphere (Wilson, 1978) and that their structure frequently prevented beneficial human cooperation (e.g., Hardin, 1968, 1982).

In the classic prisoner's dilemma, for instance, convicts chose between cooperating in digging a tunnel to escape, which takes time that is wasted if they are caught, or snitching on a tunnel-digging cellmate in exchange for a reduction in sentence that sets them free sooner than tunneling. In that case, whereas cooperation produces the greatest group benefit (both cellmates escape scot-free), snitching produces a better—risk and cost free—return for the individual convict. Thus, rather than digging, the prisoners stand around waiting for signs of digging they can report; no one escapes and everyone serves out a full term. Failure to cooperate in this case does not arise from ignorance of the payoff structure or the fear of snitching. It arises because the payoff structure for individuals makes snitching the best strategy whether one's cellmate is a digger or a snitcher. Snitching here is what is called an evolutionary stable strategy (ESS). Snitching increases when it is rare and cannot be displaced (invaded) when common—it simply beats digging every time. Such game scenarios have proven quite useful in evolutionary biology and are surely applicable to human behavior. Thus even if one agreed with the neofunctionalists that it was unnecessary, indeed frequently impossible, to document the origin of a group beneficial behavior (Vayda and Rappaport, 1968), one would still need to *imagine* the plausibility of it evolving at all, and subsequently persisting, in the presence of potential counter-strategies.

There is nothing like this in Steward's work, although he was less committed to collectivist interpretation than many of his contemporaries (witness his characterization of Shoshonean culture as "gastric" and driven almost exclusively by self-interest). Indeed, he took more or less for granted that, where hunter–gatherers had access to abundant resources, self-interest would cause some to gain unequal access to them and these individuals would come to dominate, control, and exploit others. Within the limitations imposed by self-interest, he viewed primitive collective action mainly as an economy of scale, occurring when groups could do something that individuals could not, or do it more efficiently. From this vantage, what is new in our current understanding of hunter–gatherer social relationships is not the concern with self-interest and manipulation of power, which, as Steward shows, is traditional, but rather the rephrasing of this concern in careful models that reveal unexpected consequences of these forces in even the simplest of settings, as in the prisoner's dilemma. Neo-Darwinians have played a major role here, but so have Marxists (Testart, 1982, 1987; Woodburn, 1980) and others who are harder to classify (Ingold, 1980, 1988).

2.2. Summary

The modern view of hunter–gatherers modifies classic cultural ecology in three ways. First, it broadens Steward's basic culture ecological equation to make room for demography and social dynamics as forces equivalent in importance to environment and technology. Second, the modern view rejects the notion that any of these forces is truly independent. Rather, each is seen as being linked to the others in relationships that make them alternately independent and dependent. For Steward, environment and technology acted as independent variables to define a more or less concrete carrying capacity, hence population size. In the modern view, population and environment are coupled in a system of mutual feedback that causes population and resources to oscillate inversely in ways that render the static concept of carrying capacity meaningless (Winterhalder et al., 1988). Sometimes resources limit population, sometimes it is the other way around; neither is cleanly dependent (or independent). Similarly, while Steward was interested in demonstrating the dependent nature of social organization, it is clear that, as much as technology, entrenched social arrangements may determine what is doable in a given techno-environmental context. In the prisoner's dilemma, social arrangements make tunneling undoable despite the requisite environment, technology, and manpower. Third, the modern view uses the concept of *adaptive strategy* to simplify the analysis of these complex relationships. Adaptive strategies are unified combinations of settlement, subsistence, organizational, and demographic tactics that optimize one or more goals (e.g., risk reduction, time minimzation, energy maximization) that promote hunter–gatherer success in a wide range of techno-environmental settings.

The enduring contribution of Steward's cultural ecology is as a program of hunter–gatherer research. Murphy (1970) observes that, in the last analysis, Steward was not arguing that environment and technology were all that mattered, simply that they were a good place to start, which is the tact followed here.

3. Holocene Environment

In classic culture ecological analysis and the modern view alike, the force of environment is seen as acting through the various resource-centered procurement systems that together determine the larger subsistence–settlement system and seasonal round of a group (e.g., Flannery, 1968). The scope of the present subject naturally precludes such a resource by resource, group by group analysis. Even to inventory the specific environments occupied by Holocene hunter–gatherers would require more space than is available. It is possible, however, using coarse proxy measures of mean productivity, and temporal and spatial variation in productivity, to glimpse some of the climatic and environmental qualities that distinguish the Holocene from previous periods in ways that must have affected hunter–gatherers. As noted in the introduction, except in far Oceania (and, of course, Antarctica), humans were successfully ensconced in all the forests, steppes, deserts, wetlands, and littorals of the world by the beginning of the Holocene (10 kya). This diversity of natural setting (i.e., environmental diversity across space) constitutes the strongest effect of environment on Holocene hunter–gatherers. Pleistocene hunter–gatherers inhabited a roughly comparable, though less productive, range of settings but were more profoundly affected by globally synchronous climatic change (i.e., environmental variability through time).

The evidence attesting to these Pleistocene/Holocene environmental contrasts derives from a variety of sources, most importantly marine sediment and polar ice cores (e.g., Dansgaard et al., 1982; Jouzel et al., 1987; Kerr, 1998) that document changes in temperature and atmospheric composition evidently in response to multiple forcing (causative) mechanisms (e.g., Genthon et al., 1987). Of these, orbital or Milankovitch forcing is the best understood and most explicitly modeled (Milankovitch, 1941). Changes in the earth's orbital geometry affect the amount and spatial and seasonal distribution of solar insolation in cycles, including one of about 100,000 years, due to changes in orbit shape (more elliptical to more circular); a second of about 41,000 years, due to change in axis tilt to plane of orbit (from 24.5° to 21.5°); and a third of about 19,000 years, due to changes in axis wobble affecting precession of the equinoxes. In theory, the interaction of these orbital cycles is sufficient to produce gradual, large-scale global climatic change on the order of those that characterize the transition between glacial and interglacial climatic regimes, hence the difference between the Holocene and the preceding (Wisconsin) glacial 65,000 to 10,000 calB.P. Within the Holocene, the most notable climatic change attributable to orbital forcing is in equability as measured by annual range in temperature: between 12,000 and 8000 calB.P. (≈ 10.2 to 6.7 kya) winters were colder and summers warmer than today in the northern (but not southern) hemisphere, with the maximum summer–winter difference occurring around 9000 calB.P. (≈ 7.7 kya; Figure 5.1C; Kutzbach and Webb, 1993). This diminishing equability has been held to account for megafaunal extinctions in North America and the emergence of agriculture in the Near East. Since both of these events were relatively drastic and short term, one must assume that critical thresholds were exceeded irreversibly. For the most part, however, major responses to Milankovitch-linked climatic/environmental change, like the cycles themselves, should be long term and gradual and, within the Holocene proper, essentially directional and trendlike. For this reason, apart from the annual changing of the seasons themselves, orbital forcing per se should be less important to hunter–gatherer behavior than other mechanisms capable of producing more rapid climatic change.

The importance of suborbital climatic forcing has been recognized only recently, almost entirely as the result of the intensive study of the marine sediment and polar ice cores mentioned earlier. The temporal resolution of these records is qualitatively better than that of those previously available, which makes it possible to track annual to decadal (and in some cases even seasonal) change in a variety of isotopic, chemical, and biotic proxies for temperature, precipitation, wind speed and direction, and the like, at various points around the globe. While these records show long cycles of change consistent with orbital forcing (Barnola et al., 1987), they also reveal highly patterned, large-scale variations that are too rapidly paced to be orbital in origin. Recognition of this has led to what has been called the "light switch" model of global climate change (Oppo, 1997). Rather than shifting gradually from one climatic extreme to another and then gradually back, as traditionally envisioned, in this model climate exists in either of two states: cold-dry or warm-wet. Within the cold-dry phase, for example, conditions gradually deteriorate, becoming progressively colder and drier, and then abruptly switch to the warm-wet state, becoming dramatically warmer and wetter within just a decade or a few decades (Figure 5.1 A and B). Conditions then become gradually colder and then abruptly colder and drier, switching to the cold-dry state, again in a matter of decades. These Dansgaard–Oeschger cycles show marked periodicity, occurring roughly every 1500 years, the warm phase of every two to four such cycles being preceded by a Heinrich event in which vast glacial ice armadas are launched into the North Atlantic (Mayewski et al., 1993, 1997).

The forcing mechanism behind all of this remains unclear. The most widely accepted model relates Dansgaard–Oeschger cycles to the transfer of heat via ocean water from the tropics to the North Atlantic, where cooled, salty ocean water sinks to form North Atlantic

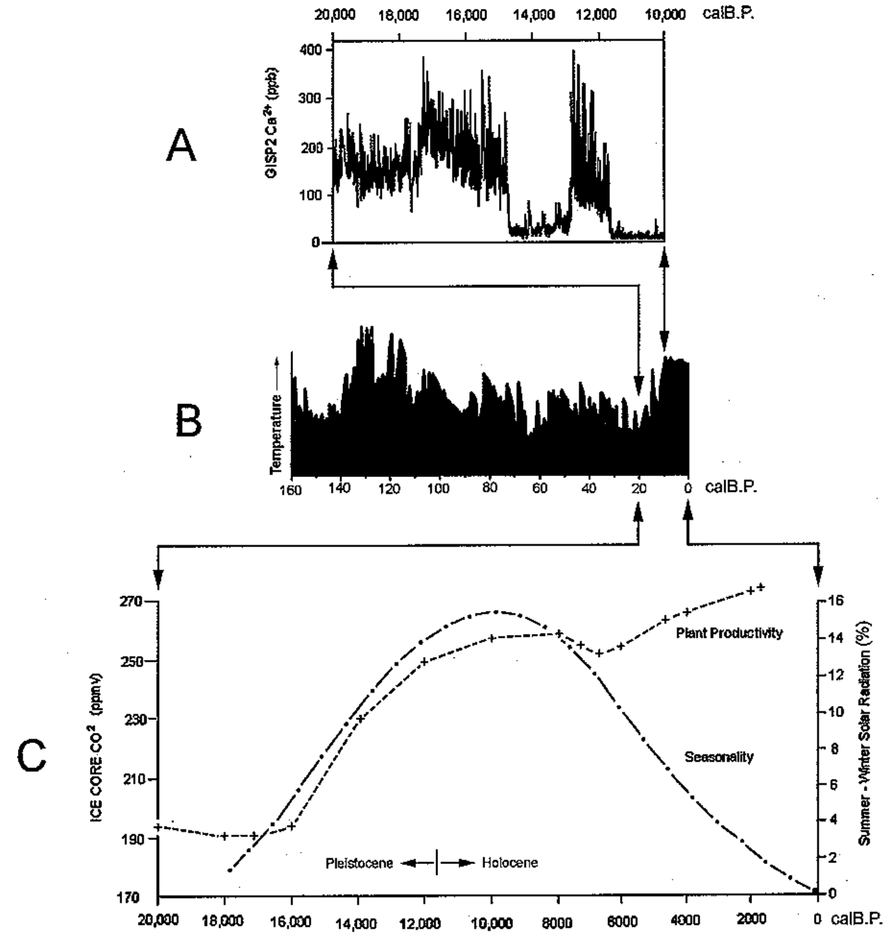

Figure 5.1. Pleistocene and Holocene climatic variability, seasonality, and plant productivity. **A:** High-resolution plot of calcium concentrations in Greenland ice core for the interval 20,000 to 10,000 calB.P.; high values indicate cold, dry conditions (Mayewski et al., 1993). **B:** Lower resolution plot of temperature for the last 160,000 years from Greenland ice core (Kerr, 1993). *C, left:* CO^2 concentrations over the last 20,000 years in Vostok (East Antarctica) ice core; plant productivity increases with higher concentrations (Barnola et al. 1987). **C, right:** Difference between summer and winter solar radiation relative to the present; seasonality is most strongly marked between 12,000 and 8000 calB.P. (Kutzbach and Webb, 1993). **A** and **B** demonstrate the dramatic climatic variability and the rapid change from near-glacial to interglacial conditions during the Pleistocene relative to the quiescent Holocene. The onset and termination of the near-glacial Younger Dryas (12,900 to 11,600 calB.P.) occurred over intervals of just 10 to 20 years.

deepwater (NADW), which returns south to upwell in the tropics, where it is again heated and moves north (Broecker, 1992). Halting this deepwater heat conveyor belt would cause dramatic global cooling. It has been argued that mass wasting of glacial ice in the North Atlantic might do this by generating fresher, lighter seawater that would not sink to form NADW. This is consistent with the ice core and sediment records, which show the Pleistocene to be dramatically more variable than the Holocene (Figure 5.1A), chiefly as a consequence of Dansgaard–Oeschger oscillations. Careful inspection of new cores and ones previously studied, however, shows that Heinrich events and switchlike Dansgaard–Oeschger cycles spaced at intervals of roughly 1500 years characterize the Holocene and Pleistocene interglacials as well as Pleistocene glacials, and thus cannot be attributed to glacial ice dynamics (Bond et al., 1997; O'Brien et al., 1995).

The amount of climatic change experienced within the two dozen Dansgaard–Oeschger episodes that occurred between 110,000 and 15,000 calB.P. was surely enough to affect hunter–gatherers. During such episodes conditions changed from full glacial to interglacial or near-interglacial conditions in just a few decades, with air temperatures rising by as much as 5° to 8° C (Oppo, 1997). The magnitude of change was evidently heightened in some as yet unknown way by the presence of Pleistocene glacial ice. Although similarly paced and switchlike, the amount of change has been an order of magnitude smaller during Holocene Dansgaard–Oeschger episodes, making the Holocene as a whole distinctively and abnormally quiescent in comparison to the Pleistocene (Figure 5.1A). As with Dansgaard–Oeschger change itself, this transition to quiescence was abrupt, occurring over a few decades at most, sharply terminating the Younger Dryas (12,900 to 11,600 calB.P., ≈ 10.8 to 10 kya), a typically "Pleistocene" interval of erratic, decadal-scale climate change. After 11,600 calB.P. (10 kya) climate change also became progressively less temporally and spatially coherent. The global synchronicity characteristic of Pleistocene climatic change was largely gone by 5600 calB.P. (≈ 4.7 kya); after that, climate change became globally asynchronous, varying locally in timing, severity, and duration (Mayewski et al., 1997; O'Brien et al., 1995). This extends evidently to ocean water, there being no evidence of El Niño/Southern Oscillation prior to the mid-Holocene (Sandweiss et al., 1996; Wells et al., 1997).

Holocene environments also differed from their Pleistocene counterparts in basic productivity. Polar ice cores show the Holocene atmosphere to have been almost a third richer in CO_2 than at any time during the preceding 120,000 years, rising from 190 to 250 μmol mol^{-1} between 15,000 and 12,000 calB.P. (≈ 12.7 to 10.2 kya; Figure 5.1C; Barnola et al., 1987). Given the critical role of CO_2 in plant growth, this enrichment likely increased photosynthetic activity, biomass and seed yield, nitrogen fixation, and efficiency of nutrient and water uptake and use by 25% to 50% (Sage, 1995). In short, Holocene plants were more productive and cold and drought tolerant than Pleistocene plants.

All of these climatic changes have important implications for hunter–gatherers; in combination they make the onset of the Holocene a landmark event 10 kya that was a critical watershed for hunter–gatherer lifeways. After 10 kya hunter–gatherers lived in a world that was abnormally productive and stable—uniquely different from the one inhabited by their anatomically modern human predecessors. This is reason enough to suggest that the behaviors of Holocene and Pleistocene hunter–gatherers were organized in fundamentally different ways. One can safely conclude, for instance, that the behaviors of Pleistocene hunter–gatherers, insofar as they reflect environment, responded more to temporal than to spatial environmental variability. The rapid and dramatic nature of Pleistocene climate change simply overwhelms the importance of spatial differences in environment, suggesting an adaptation of Mark Twain's quip: "If you don't like the weather just wait a minute." Put more concretely, Pleistocene hunter–gatherers must have had the technological and behavioral capacity needed to thrive, or at least survive, in both *full glacial* and *full interglacial* conditions. One suspects, too, that they may have accomplished this by being highly mobile "niche chasers," moving rapidly across the landscape to keep pace with abrupt changes in climate.

The Holocene climate made no such demands. As the magnitude and spatial extent of climatic change dropped sharply within the Holocene, hunter–gatherer behaviors became increasingly more affected by immediate location, opening the door for more diverse and specialized tactics and strategies. With increasing temperateness of climate, hunter–gatherer populations likely grew (Keeley, 1988:Table 2) and at the same time became more dependent on plants (Belovsky, 1987: Figure 5; Keeley, 1992:32). By increasing plant productivity, CO_2 enrichment independently reinforced these tendencies exponentially. In short, all of these climatic differences tell us that plants must have been vastly more important to Holocene than Pleistocene hunter–gatherers, and why. They also tell us that, with reduced climatic variability, the status of women probably increased (Hayden et al., 1986), and that, probably for the first time in human history, in many places men came to depend on women for their food (Belovsky, 1987:Figure 7).

4. Holocene Technology

Technology is a stock of production assets—goods, services, and knowledge—that is diverted from immediate consumption to increase future consumption, in other words, as a form of capital (Firth, 1964). For hunter–gatherers, it is always the dominant, and largely the only, form of capital. In cultural ecology, the amount and kind of technological capital defines a range of feasible options in any environment and shapes the forms of labor needed to harness them. The bow, for instance, is limited to use on prey that must be sighted and closely approached, requires the trailing of struck prey over distances proportional to their size, and, more than the atlatl, lends itself to small prey and individualized hunting. It is, of course, impossible here to review the whole of Holocene hunter–gatherer technology in this way, just as it was impossible with Holocene environments. Still, as with environment, it should be possible to identify some basic patterns and ask whether Holocene hunter–gatherers were doing anything radically different. The possibilities for this are naturally limited because Holocene technology incorporates the full range of Pleistocene technology and is bound to be "Pleistocene" in character (whence the common characterization of ethnographic hunter–gatherer technology as "Paleolithic"). There are surely quantitative differences in technological variety and complexity, but that is to be expected, because technological innovation is a function of population size, which is a function of environmental productivity, which, as we have seen, is much higher in the Holocene. The more interesting question is whether there are any qualitative differences between Pleistocene and Holocene technology suggesting major Holocene innovations that rivaled or eclipsed the impact of climatic change. Were there any major Holocene technological breakthroughs? ?

4.1. Holocene Inventions

As defined here, a major technological breakthrough is one that fundamentally restructures the effective environment of a whole technocomplex (sensu Clarke, 1968), removing broadly limiting constraints on production costs (e.g., rate of return) or production limits (e.g., amount of return). One expects such innovations to spread rapidly and entrain basic changes in subsistence, settlement, and social organization. For example, development of the ability to control, and especially to produce, fire certainly counts as such a major Pleistocene breakthrough, as does the invention of the spear and later the atlatl

(Davidson, 1989). In that sense, the groundstone, microblade, and ceramic technologies that archaeologically herald the Holocene in various regions of the Old World technically cannot qualify because they either developed during, derive from trajectories that developed during, or represent abilities present during the Pleistocene (Figure 5.2). Microblades clearly increased in abundance with the onset of the Holocene in Africa and Eurasia, but just as clearly developed out of Pleistocene blade traditions and, more to the point, within the Pleistocene proper. At any rate, producing microblades seems not to have been a great difficulty—groups along the California coast without any prior blade-making tradition developed them in short order when the need arose, for example (Arnold, 1986). Groundstone plant processing and wood working tools are similarly anticipated by Pleistocene finds (e.g., edge-ground axes and grinding tools by ca. 20 kya in Australia), indicating humans grasped the simple principles that were involved long before the Holocene. In the same way, the fired clay "Venus figurines" from Dolni Vestonice (ca. 26 kya) and the small vessels of the Japanese Incipient Jomon (12.7 kya) demonstrate that Pleistocene hunter–gatherers knew enough about fired clay to make rudimentary containers, much as did myriad "aceramic" Holocene hunter–gatherers who limited their use of fired clay to other objects: figurines, boiling stones, etc.

The late Pleistocene appearance, and Holocene proliferation, of these technologies is surely connected directly with the dramatic climatic changes mentioned earlier. In fact, it is easy to see microblades, groundstone, and ceramics being brought into play to facilitate subsistence–settlement shifts that responded to increasing environmental stability and biotic productivity (Bettinger et al., 1994). These adaptive changes—and dependence on fish, game, and plants - may have first taken firm hold 12.7 to 10.8 kya (15 to 12.9 calB.P.). This was an interval of Holocene-like quiescence during which rising CO_2 levels dramatically increased plant productivity just as orbital forcing was producing more clearly defined seasons, precisely the conditions under which one would anticipate technological specialization (Figure 5.1C).

Less clear is why small, previously low-ranking resources such as fish and plants should have come to be the focus of this specialization. After all, OFT predicts that an increase in overall resource abundance should result in a narrowing of diet breadth to include only high-ranking resources, not low-ranking, which should be *deleted* from the diet. Indeed, as we have seen, this inclusion of low-ranking species is often cited as presumptive evidence that population increase, hence decreasing resource abundance, was responsible for the so-called "broad-spectrum revolution." Instead, as we have seen, overall abundance (encounter rates) of all resources almost surely increased. Why, then, the inclusion of low-ranking species? Very likely this was due to the effect of increasing productivity that increased the return rates (i.e., on food-getting time) of resources taken by mass capture and procurement (e.g., gregarious game and seeds). In contrast to resources taken individually, the return rates, hence ranking, of these (mass capture) resources increases dramatically with density (Bettinger, 1993; Madsen and Schmitt, 1998). As we have seen, the archaeological record suggests such mass-capture technologies were already present in many places during the Pleistocene, being pressed into service when resources were scarce. Given that backdrop, increasing biotic productivity in the early Holocene likely reshuffled resource rankings as diet breadth narrowed and became more selective, producing local resource specializations that, taken altogether, have perhaps given the misimpression of a population-induced broad-spectrum revolution (i.e., expansion of diet breadth) to which Henry (1989:13–20) refers.

IN HOLOCENE, INC. PRODUCTIVITY
OF PLANTS INC. THEIR RANK

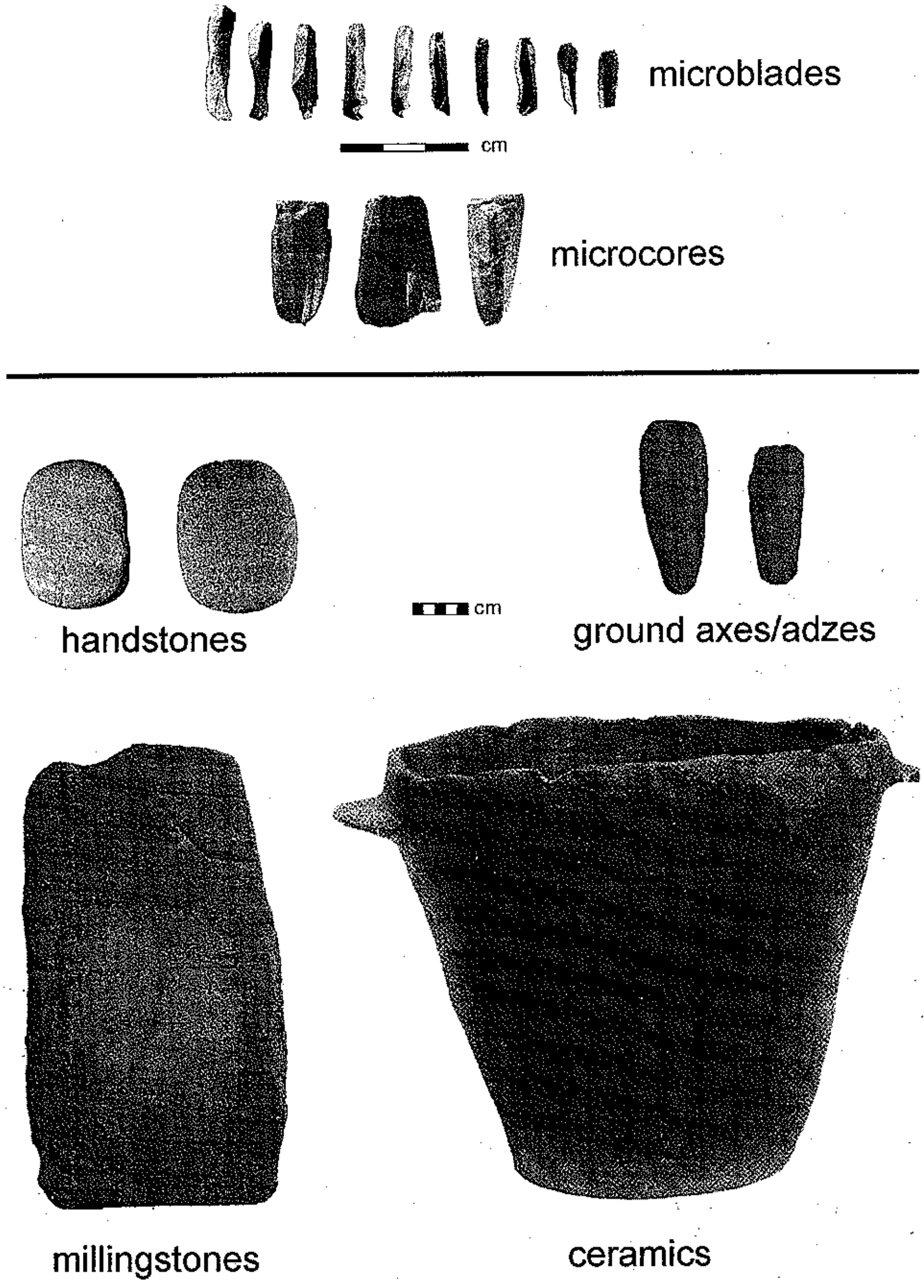

Figure 5.2. Hallmark Holocene hunter–gatherer technologies: microblades and microcores, groundstone plant processing tools (handstones and millingstones), ground axes/adzes, and ceramics. All of these technologies have Pleistocene antecedents.

Returning to technology, microblades, ceramics, and groundstone all make good sense not as major innovations, but as adaptations of Pleistocene technology that facilitated the procurement and processing of monotonously productive, mass-capture resources at intensities anticipating those of early agriculture. I am inclined to see most of the other technological changes that occurred at the Pleistocene–Holocene boundary in much the same way, as responses to climatically induced environmental change, rather than as the consequence of radical innovations in hard technology, as Hayden (1981, this volume) suggests. Unquestionably, such innovations in trapping (e.g., nets, snares, pitfalls, deadfalls), fishing (nets, hooks, harpoons, weirs; e.g., Clark, 1952; Price, 1983; Smith and Bonsall, 1991), and plant procurement (e.g., sickles) contributed incrementally to success in coping with Holocene abundance, but their impact was likely an order of magnitude less than that of climate.

4.1.1. The Bow and Arrow

Insofar as hard technology is concerned, the bow is the only reasonable candidate for a major Holocene hunter–gatherer breakthrough. The weapon of choice for hunter–gatherers from the arctic to the equator as well as for state-level military organizations until the invention of gunpowder, it was clearly a breakthrough. The bow is a complicated device that the record suggests was invented once and subsequently maintained and spread globally by social transmission (Blitz, 1988). On its assumed connection with microblade technology, many have argued that it was present in Europe and elsewhere during the final Epipaleolithic. The earliest sure evidence in the form of notched shafts (Bratlund, 1991; Rust, 1943) is 10 kya, by which time indirect evidence (e.g., delicate projectile points) places it throughout much of the Old World (e.g., Elston et al., 1997; Valla, 1995:182). But there are no unequivocal data, however, that would place it significantly before 11.6 kya (e.g., Bokelmann, 1991). It was not in the technological inventory of New World Paleoindians, hence either not in Arctic Asia in time to cross with them, or at the time too crudely developed to be of use when large game were common, bow wood scarce, and tool kits pared to a minimum. Remarkably, despite its continued and general use throughout Eurasia after 10 kya, it came to the Americas south of the Arctic only after 2 kya. This failure to diffuse cannot be attributed to want of demand. When it did arrive, it spread south rapidly, in many places completely supplanting the atlatl within a century or two, as if New World hunter–gatherers had been waiting for it all their lives (e.g., Thomas, 1983:Figure 66).

The revolutionary effect of the bow is more easily seen in the late Holocene New World than in the early Holocene Old World, where these effects are confounded with the welter of other adaptive shifts connected with post-Pleistocene climatic change. There are good reasons for thinking that in the New World the bow profoundly changed hunting patterns and, perhaps more fundamentally, social relationships. There is good evidence, for example, to suggest that diet breadth expanded to include smaller game and larger game at greater distances, making hunting both more productive and more reliable, encouraging hunters and their families to be "loners." In some places the surfeit of large game distributed to the community at large seems to have been enough to permit the accumulation of privately held plant resources (Bettinger, 1999a). Apart from that, the bow made individual males and groups of males more capable of defending themselves and attacking others, raising the overall threshold of New World violence (e.g., LeBlanc, 1997; Maschner, 1992). In short, the effect of the introduction of the bow in the New World was in all respects that of a major technological revolution. Presumably, the effects were equally significant in the Old World, although, as we have said, they are impossible to segregate from the effects of climatic change during the period of its introduction there. The question arises, of course, as to why the bow did not reach deeper into the New World sooner than it did.

One explanation is that the spread of the bow in the New World was contingent on the perfection of the sinew binding and reinforcement necessary to cobble together a workable composite form in the treeless Arctic, through which bow technology had to pass in order to enter the Americas. Alternatively, since these techniques must have been present when the bow first spread from Asia through Alaska to the northern Arctic with the Arctic Small Tool Tradition 4.5 kya, only to disappear in Arctic Canada, perhaps it required adaptations that emphasized land game or small game, or more individualized hunting techniques. Either way, the transfer involved distinctively Holocene social and adaptive barriers. Simply put, the bow could not be passed to midlatitude and tropical New World hunter–gatherers other than by groups with specialized adaptations to the Arctic. On this count, one is inclined to think that, with less adaptive specialization and greater mobility, technological innovations may have spread more rapidly in the Pleistocene. Conversely, as Holocene adaptations became more specialized, hard technology was increasingly liable to spread directly by the physical movement of populations rather than indirectly, by person to person, group to group, social transmission. This is because, as hunter–gatherer adaptation becomes more specialized and complex, hardware by itself (sheer technical capacity) decreases in importance relative to the software that produces and mobilizes technology—the adaptive strategy and its social, economic, and political accoutrements. Because they coordinate many disparate and potentially conflicting spheres of interest (e.g., hunting versus gathering, subsistence versus prestige), adaptive strategies resist cultural transmission piecemeal, trait by trait (Bettinger, 1994:542; Bettinger and Baumhoff, 1982). Accordingly, it will often be true that for a hard technology to move the adaptive strategy must move with it, which is easiest with population movement. Thus the bow initially came to Alaska, the Canadian Arctic, and Greenland as part of an adaptive whole (Arctic Small Tool Tradition), and was later reintroduced to Canada and Greenland (where it had fallen into disuse) as part of the larger adaptive package that characterized Thule expansion (McGhee, 1984).

· NOT IF THEY WERE THIN
· ALSO IT'S RELATIVE TO MOBILITY
?

It emerges, then, that the really important innovations of Holocene hunter–gatherers are more likely in adaptive strategies than in hard technology. Indeed, if population densities changed drastically as a function of increased resource abundance in the Holocene, one is bound to see novel strategies and tactics, simply because adaptive strategy and population density are inextricably related; strategies and tactics that work at one density may fail at higher densities. However, granting that populations probably grew, all Holocene strategy change is not thereby accounted for, as though it were some sort of conditioned reflex. Indeed, strategy change is never inevitable and always requires explanation, because, as we have just said, adaptive strategies are set up in ways that inherently resist restructuring, whatever the benefits.

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Just as it is important not to think of individuals as groups writ small, it is important here not think of groups as regions writ small, giving special priority to regional population densities. Whereas strategy success depends on regional population, individual group size is really an element of strategy determined by conventions and tastes often having little directly to do with subsistence and regional demography. That individual motives may prevent group beneficial strategy change, as in the prisoner's dilemma, is obviously a possibility. Paradoxically, even group beneficial cooperative behaviors themselves may be coordinated in ways that defy change. Many ethnographic hunter–gatherers maintained access to territories and resources by supporting larger populations through storage and sedentism, two key tactics that became prevalent only in the Holocene. Neither involves any real "trick." To become sedentary: "stop moving." To store resources: "don't eat' em; put 'em away for later." The premise is simple, yet neither can happen without complete restructuring of resource rights and priorities and social relationships. The advantages of well-built, permanent shelters and residential housing (another trait common only in the Holocene) seems equally straightforward, yet O'Connell (1979) shows how forms of social organization, conflict resolution, and refuse disposal that are common to hunter–gatherers can militate against their adoption, even among groups that have become essentially sedentary.

5. Holocene Adaptive Strategies

It should be clear from this discussion that my meaning of adaptive strategy does not imply that subsistence, technology, resources, and population are all that matter. They are important, of course, because in the last analysis these things largely determine winners and losers, and adaptive strategies are the linchpin connecting them. However, no more than potsherds, adaptive strategies cannot reproduce, although they can be reproduced by individuals who do—provided they are generally successful in getting food, finding mates, producing offspring, and passing along all the critical information and behaviors. Adaptive strategies are part of this larger whole and constrained by it. This is why the present discussion has moved from technology to adaptive strategy: very little of technology makes any sense absent the notion of what the technology is suppose to "do." Adaptive strategies provide that context.

Holocene resource abundance may not have guaranteed population increase, but certainly increased its chances. And, although one may quibble over the details, it is clear that on the whole hunter–gatherer population densities did increase during the Holocene, although not everywhere at the same rate or time. What we are interested in, then, are the adaptive strategies connected with this growth. The forager–collector model provides a convenient point of departure.

5.1. Foragers and Collectors

The major elements of the forager–collector model are well known. On the premise that population/resource ratios mattered most of all, Binford (1980) proposed a continuum of hunter–gatherer adaptive strategies for coping with unfavorable population/resource mismatches in space (too many people or too few resources at a place) or time (too many people or too few resources in a season). The severity of both increases as resources decrease. This is obviously true for spatial mismatches, since, holding population constant, a uniform decrease in resources means less per person everywhere. It is also true for temporal mismatches because, as a rule, decreasing environmental productivity implies short growing seasons, and hence distinct periods of resource abundance and scarcity that increase the probability of temporal mismatches between population and resources.

Spatial and temporal mismatches are unproblematic if environmental productivity is high, which favors the simpler *forager strategy*. If the growing season runs year round, the problem of temporal mismatches vanishes. Then the problem of too many people or too few resources is mostly due to local resource exhaustion, which can be solved simply by moving the residential base, that is, by moving people to resources. Such *residential mobility* will not solve the problem, however, if environmental productivity is so low that sometimes no one base camp produces enough food to go around. In such environments, it becomes necessary to use the base camp as a central place from which task groups radiate, targeting resources of different kinds that can be brought back and pooled, a practice that is termed *logistical mobility*. The division of foraging tasks by sex (hunting by men, gathering by women) generally ensures daily logistical procurement even where resources are abundant (as among foragers), but as productivity drops, logistical procurement changes form and increasingly involves camping and resource processing away from home, which characterizes the more complex *collector strategy*, in which resources are moved to people. If productivity is so low that there are distinct periods in which resources are insufficient, storage is required. Storage tethers groups to resource stores, increasing reliance on logistical procurement, and requires more intensive, excess procurement for storage. Technology changes in concert with settlement and subsistence patterns. As the use of resources becomes more seasonal and intensive, technology becomes more specialized and is frequently made ahead of time during periods of "gearing up," then stored for future use (curated). In sum, where resources are available in reasonable quantity year round, one expects the simpler foraging strategy: high residential mobility, nonintensive resource procurement, and relatively simple and generalized procurement technology. Where resources are highly seasonal and at some times scarce or altogether unavailable, one expects the more complex collector strategy: relatively stable residential bases, logistical procurement staged from nonresidential settlements, and more complex and specialized procurement technology.

The San-speaking !Kung of southern Africa are nearly always chosen to exemplify the forager strategy. Resources cannot be said to be abundant in the desert environment they occupy, but daily hunting and gathering provide all basic dietary needs year round. As a consequence, the !Kung are residentially mobile, moving camp when local resources play out, save in the dry season when they are tethered to permanent water. They do not store food, relying on the low bulk inputs of daily foraging, approximately 70% of which by weight is plants. Technology overall is quite simple, especially that connected with plant procurement and processing, which is mainly digging sticks, carrying nets and bags, nut-cracking stones and anvils, and metal cooking pots. Hunting technology is similarly limited but more sophisticated in that it consists of, in addition to simple spears and clubs, snares and a low-power self-bow with unfletched, metal-tipped, poisoned arrows. Dwellings are simple brush huts during seasons when available water permits mobility, and slightly more complex thatched pole and lattice huts at dry season settlements, which are of longer duration.

As with the !Kung, the Nunamiut of Alaska are frequently chosen to exemplify the collector strategy. Arctic resources are quite limited, and the most attractive of these are highly seasonal. As a consequence, unlike the !Kung, the Nunamiut rely heavily on stored food. No less than 70% of the food they consume is obtained in just 30 days of spring and fall caribou hunting (Binford, 1978). Given this time constraint, the technology needed to accomplish this is understandably complex: binoculars, rifles, and metal traps (formerly bow and arrow, spears, and traps and snares). Tethered to these stores, the Nunamiut nevertheless manage to make use of a much larger area through the use of snowmobiles (formerly sleds), processing kills in the field to economize on transportation costs. In contrast to the !Kung, who use essentially the same tools and implements year round, Nunamiut technology constantly cycles in and out of use.

Although the essence of the forager–collector concept is straightforward, its archaeological implications are not. That is because, as Binford (1980) notes, the forager–collector model implies a continuum of behavioral combinations in which there can be much seasonal and situational mixing and matching of mobility and technology, as opposed to a simple forager versus collector dichotomy. Thus it is possible to find collectorlike tactics among the foraging !Kung (e.g., occasional logistical hunting), just as it is possible to find foragerlike tactics among the collector Nunamiut (e.g., certain times of high residential mobility). That the transition from forager to collector (or the other way around) is gradual, then, complicates archaeological distinction. For this reason, the model works best when applied to specific behaviors or tactics—technology, for instance.

5.1.1. Forager and Collector Technology and Risk

Although the concepts of time stress and risk are fundamental to the forager–collector model, Torrence (1983, 1989) was among the first to investigate their implications for subsistence technology specifically. She argues that risk—probability of failure—is greatest with resources that are seasonal, mobile, and aquatic, prompting the use of more specialized and more complex procurement technology to reduce that risk. This is sensible, not only because more specialized technologies increase return rates and reduce their variability, but also because specialization makes these return rates increasingly independent, spreading risk over more kinds of activities, thus reducing variation in pooled returns. Torrence supports this argument using data from Oswalt (1976), which show that, as reliance on risky resources increases with latitude among ethnographic hunter–gatherers, so does the diversity (number of tools and facilities) and complexity (number of parts per tool/facility) of subsistence technology. However, by separating the effects of latitude and resource type, Bamforth and Bleed (1997) found that, while technological diversity increases with seasonality (temporal incongruity) as Torrence suggests, technological complexity does not. It is mainly an inverse function of subsistence alternatives, being greatest where resource options are limited. This, too, makes sense, since the price of failure is greatest where fallback substitutes are few; hence risk cannot be countered by diversifying subsistence effort.

The Z-score model provides a measure of risk that incorporates both this cost of failure as well its probability. In the Z-score model (Bettinger, 1991a; Stephens and Charnov, 1982; Winterhalder, 1986a, 1986b), the probability of resource shortfall is calculated as the standardized normal deviate of the shortfall threshold (r_{min}) relative to the mean (μ) and the standard deviation (s) of expected return,

$$Z = (r_{min} - \mu) / s \qquad (1)$$

Since Z will be negative when expected return is above the threshold level (i.e., $\mu > r_{min}$), and positive when it is not, it follows that risk-sensitive hunter–gatherers should be Z-minimizers (note that Eq. 1 is sometimes written as $Z = [\mu - r_{min}] / \sigma$, in which case hunter–gatherers should be Z-maximizers). Note that standard deviation affects the magnitude of

Z but not its sign. Therefore, increasing standard deviation will reduce Z when Z is positive (i.e., by making Z a smaller positive number), implying reduced risk. Conversely, increasing standard deviation will increase Z when Z is negative (i.e., by making Z a smaller negative number), implying increased risk. In other words, activities with variable outcomes are not inherently risky relative to activities with less variable outcomes. For example, in Table 5.1, even though activity A has higher standard deviation (and lower mean) than activity B, when the shortfall threshold is 2 (i.e., $r_{min} = 2$), they entail exactly the same probability of resource shortfall, hence are equally risky. In general, when expected return is *below* the shortfall threshold, a more variable activity is less risky than a less variable one with the same mean (compare B and C). By contrast, when expected return is *above* the shortfall threshold, a less variable activity is less risky than a more variable one with the same mean (compare D and E). Finally, activities E, F, and G demonstrate that the shortfall threshold, the quantity of resources an activity must provide, also determines the amount of technological risk—the higher the threshold, the greater risk, as Bamforth and Bleed (1997) argue.

5.1.2. Reliability and Maintainability

Not all risk is the same, of course. While Torrence seems primarily concerned with the risk that tools may fail to do their job *this time* (i.e., they may be *unreliable*), Bleed (1987) notes that there is also the risk tools may break so badly they cannot be fixed and used *next time* (i.e., they may be *nonmaintainable*). Many have speculated that time-stressed collectors should be relatively more concerned with reliability, while foragers, being less time stressed, should be more concerned with maintainability, but this holds only in a relative sense. The forager–collector model clearly implies that risk thresholds of both kinds will be absolutely greater for collectors than foragers. Maintainability, for instance, is surely more critical to collectors attempting to maximize harvest of plants or migratory waterfowl than for foragers not dependent on the bulk acquisition of these same resources.

Table 5.1. *Z*-Scores for Activities Whose Expected Returns Differ in Mean (u) and Standard Deviation (std), Expressing the Probability an Activity Will Return Less Than a Specified Shortfall Threshold (r_{min})[a]

Activity	Shortfall Threshold (r_{min})	Mean of Return (u)	Standard Deviation of Return (std)	Z-Score	Probability of Shortfall
A	2.0	0.5	1.5	1.0	0.84[b]
B	2.0	1.0	1.0	1.0	0.84[b]
C	2.0	1.0	2.0	0.5	0.69
D	2.0	3.0	2.0	–0.5	0.31[b]
E	2.0	3.0	1.0	–1.0	0.16[b]
F	3.0	3.0	1.0	0.0	0.50
G	4.0	3.0	1.0	1.0	0.84

[a]A and B are equally likely to return less than 2.0 kg. C is more than twice as likely to result in shortfall as D. E, F, and G represent the same activity under different shortfall requirements. As these increase, so does the probability the activity will fail to meet them.
[b]Optimal

Holocene lithic assemblages vary in ways that can be related to these kinds of risk and provide an opportunity to track the dimensions of behavior that distinguish foragers from collectors in the archaeological record.

The edge-ground and blade-based technologies that characterize the early Holocene in various parts of Eurasia provide a fitting starting point. Both are highly circumscribed in time and space worldwide (Hayden, 1981, 1987), suggesting they arose only in the presence of specific conditions. In these cases, maintainability seems to have been of paramount importance. Both technologies are supremely maintainable, indeed, they are entirely without parallel in this regard (Zvelebil, 1993). Composite microblade armatures and harvesting tools were quite reliable (worked well), to be sure, but the ease of replacing worn/broken elements with near duplicates pressed from small and highly portable cores was arguably more important. Microblades are no sharper than other kinds of flakes, nor do they conserve more raw material than flakes produced by bifacial retouch, but they are unquestionably more uniform, lending themselves to substitution (Flenniken, 1987). Adding to this, both core preparation (e.g., Bamforth and Bleed, 1997) and flake removal (e.g., Flenniken, 1987) are highly controlled and very sure (i.e., low risk). The same is true of edge-ground implements. Resharpening is relatively uncomplicated, produces very regular edges, and is essentially risk free in comparison to, say, percussion-retouch, which involves the possibility of catastrophic errors. As we noted much earlier, where these technologies are found in the early Holocene, they make the most sense when connected with the bulk acquisition of seasonally abundant resources, especially smaller and more costly to handle fish, birds, rodents, and seeds. The emphasis here would be on resources taken continuously over a season rather than in a specific episode. The evidence for this is rather clear in China, where microblades occur only in highly seasonal environments, specifically where range in annual temperature is greater than 30°C (Bettinger et al., 1994).

Reliability was important with these technologies, but there are reasons to question whether it was paramount. It is commonly supposed, for instance, that the sharpness of microblades makes them ideal for efficient mass plant harvesting (i.e., stalk cutting). However, that microblades, although present, were never used for this purpose by the intensive wild plant harvesters and agriculturalists of China suggests there may be superior alternatives. This raises the possibility that the use of microblades for plant harvesting in the Near East is more historical than functional—a convenient application of a preexisting microblade technology developed to do other things. Indeed, the denticulation of Near Eastern sickle blade segments (Gopher, 1995:Figure 2) suggests that their sharpness may not maximize harvesting effectiveness (i.e., reliability), although it clearly sufficed in most cases. Similarly, that blade tools produce surgically clean incisions suggests that less regular, more serrated edges would do more damage when used against game. Thus it is perhaps not surprising that the blade-making Clovis hunters (Green, 1963) of North America (11.6 to 11 kya) chose to tip their weapons with bifacial points, not blade segments. Since encounters with mammoths were presumably less frequent and more critical than encounters with the game targeted by early Holocene microblade users (e.g., forest and plains ungulates, migratory birds, etc.), one is inclined to argue that the bifacial projectile is more reliable when the chips are down. Bifacial points, of course, are maintainable, too, since they can be resharpened (Flenniken and Wilke, 1989), but their use-lives are clearly shorter than those of composite tools with replaceable parts.

Would this make early Mesolithic hunters collectors and Clovis hunters foragers? Clearly not. As we have said, the forager–collector model is not a dichotomy but rather a series of tactical, in this case technological, alternatives for coping with varying degrees of population–resource mismatches in time and space. In the larger scheme of things, both Clovis bifacial technology and Eurasian microblade technology suggest the presence of high risk thresholds, but of differing duration, that were compensated by sophisticated lithic technology. Where thresholds are lower, simpler technologies suffice. If thresholds are very low, for example, one expects a simple expedient core technology: amorphous cobbles are repeatedly percussion-struck, producing a mass of flakes, a very small fraction of which are then selected for desired size and edge characteristics (e.g., White, 1968). This is wasteful of raw material, perhaps, and such flakes may not be exactly the right shape, but this is of little matter if the task at hand is undemanding and suitable raw material is readily available (threshold levels are low). As task demand increases (e.g., for bulk acquisition), one expects to see more parsimonious use of raw material and more uniform flake production involving careful core preparation, as well as the production of more formal and specialized tool forms. Such trajectories are visible in many Holocene lithic sequences around the world, but in most places the hunter–gatherer contribution is cut short by the appearance of agriculture. This is not so for the western Great Basin of North America and Australia, two arid settings where hunter–gatherers dominated from start to finish.

In both places there is evidence for substantial population increase from very low early Holocene densities to much higher ones in the late Holocene. In Australia, this occurs in the mid-Holocene (ca. 7 to 4.5 kya), and more significantly after about 3 kya (Beaton, 1990; Lourandos, 1993). In the western Great Basin, on the other hand, there would appear to be moderately steady increase until about 1.5 kya, when the population rose very sharply (Bettinger, 1999b). In both places these population increases have been tied to more intensive use of resources. Thus one is inclined to expect a shift from more foragerlike behaviors to more collectorlike ones. Surprisingly, in neither place did lithic sequences move steadily from more expedient core technologies to more costly, but reliable and maintainable, prepared core, blade core, and bifacial technologies. Rather, in both places the trajectory was from simpler to more complex until an interval of late Holocene intensification, when the trend reversed.

Some basic differences in the overall composition of Australian and western Great Basin Holocene lithic assemblages are worth noting at the outset. Most notably, expedient core technology was substantially more important throughout the Holocene in Australia than the western Great Basin. Conversely, bifacial projectile points and knives were substantially more important throughout the Holocene in the western Great Basin (and the New World as a whole) than Australia. Despite these overall differences, the Australian and western Great Basin sequences (both very much simplified here) both demonstrate heavy reliance on shaped percussion cores, core tools, and scrapers in the early Holocene (Figures 5.3 and 5.4; Basgall, 1993; Bettinger, 1999a; Bowler et al., 1970; Hiscock, 1994; Morwood, 1984). In the western Great Basin, projectile points (dart points) were comparatively rare, and bifaces only moderately abundant at this time. In both cases, the picture is one of relatively high mobility and moderately low risk thresholds favoring reasonably simple prepared-core lithic technology. From here, assemblages in both places became more sophisticated and specialized with the incorporation of more specific formal tools later in the Holocene.

In Australia, this is known as the Small Tool Tradition (Figure 5.3), developing between about 6.5 and 3 kya, and characterized by small backed blades, percussion-retouched

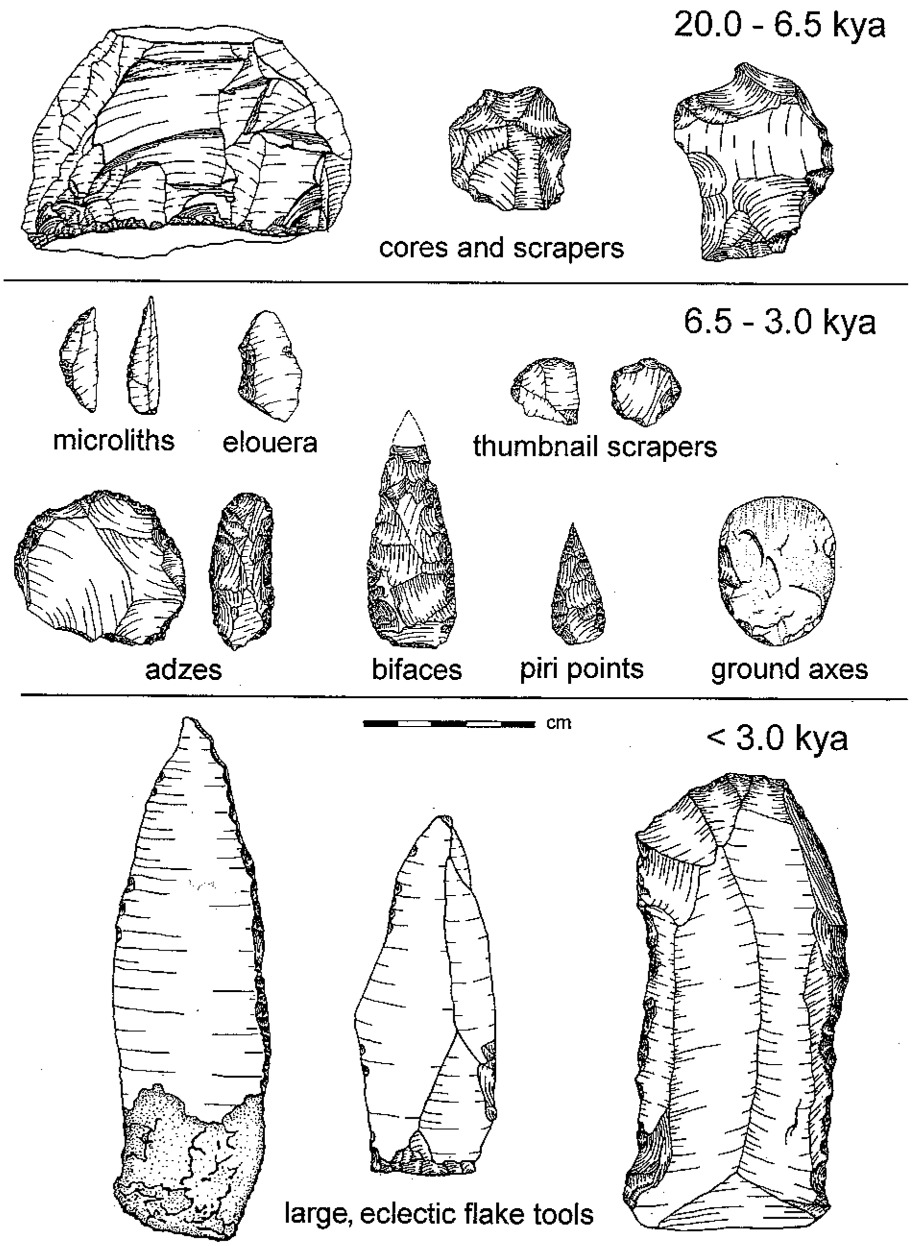

Figure 5.3. Holocene lithic technologies of Australia (after Morwood, 1984; White and O'Connell, 1982). Much simplified, scraper and core forms, dominant before 6.5 kya, diminished in relative importance after that, but persisted through the sequence. Tools shown for the period 6.5 to 3 kya constitute what is known as the Small Tool Tradition. Most of them became rare or disappeared altogether after 3 kya, with the exception of adzes, also known as *tula*, which are prominent in ethnographic toolkits. The large, eclectic flake knives and scrapers characteristic in some places after 3 kya have antecedents likely connected with the Small Tool Tradition.

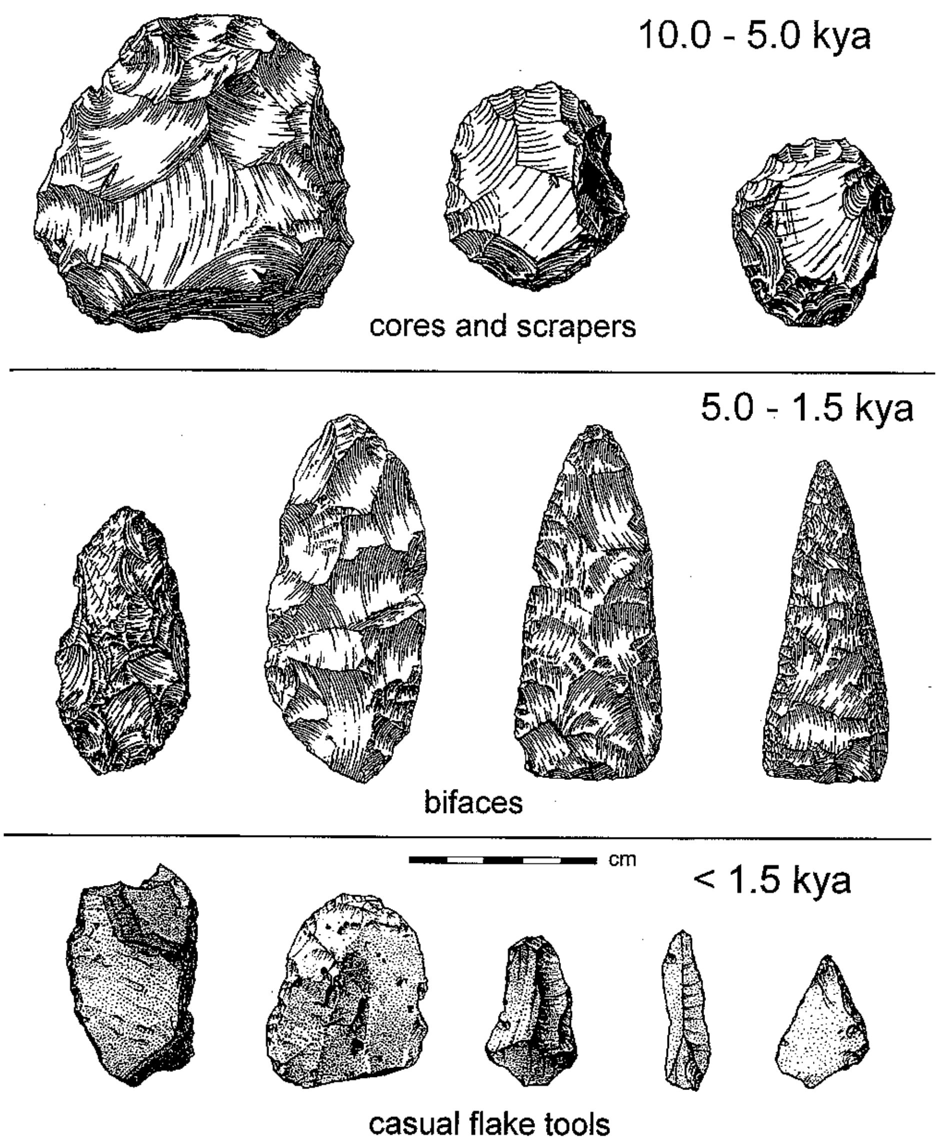

Figure 5.4. Holocene lithic technologies of the western Great Basin of North America (Basgall, 1993; McGuire and Hall, 1988). Cores and scrapers dominated early Holocene assemblages but subsequently diminished in relative and absolute abundance. Bifaces dominated archaeological assemblages from 5 kya until 1.5 kya, when they were eclipsed in importance by casual flake tools, but both were common assemblage components throughout the Holocene. Assemblage change was mainly in relative tool type frequencies, which changed as a function of adaptive strategies. Most specimens illustrated here date prior to 5 kya.

and hafted adzes, edge-ground axes, and bifacial and unifacial points (Hiscock, 1994; Morwood, 1984). The trajectory is analogous, but occurred slightly later, in the western Great Basin. Between about 5 and 1.5 kya formal projectile points (again dart points) and especially bifaces became dominant, while more generalized core tools, scrapers, and cores, diminished in importance (Figure 5.4). In both cases, high discard rates and increasing tool formalization suggest an emphasis on tool reliability rather than tool maintainability (Bettinger, 1999a; Hiscock, 1994; Hiscock and Attenbrow, 1998). Finally, in Australia after about 3 kya there was a reversal to what is sometimes called the Lesser Retouched Tradition (Figure 5.3). Unifacial points largely disappeared; other formal tool types decreased in absolute and relative abundance; and casual flake tools increased accordingly, along with an eclectic array of elongate flake knives and scrapers, some of which are linked to plant consumption (e.g., Hiscock and Attenbrow, 1998:6; Morwood, 1984; O'Connell, 1974). Much the same thing happened in the western Great Basin, but again slightly later, at 1.5 kya. Formal tools—bifaces, scrapers, core tools, and cores—became much less abundant and casual flake tools much more abundant in these assemblages, relative to those of the early and middle Holocene (Figure 5.4). Projectile points (now arrow points), however, also increased in relative abundance.

A surprisingly similar trajectory (again, very much simplified) is apparent in South Africa (e.g., Deacon, 1984; Parkington, 1984; Sampson, 1974), where lithic assemblages 12 to 8 kya (Albany, Oakhurst, Lockshoek) are poor in formal tools, which consist mainly of large cores and flakes that are sometimes retouched as scrapers and denticulates (Figure 5.5). Between 8 and 3 kya the frequency and standardization of formal tools increased dramatically in assemblages (Wilton) that include small, finely worked scrapers, adzes, and backed microliths, including forms essentially identical to those of the Australian Small Tool Tradition (e.g., Clark, 1959:177, 234). As in Australia and the western Great Basin, frequency and standardization of formal tools decreased in the late Holocene, after 3 to 2 kya, especially on the coast, where the principal stone artifacts were adzes connected with plant procurement (Mazel and Parkington, 1981) and large scrapers, reminiscent of late Holocene Australian examples (Deacon, 1984:310–315, Figures 13, 14; Sampson, 1988).

Hiscock (1994) has noted the striking correspondence between the Australian trajectory and the one Parry and Kelly (1987) document for Mesoamerica and the Eastern Woodlands, Plains, and Southwest of North America, in which expedient core technology replaced formal core (biface and prepared core) technology between 3 and 1.4 kya. Parry and Kelly attribute this to changes in mobility, specifically the reduction in risk attending the shift to sedentary lifeways associated with increasing reliance on agriculture. In the Australian case, Hiscock argues that populations expanding into new, unfamiliar areas in the middle Holocene developed the more reliable tool kits of the Small Tool Tradition to counteract the risks entailed by this move. He argues that increasing familiarity with these environments, increasing sedentism, and a subsistence shift from large to smaller game reduced these risks, thus relaxing the technological necessity to maintain formal tools, just as Parry and Kelly argue for North America and Mesoamerica. Significantly, Hiscock (1994) argues the Australian shift was also the result of increasing familiarity with plant resources specifically, for example seeds, that became important only after 3 kya (Smith, 1986). Plants, and especially small seeds, clearly figure in the western North American pattern, too, as shown by plant processing tools, which became dominant assemblage elements only in the late Holocene. The same trend is evident in South Africa, where Parkington (1984) suggests that truly intensive reliance on plants, such as characterizes the ethnographic San, began as recently as 2 kya. From this vantage, the Australian, North American, South African, and Mesoamerican trajectories share much more in common than just decreasing mobility. In all of these cases, increasing reliance on more expedient technology is also associated with increasing reliance on either wild or domesticated plant resources and growing population. Thus while the changes in lithic technology are connected with mobility, the root cause is change in diet, in particular increasing reliance on

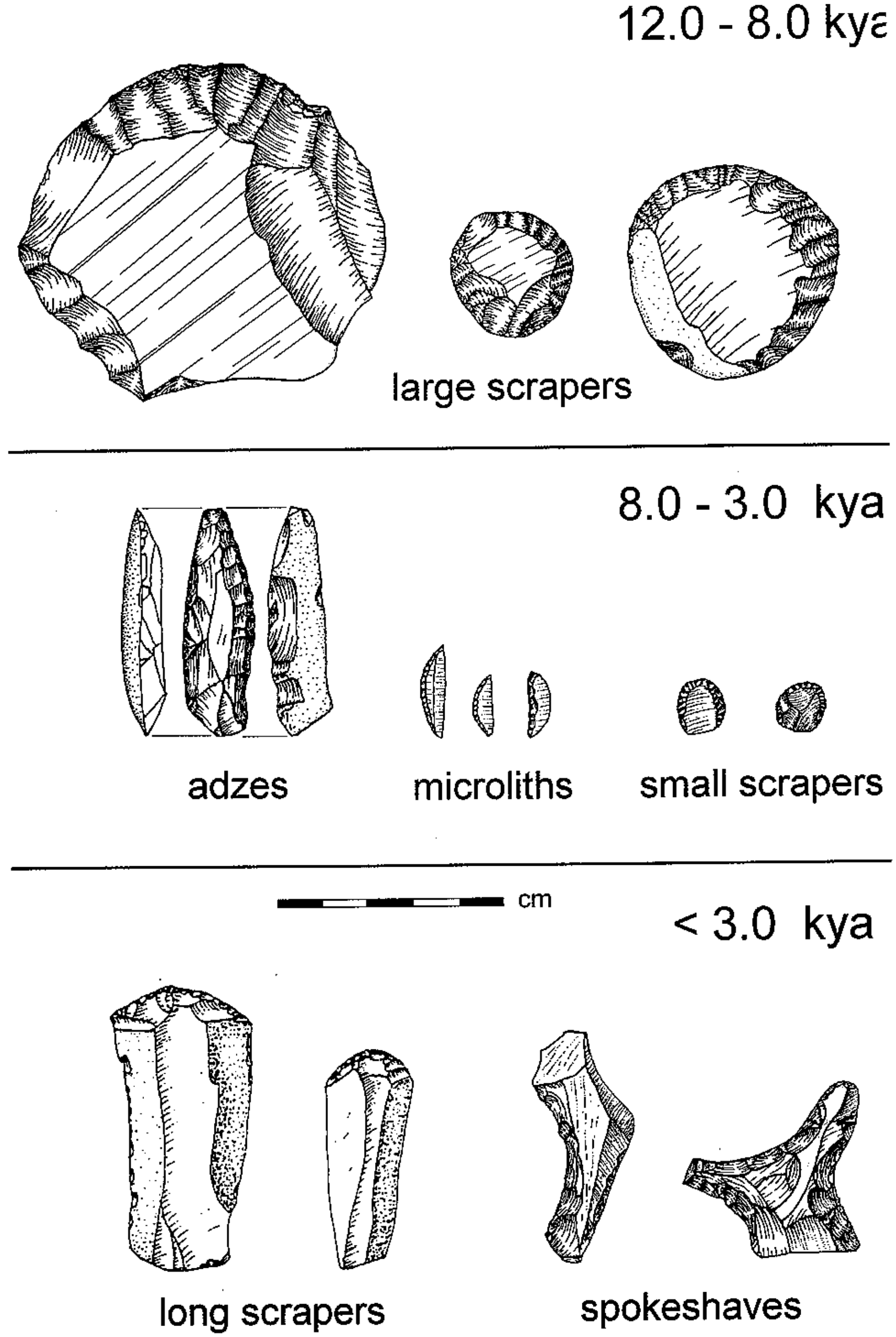

Figure 5.5. Holocene lithic technologies of South Africa (after Deacon, 1984). As in Australia and the western Great Basin of North America, large scrapers and core scapers were the initially dominant formal (albeit relatively rare) tool form. Between about 8 and 3 kya formal tools, including very small scrapers, backed tools, and adzes, increased in frequency. Formal tool frequencies declined after 3 kya, except for adzes and scraper forms likely connected with plant procurement.

plant resources whose procurement and processing does not require much in the way of chipped stone tools (Abbott et al., 1996; Bettinger, 1999a). It is difficult to ignore the possibility that population growth is ultimately connected with all these changes.

As we have said and shown, at least for Australia and the western Great Basin of North America, hunter–gatherer populations almost certainly increased during the Holocene, which surely affected the viability of different adaptive strategies. This is a problem for the forager–collector model because it is crafted to deal with environmental, not demographic, variability. The chief difference between foragers and collectors, for example, is that the latter store to offset seasonal shortages as environmental productivity diminishes. However, shortages due to environmental productivity and those due to population increase differ fundamentally; the former are seasonal, the latter are not. Similarly, although Binford is quite right that increased population reduces opportunities for residential mobility, increased reliance on logistical mobility is not thereby guaranteed, since growing population limits these opportunities as well. For instance, the San-type forager pattern of limited logistical mobility can be seen mainly as a late prehistoric response to Khoi pastoral incursion that limited residential and logistical mobility at the same time (Parkington, 1984; Parkington et al. 1986). The point is not that the tactics of foraging and collecting are unrelated to population density, but rather that these relationships are ambiguous in the forager–collector model, which was developed specifically to understand hunter–gatherer tactical response to variations in the natural environment. To do so, it necessarily relegated a population to the status of a dependent variable. The traveler–processor model is better suited to understanding how population increase might affect the kinds of changes observed in Holocene lithic technology.

5.2. Traveler–Processor Model

The traveler–processor model (Bettinger, 1999a; Bettinger and Baumhoff, 1982) unites the diet breadth and patch choice models of optimal foraging theory to clarify how population growth and resource depletion affect the way hunter–gatherers allocate time, use space, and acquire energy. Recall from the brief description at the start of this chapter that both the diet breadth and patch choice models distinguish between food-getting time (in diet breadth = *handling time*; in patch choice = *foraging time*) and time spent moving to places where food getting can occur (in diet breadth = *search time*; in patch choice = *travel time*). Both resources and patches are ranked by energetic yield per unit of food-getting time only. Starting with the highest ranked choice, lower ranked choices enter the optimal set if the resulting decrease in time spent moving to food-getting places (search or travel) is enough to offset the increase in time spent in getting food. It is easy, then, to calculate the effect of resource depletion because resource abundance directly affects search and travel time, leaving handling time unchanged.

Because only search time (and not handling time) is affected, diet breadth changes transparently with resource depletion: it expands to include resources that are more costly to procure and process. In the patch model, however, depletion increases *both* foraging time (because search increases) *and* travel time (fewer resources means more moves between patches) with contradictory implications. The increase in foraging time favors more selective patch use; the increase in travel time favors less selective patch use. Because of this, the effect of depletion on patch choice will hinge on the proportion of foraging time that is given to searching, and whether this proportion varies by patch. If these proportions do vary, depletion may change patch rankings. For example, depletion has no effect on return rates in patches where foraging is given entirely to procurement and processing (i.e., there is no search time); it only decreases the amount of time spent in the patch (less resources means less procurement and processing). Therefore, resource depletion may elevate the rank of such patches relative to patches in which foraging is mostly given to searching, which increases with depletion, thereby reducing return rates. Overall, then, resource depletion changes patch choice in greater or lesser degree depending on the fraction of subsistence effort devoted to procurement and processing.

Specifically, then, if foraging consists entirely of search (i.e., no procurement and processing in any patch), depletion will leave both patch ranking and patch choice unchanged. This is because foraging time (consisting here only of search time) and travel time will increase in equal proportion for all patches. Conversely, if foraging consists entirely of procurement and processing (no search in any patch), patch ranking will again remain unchanged because foraging time (involving no search) is unaffected, but patch choice will expand (in the same way that diet breadth expands) to include lower ranked patches. Finally, between these extremes, if foraging is a mixture of search, procurement, and processing, and patches differ markedly in amount of search relative to procurement and processing, three things will happen as depletion increases. First, as we have said, patch rankings will change. Second, patch choice will increasingly *exclude* patches with high search times. Third, patch choice will increasingly *include* patches where foraging entails more costly procurement and processing. The traveler–processor model tracks these changes in diet breadth and patch choice simultaneously as resource abundance changes in response to growing population.

When high-quality resources are abundant and the population is small, relatively more time is spent traveling between rich resource concentrations or "patches," and in searching for high-quality resources within these patches, than is spent actually procuring and processing these resources. Given these conditions, as resources grow locally scarce, groups pick up and move camp to richer patches, via residential mobility. This is the *traveler strategy*. Moving the family camp in this way, however, is less effective as more people compete for the same resources. Competition decreases the attraction of distant resource patches as a consequence of the possibility they may already be occupied or their resources depleted. In the sense that a rising population decreases the advantages of moving camp, it makes within-patch foraging increasingly less costly relative to other opportunities that require travel. Thus we may say that a rising population reduces the *opportunity cost* of within-patch foraging; it reduces the chance that a group that stays put to forage within its patch will regret having done so. Faced with this, rational hunter–gatherers should spend less time traveling between patches, expanding patch choice to include lower quality patches, where search time or procurement and processing time are higher. Further, because more food must now be obtained in one large patch (i.e., without moving), or a set of closely spaced patches (by logistical mobility), the range of resources used (or diet breadth) will increase to include lower quality resources, which take more time to procure and process. Accordingly, within the patch, less time is spent searching for high-quality resources and more time procuring and processing lower quality resources. Logistical procurement involving separate camps becomes uneconomical as these conditions grow more severe, because procurement is increasingly directed toward low-quality resources that are so time consuming to process it becomes cheaper to reside and consume resources at locations of procurement (Barlow and Metcalfe, 1996; Bettinger et al., 1997). This is the *processor* *strategy*. When this trajectory of depletion is taken to its logical conclusion, there is little or no travel between patches and foraging is devoted wholly to procurement and processing—which is the processor strategy taken to its sedentary extreme. The trajectory of intensification, then, is essentially a matter of deferring subsistence costs by shifting the weight of expenditure continually from earlier to later stages of the foraging process—from travel to foraging, from search to procurement, and from procurement to processing.

The transition from traveler to processor is attended by a fundamental change in the logic of subsistence. For travelers, resources are relatively abundant; it is time that is in shortest supply. For processors, it is just the opposite: energy is in shortest supply. Because that is so, travelers will minimize the amount of time invested in subsistence, devoting as much as they can to other vital activities: finding, attracting, and defending mates; childcare; and the like. When pressed, travelers will initially maintain existing patterns of resource and patch use and intensify through time-minimizing tactics—trying to do more in the same amount of time, for example, by dividing labor in more specialized ways, by logistical procurement, by making and using more specialized tools in ways that sacrifice raw materials but save time (i.e., higher discard rates). There are limits to this. If densities rise further, and free access to resources diminishes, logistical procurement may become infeasible, for instance. Because there are now more consumers per patch, harvesting efficiency (as measured by fraction of available resources actually harvested) ultimately increases to the point that energy becomes more limiting than time. For processors, it is the overall energetic yield that can be obtained from fixed amounts of space that most determines choices about where they live and what they do. Because resources are more valuable than time, processors will intensify through time-costly procurement and processing methods that maximize yields over extended periods.

5.2.1. Implications for Holocene Hunter–Gatherers

The traveler–processor model implies that where hunter–gatherer populations grew during the Holocene, as they evidently did in Australia, South Africa, and the western Great Basin of North America, energy acquisition increasingly replaced time saving as the fundamental goal of subsistence behavior in three phases. First, in a *nonintensive* traveler phase, travel, search, and, especially processing, time is relatively easy to minimize because population densities are low. Second, during an *intensive* traveler phase, it becomes increasingly difficult to minimize travel and search time because population densities have risen without significant change in patch choice and diet breadth. Third, in a processor phase, acquiring energy is far more critical than minimizing time because patch choice and diet breadth have changed to accommodate still higher population densities. The three-stage lithic trajectories described earlier for Australia, western North America, and South Africa can be linked to these phases. In particular, the high discard rates and formalized lithic technology of their middle stages conforms to the intensive time-minimizing phase, when time is most constraining, and is consistent with the notion that risk is involved, as Hiscock (1994) argues. This risk, however, is very likely the result of population growth that had stretched travelerlike strategies to their limit (Hiscock and Attenbrow, 1998). Following this, subsistence and settlement both changed in ways that made energy more limiting than time, which characterizes the processor strategy with its increased emphasis on plant processing and decreased emphasis on time-saving lithic technologies, especially those connected with hunting.

Just as differences of climate/environment make Holocene hunter–gatherers poor analogs for Pleistocene hunter–gatherers, then, population growth makes ethnographic hunter–gatherers poor analogs for time-minimizing hunter–gatherers of the early and middle Holocene. The traveler–processor model implies that *all* ethnographic hunter–gatherers fall at the processor end of the spectrum, being energy maximizers rather than time minimizers. Of course, this prediction is in direct contradiction to arguments (e.g., Sahlins, 1968) that ethnographic hunter–gatherers generally are, in fact, time minimizers (but see Winterhalder, 1990), just as it is at odds with the suggestion that the !Kung specifically enjoy abundant resources, which should make saving time more important than acquiring energy (but see Hawkes and O'Connell, 1981; Lee, 1969). Nevertheless, the argument that the !Kung pattern should be more processor-like than travelerlike does make sense if, it is recalled, it appeared in response to pastoral incursion that greatly limited mobility and access to resources. It is not possible, however, to test these alternatives by observing patch choice and diet breadth among the !Kung, as Hawkes et al. (1982) have done for the Paraguayan Aché, and O'Connell and Hawkes (1984) have done for the Australian Alyawara. That is because the patch choice and diet breadth models use return rates (e.g., time/kcal), rather than absolute quantities, to determine optimality. Because of this, an optimal diet (or patch itinerary) is at once energy maximizing and time minimizing; doing one guarantees the other. Linear programming makes it possible to disentangle the two.

5.3. Linear Programming Models of Ethnographic Hunter–Gatherer Diets

Whereas neither the diet breadth nor patch choice models asks whether an optimal solution actually produces enough calories to survive, that is the central issue in the linear programming models of hunter–gatherer diets. In its simplest form, such a model consists of two alternative choices. In Figure 5.6 these are two kinds of foods, specifically vegetables and meat, the quantities of which are treated as the X (vegetable) and Y (meat) coordinates of a graph. The origin in the lower left corner of the graph represents zero quantities of both foods.

The heart of such a model is in its constraints. In the hunter–gatherer diet model, these represent specific quantities of important currencies (e.g., nutrients, calories, time, and stomach capacity) that must be met (minimal constraints) or that cannot be exceeded (maximal constraints). Each constraint implies a specific equivalent of vegetables and another of meat. Thus if vegetables produce 5 kcal/g (they do not) and meat 2 kcal/g (it does not), an energetic constraint of 10 kcal can be satisfied either by 2 g of vegetables or 5 gm of meat. The energetic constraint is graphed simply as a line connecting 2 g on the vegetable (X) axis to 5 g on the meat (Y) axis. It defines an infinite series of vegetable–meat combinations that will satisfy the energetic constraint, running from all vegetable (2 g) to all meat (5 g). Constraint lines running parallel to an axis imply that no amount of the resource represented by that axis will satisfy the constraint. In Figure 6.6, for example, 1 g of vegetables will generate the required 5 mg of vitamin C, but no amount of meat will do so. Graphed, therefore, one or more constraints will define a region of *feasible solutions* (if the problem has a solution, which it may not). In Figure 5.6, where energy and vitamin C are both minimal constraints, any diet that falls in the region above both lines (or on its borders) will provide the required amounts of both. Linear programming is normally used to find solutions that optimize (minimize or maximize) some nonconstraint currency (e.g., prestige) within the feasible region. It is possible, however, to proceed empirically by com-

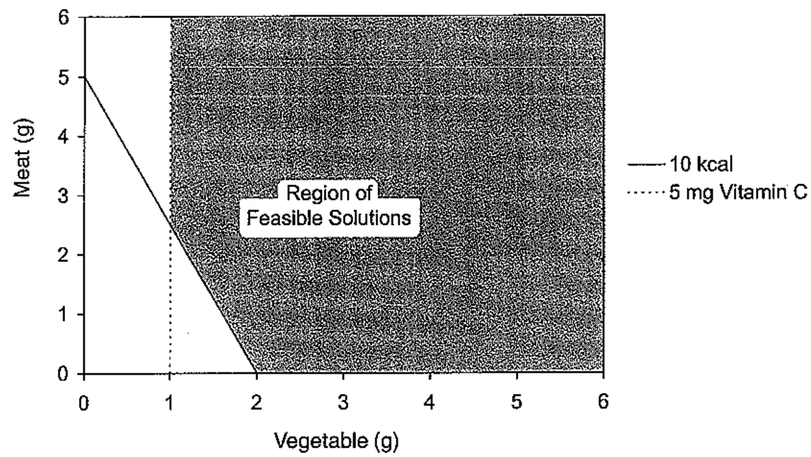

Figure 5.6. General form of programming problem with two resources and two constraints. The feasible region lies to the right of the horizontal 5 mg vitamin C constraint and above the diagonal 10 kcal energy constraint.

paring actual behavior against the boundaries of a feasible region to determine what is being optimized in a given situation. Fortunately, Belovsky (1987) has done this for us with the !Kung.

Belovsky casts plants and meat by weight (g) against four major constraints: time, protein, energy, and stomach capacity (one can eat more plant food because gut passage is faster). Surprisingly at first, but not in retrospect, these define a feasible region for individual foragers that matches very poorly with actual !Kung foraging. As Belovsky shows, this is because adult !Kung are actually foraging for themselves and subadult dependents. This increases nutritional constraints (e.g., more stomach to fill) but reduces (slightly) the time constraint for plants because some subadult !Kung help in plant processing. The adjusted constraint solution is shown in Figure 5.7. Note that the minimal energy constraint line is below, and essentially parallel to, the maximal time constraint line, suggesting that time minimizing and energy maximizing are both feasible.

If the !Kung are minimizing time, the mixture of plants and meat they consume should lie somewhere along the lower energy constraint line. If they are maximizing energy, as the traveler–processor model implies, it should lie somewhere along the higher time constraint line, which, in fact, it does. The !Kung are energy maximizers. As we have said, this is not surprising given evidence that !Kung subsistence and settlement is a post-2 kya response to pastoral incursion that reduced access to high-quality resources. Parkington (1984) suggests that prior to that, the pattern was more hunter than gatherer oriented. It is most revealing in this regard that the proportional contribution of meat in the time-minimizing solution to the !Kung problem (58%) is nearly twice that of the energy–maximizing solution (32%) observed ethnographically, which is in full agreement with Parkington's notion of prepastoral hunter–gatherer subsistence in South Africa. This strongly suggests that early and middle Holocene South African hunter–gatherers were time minimizers, as the traveler–processor model implies.

Belovsky, on the other hand, generalizes from the !Kung, and from more limited data available for other ethnographic groups, that hunter–gatherers universally are energy maximizers. Note, however, that the other energy-maximizing groups mentioned, specifically

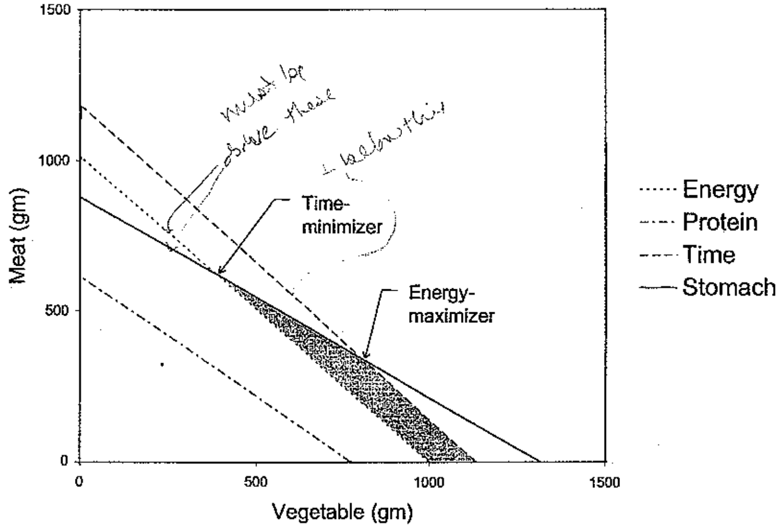

Figure 5.7. Linear programming model of !Kung diet (Belovsky, 1987). The feasible region lies above the energy and protein constraint lines and below the time and stomach constraint lines. The !Kung consume a mixture of plants and animals that closely approximates the energy-maximizer solution. Archaeological evidence suggests that prior to pastoral incursion, they consumed a combination containing more meat and less plants, suggesting a time-minimizing solution.

the Aché and groups of San other than the !Kung, had all developed foraging patterns that permitted them to live side by side with agriculturalists long before European contact (Wilmsen, 1989), so energy maximizing is exactly what we would expect. Energy maximizing is not a hunter–gatherer universal. Quite the contrary, the evidence would suggest that in South Africa, Australia, and the New World it is a late Holocene hunter–gatherer strategy that developed in response to a growing hunter–gatherer population or agricultural incursion. It is symptomatic of this demographic effect that hunter–gatherers in Australia, South Africa, and California all seem to have been operating at the same marginal rate of subsistence return at contact. At least the handling times for their key staples are approximately the same: seeds in Australia, 670 kcal/h (O'Connell and Hawkes, 1981); mongongo nut in South Africa, 700 kcal/h (Hawkes and O'Connell, 1981; Lee, 1979); and acorns in California, 790 kcal/h (Bettinger et al., 1997).

As the traveler–processor model predicts, all of these resources are more costly to procure than to locate (i.e., search time < procurement time), and at the same time substantially more costly to process than to procure (procurement time < processing time). Thus for every hour an Australian forager expends collecting the seeds of the Australian *Acacia coriacea*, another three hours must be expended in parching, winnowing, and grinding to render them edible (Figure 5.8). The disparity is more spectacular for mongongo nuts, which require 12 hours of processing for every hour of collecting, and even more so for acorns, which require 19 hours for every hour of collecting (Figure 5.9). These similarities in return rates and processing costs are quite remarkable given the differences between these groups in mobility and reliance on storage. Viewed as the culmination of the larger trajectories of Holocene adaptive change discussed earlier, they underscore the peculiar nature of ethnographic hunter–gatherer adaptive strategies, their energy-maximizing quality in particular.

Figure 5.8. Alyawara woman grinding *Acacia aneura*. Processing accounts for 66% of the time invested in this and other kinds of seeds important to Australian hunter–gatherers. (Courtesy of J. F. O'Connell)

Perhaps the most convincing evidence that energy maximizing is not a hunter–gatherer universal, however, is provided by Belovsky's remarkable and very enlightening simulation of hunter–gatherer population dynamics, which he applies to the problem of New World colonization (Belovsky, 1988). He concludes that energy-maximizing hunter–gatherers would have established stable limit cycles (see earlier) throughout the New World by at least 7 kya, which is said to correspond to the transition from Paleoindian to Archaic. From that view, adaptations after 7 kya should have been roughly the same. As we have seen, however, lithic sequences in North America and Mesoamerica suggest otherwise. All of them changed rather dramatically in composition much later in time—at 3 kya in Mesoamerica, and between 1.7 and 1.4 kya elsewhere. The advent and spread of agriculture accounts for this in Mesoamerica and, to a lesser extent, the Eastern Woodlands, Plains, and American Southwest. It does not, however, explain the same change at the same time in the western Great Basin of North America, where only hunter–gatherers were involved, the shift there being associated with a growing population and greater reliance on wild plants. Similarly, despite much earlier records of human colonization, essentially the same lithic and adaptive changes occurred at roughly the same time (in the sense they are very late) without agriculture in Australia and with the spread of agropastoralists in South Africa. The coincidence in timing between the changes in Australia and the western Great Basin of North America is particularly intriguing because only hunter–gatherers were involved and because, being occupied well back in the Pleistocene, populations in Australian should have grown and made these changes much sooner. Perhaps erratic Pleistocene environmental change kept the Australian population very low before 12.5 kya. The onset of the more benign Holocene may have in effect "reset" the demographic clock to start at the same time in both the New World and Australia. However that may be, the hunter–gatherer populations of South Africa, Australia, and the western Great Basin of North America clearly did not grow nearly as fast as Belovsky's energy-maximizer model predicts. Indeed, it is unclear whether the energy-maximizing !Kung pattern would have developed at all absent the spread of exotic agropastoralism. Although major lithic and adaptive changes did occur about 8 to 5 kya in all three places, they do not suggest energy maximizing at all, this being evident only after 3 kya.

As Belovsky (1987) suggests, technological innovations might account for these discrepancies. It is sometimes argued, for instance, that intensive acorn use developed in aboriginal California fairly late in time upon the discovery of leaching, which made the crop digestible (Gifford, 1971). Basgall (1987), however, has rather convincingly argued that the onset of intensive acorn use in California is more likely the result of population growth

Figure 5.9. Mono woman (California) shucking acorns. This and other processing steps account for 95% of the time invested in this resource. (Courtesy of C. H. Merriam)

than invention. Not surprisingly, this development in California coincides closely in time with similar adaptive changes we have noted for the neighboring western Great Basin, reaching full force only after 2 kya (Wohlgemuth, 1996). In both places, the change coincides with evidence suggesting much greater reliance on storage and, of course, much reduced mobility. None of the energy-maximizing hunter–gatherers (San, Aché) examined by Belovsky (1987) relied on storage, perhaps because the necessary seasonal resource fluctuations were lacking (Binford, 1980). Storage is clearly associated with energy maximizing in Australia, however (contra Testart, 1982). The most common form is short-term storage of seeds, roots, and other resources to support ritual gatherings (e.g., Layton et al., 1991), a pattern that Lourandos (1993) suggests developed late in time, after 3 kya. In addition, Allen (1975) documents storage as a basic subsistence practice (i.e., not ritually related) in Queensland, New South Wales, and central Australia that involved grass seeds, which, as we also have seen, became important in the diet only after 3 kya (Smith, 1986). Thus both kinds of Australian storage coincide with other behaviors that suggest a shift to energy maximizing late in time, as in California and the Great Basin. Why does energy maximizing appear so late in these places? To understand this requires closer inspection of three key energy-maximizing tactics: storage, sedentism, and territoriality.

6. Storage, Sedentism, and Territoriality

Just about everyone agrees that hunter–gatherers who store differ fundamentally from those who do not: they live at higher population densities and are more complex sociopolitically (Binford, 1980; Hayden, 1981, 1995a; Keeley, 1988; Price and Brown, 1985a,b; Testart, 1982; Woodburn, 1980). There is fairly general agreement, too, that hunter–gatherer storage is favored where there are at least some reasonably abundant, seasonally predictable resources and, at the same time, seasons of resource shortage (e.g., Binford, 1980; Goland, 1991; Rowley-Conwy, 2000; Rowley-Conwy and Zvelebil, 1989). Further, since the acquisition of surplus resources for storage is costly, it is widely, although not universally (e.g., Hayden, 1981, 1995a), argued that population pressure causes the practice in the presence of these environmental conditions (Keeley, 1988; Rosenberg, 1998). In the same way, and for essentially the same reasons, all the above authors agree that sedentary hunter–gatherers differ fundamentally from mobile ones. Here it is argued that sedentism and territoriality are favored in environments where resources are abundant and predictable (e.g., Dyson-Hudson and Smith, 1978). Again, both sedentism and territoriality being costly and risky, population growth is often said to be the cause (e.g., Keeley, 1988; Kelly, 1995; Rosenberg, 1998).

Such arguments are plausible enough, provided one is willing to assume that all hunter–gatherers are energy maximizers, since storage, territoriality, and sedentism are obviously energy-maximizing propositions. As we have shown, however, this assumption may not be reasonable for all times and places. It is certainly not reasonable until fairly late in time for the hunter–gatherer populations of North America, South Africa, and Australia, which did not grow at rates suggesting energy-maximizing strategies. Put another way, population growth makes for sedentism, territoriality, and storage only where hunter–gatherers are energy maximizing. Accordingly, it is the transition to energy maximizing that needs explaining. Once that occurs, population growth will follow, as in Belovsky's model. Population growth, however, also must lead this transition, too, since it is a rising population that is most likely to make energy more valuable than time, favoring energy-maximizing strategies. Therefore something must limit this tendency for time minimizers. Were that not so, the transition from time minimizing to energy maximizing and ensuing population growth would occur essentially as fast as Belvosky's model predicts, which it does not in the cases reviewed in the preceeding.

In a way, of course, time-minimizing hunter–gatherer systems are inherently growth discouraging. Time-minimizer reliance on high-quality, low-cost animal resources, for instance, entails important nutritional liabilities (e.g., Speth and Spielmann, 1983). Similarly, time minimizers are mobile, and mobility depresses fertility (Kelly, 1995). It would appear, too, that time minimizers suffer significant reductions in fertility by failing to take advantage of the opportunities to store resources when they are abundant (Keeley, 1988). Unfortunately, these limitations simply make it all the more likely that innovative hunter–gatherers would rapidly devise energy-maximizing solutions fairly early on, which, once again, many seem not to have done. What, then, kept the hunter–gatherer population in South Africa, Australia, and North America from rising as fast as it could have? The answer, I suspect, is that time minimizing as practiced by early and middle Holocene hunter–gatherers in many parts of the New and Old World was an evolutionarily stable strategy (ESS), inherently resistant to the energy-maximizing tactics entailed in sedentism, territoriality, and storage. To move from time minimizing to energy maximizing required an almost impossible restructuring of social relationships and use rights.

This is easiest to see in the case of storage as practiced in California and arid western North America, where stores of plant food were privately owned, although food itself was widely shared. The distinction is critical: cache robbing was criminal, freeloading was not. Privatization of stored resources limited losses to freeloaders, who were entitled (once invited) to a share of what was extracted from the cache, but not to the contents of the cache directly, which often remained hidden from public view. One suspects cache owners were judicious in choosing the times at which resources were withdrawn from caches and how much was withdrawn. In both places, gathered food itself was generally private, not public, goods. Again, it might be (and generally was) given freely to others, but the right was the giver's, not the taker's. It is quite the opposite among many ethnographic hunter–gatherers, of course, where resources of virtually every kind are taken to belong to the group as a whole rather than any of its individuals (e.g., Kaplan and Hill, 1985; Lee, 1979). Woodburn (1980) summarizes the essential characteristics of such groups and establishes that where such rules obtain there remains no surplus, such as might be diverted to stores. The relationship between private ownership and storage is therefore clear. This form of public goods transfer follows the pattern of what Blurton-Jones (1984) terms tolerated theft.

In tolerated theft, resources pass from a giver, who starts with *more* than he can use or is prepared to defend, to a taker, who starts with *less* than he can use and is prepared to use force to extract some from the giver. Resources pass from giver to taker until an equilibrium is reached at which the marginal utility of one unit of resource is the same for both giver and taker; that is, the price of defense has equaled the price of extraction. This results in a net gain in overall utility for the giver–taker pair because resources are transferred from giver to taker precisely because they are more valuable to the taker than to the giver. That is, in each transfer the taker gains more utility than the giver loses, so net utility for the two increases overall. Further, because the utility of a resource decreases as its quantity increases, overall giver–taker utility increases with the number of takers: smaller gifts to many takers produces more overall (group) utility than larger gifts to fewer. As Winterhalder

(1996) shows, none of this guarantees either equal resource distributions or a long-term balance of transfers. Givers or takers may well end up with less than half of a resource package in the event either holds other resources to start with, or there are many takers; and givers may still benefit when giving more than they receive in the long run. The model predicts, and empirical evidence confirms (e.g., Kaplan and Hill, 1985), that resources that come in large packages, such as meat, will be more widely divided (shared) as a consequence of tolerated theft-type transfers.

Resource transfers profoundly affect subsistence behavior because they determine the benefits individuals actually receive in return for time spent foraging. That is, although large game may return more calories per unit of hunting time than small game, resource transfers may make small game more profitable, being less subject to transfer (Bettinger, 1999a; Hawkes et al., 1991; Winterhalder, 1996). Extensive transfer is unavoidable for resources that are large and rare—large game, for instance (Figure 5.10). However, if the resource is large enough, it may still be worth pursuing even though most of it will go to others. Individual foragers can and should limit procurement of resources that come in very small packages, such as plants, to minimize the portion that is subject to transfer by tolerated theft. Thus, that small package resources are empirically less subject to sharing is more likely a function of self-limited forager effort than of their package size (i.e., foragers limit their acquisition to quantities that minimize transfer losses). Large quantities of small package resources are no less subject to transfer than are large packages, and plants are certainly not exempt (Kent, 1993:495–496, 505–506). As an example of this, Kristen Hawkes (personal communication) tells me that Hadza women, returning with large loads from berry picking, habitually wait for each other to assemble in a group outside camp, to equalize the losses that result from the ensuing scramble for their products by those waiting in

Figure 5.10. Passing food in an Aché camp. Meat is widely shared and most of what hunters take goes to unrelated individuals (Courtesy of Department of Anthropology, University of Utah).

Figure 5.11. Hadza berry (*Cordia* spp.) gatherers approaching camp. They form a group to equalize individual losses of berries to individuals waiting in camp. (Courtesy of J. F. O'Connell, December 1985)

camp (Figure 5.11). All of this makes it quite clear why hunter–gatherers who regard food as a public good generally do not store: under tolerated theft, resource transfers provide no incentive for individuals to acquire more than they need and can defend. It similarly suggests why storage and intensive use of small package resources, such as plants, often develop coincidentally, as in Australia, California, and the western Great Basin: tolerated theft limits forager willingness to invest in small package resources. When rules change in a way that limits tolerated theft, storage will occur and foragers will invest more in small package resources. As Winterhalder (1996) observes, the problem of tolerated theft worsens as group size increases. Thus, while storage may be a response to growing population pressure, that pressure cannot itself cause it so long as food is a public good.

It is much the same with sedentism and territoriality, the development of which Rosenberg (1998) likens to cheating at musical chairs. The analogy is particularly apt in that it demonstrates the improbability that territoriality will develop smoothly among hunter–gatherers whose subsistence–settlement system hinges on mobility and free access to resources. Territoriality is "cheating" in the same way that hoarding food is "cheating" where food is a public good. Balicki (1970:176) spells out the likely scenario via a Netsilik tale.

> An elderly man, N., used to camp alone with his wife and three grown-up sons at *Oadliq*, a crossing point for caribou . . . and an excellent hunting area. One day when N. was alone in his tent three hunters arrived there with their kayaks to catch caribou. They were coldly received by N., who told them: "Nobody should come here unless they want to look at the sky" ("looking at the sky," meaning to lie dead on the ground with the face turned up to the sky). The people said nothing, but went down to

> the lake shore where they waited until N's sons returned and then killed them. N. went insane with anger and ran around screaming, until the three hunters killed him also. After these murders the lake was open hunting for everybody.

Here, as in the two-person prisoner's dilemma, there is an impasse of conflicting individual, group, and intergroup interests. Further, while it is clear that territories may emerge when there are defendable territories/resources that are worth defending (Dyson-Hudson and Smith, 1978), the circumstance most likely to prevent this is precisely the one that would cause groups to want to define territories in the first place: too many competitors. In a nutshell, storage, territoriality, and sedentism all require the development of practices at levels that are beyond the ability of individuals or groups to develop on their own. Rosenberg (1998) cites violence as a signature of developing territoriality in the Near East and Europe, but violence alone will not solve the problem. In the case of territoriality and sedentism, it merely results in a war of all-against-all in which territorial innovators are always badly outnumbered. Violence similarly presaged the development of more nonegalitarian sociopolitical systems in the Northwest Coast and coastal California (Hayden, 1995b; Moratto et al., 1978), but in those cases, violence increased and then decreased, suggesting the appearance of a new set of social relationships that reduced violence.

In broad stroke, while the hunter–gatherers of Australia, South Africa, California, and the western Great Basin differ markedly in degree of territoriality, sedentism, and storage, all three operated in the presence of rather specific sets of rules that define access to resources and space. In California, food was private property and territories were sharply marked and defended by sedentary groups (Kroeber, 1939). In most western Great Basin groups, proprietary claims were less sharply defined with respect to territory, and in many cases lacking altogether, but reemerged at the level of gathered food, which was everywhere private property (Steward, 1938:253), just as in California, and going hand in hand with storage on a similar scale. Storage was not as extensively practiced in Australia, but what there was of it is demonstrably connected with territoriality. In instances where it was used as a basic subsistence practice, it permitted groups to maintain a presence within a smaller territory than would have otherwise been possible (Allen, 1975). As noted earlier, it more frequently occurs as a means of supporting large aggregations for the purpose of conducting a rather elaborate system of totemic clan ritual. These rites reinforced a highly developed system of territoriality framed around sacred sites that frequently coincided with reliable springs and resource-rich areas (Gould, 1969; Layton, 1992; Layton et al., 1991; Tindale, 1972). Access to clan sacred sites and their resources required verbal permission, which was extended reciprocally between the elders of neighboring clans. The centripetal force created by these clan territories likely explains the Australian section system that forced males to seek mates in distant territories in which they could take refuge when local resources failed (e.g., Yengoyan, 1968). The nonstoring San observed an analogous territorial system, not ritually elaborated, that similarly required outsiders to obtain permission in person from the owners of a territory (e.g., Lee, 1984:58; Silberbauer, 1972:295–298).

In all these cases, one sees sets of social relationships and resource use rights that make sense only in the presence of energy maximizing, and that could not easily evolve directly out of the less structured set of relationships appropriate for time-minimizing hunter–gatherers. At the same time, energy maximization itself is unlikely to succeed without the prior existence of some combination of these or similar practices, which are wholly antithetical to time minimization. The associated shifts in diet breadth and patch choice, for instance, require reduced mobility verging on territoriality. In sum, storage, sedentism, and territoriality will arise only when hunter–gatherers maximize energy, which itself cannot arise unless these practices are present to some degree. Thus energy maximizing and its supporting practices must evolve as an adaptive whole, that is, as an adaptive strategy. For this reason, the transition from time minimization to energy maximization must be rapid rather than gradual.

The nature of the problem is illustrated in Figure 5.12, graphing hypothetical payoff curves for two strategies (energy maximizer and time minimizer), which change as a function of their relative proportions in an imagined regional population. The payoffs (say, in mating opportunities or resource access) are those received by an individual when the rest of the population consists of various mixtures of the two strategies ranging from 100% time minimizer to 100% energy maximizer. The payoff an individual receives for becoming a time minimizer is highest (400) when time minimizers constitute 100% of the population (i.e., energy maximizers = 0%), and declines as their number decreases, reaching a minimum of 100 when there are no other time minimizers. Similarly, the payoff for becoming an energy maximizer is highest (500) when energy maximizers comprise 100% of the population, and declines as their number decreases, reaching a minimum of 200 when there are no energy maximizers. Given these schedules, the energy-maximizer payoff is superior whenever energy maximizers constitute more than a third (33.3%) of the population. Energy maximization is clearly the optimal strategy, and the payoff for becoming an energy maximizer is higher than the highest possible time-minimizer payoff (400) whenever energy maximizers constitute more than two-thirds of the population. Figure 5.12 also graphs the average individual payoff for the population as a whole as it moves from all time minimizers to all energy maximizers. Note that this average payoff is higher when the

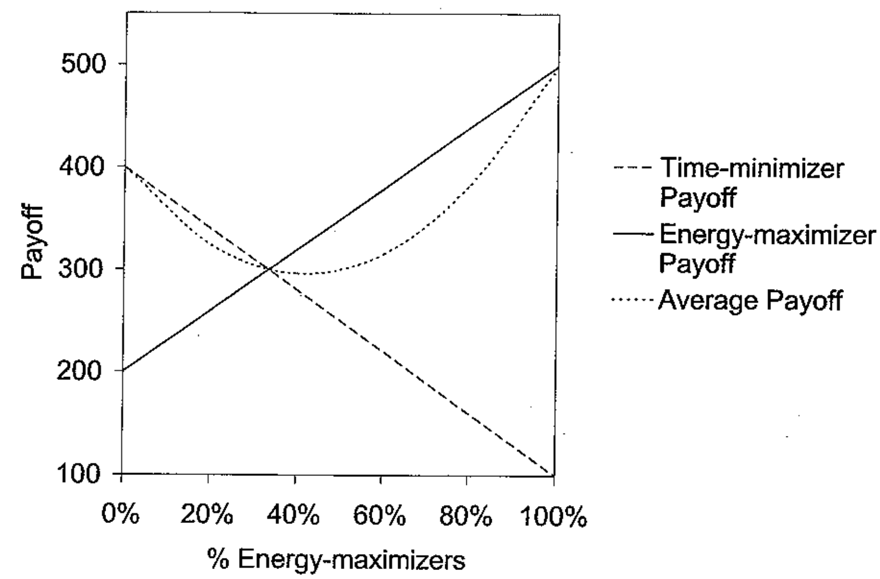

Figure 5.12. Hypothetical payoff schedule for an individual choosing time minimizing and energy maximizing as a function of the fraction of energy maximizers in the population. Time minimizing is superior when time minimizers constitute more than 66.7% of the population. Energy maximizing is superior when energy maximizers constitute more than 33.3% of the population. Average payoff is higher when the population is 100% energy maximizing than when it is 100% time minimizing, but nearly all mixtures of energy maximizing and time minimizing lead to an average payoff that is lower than when the population is 100% time minimizers.

population is 100% energy maximizing than when it is 100% time minimizing but nearly all mixtures of maximizing energy and minimizing time lead to an average payoff that is lower than when the population is 100% time minimizers.

In this case, time minimization and energy maximization are both evolutionary stable strategies (ESS). Individuals will always opt to be time minimizers when time minimizers constitute more than 66.7% of the population, and will always opt to be energy maximizers when energy maximizers constitute more than 33.3% of the population. The situation thus has two stable equilibria (time minimizing and energy maximizing). Energy maximization is obviously the optimal strategy, but the population can easily be trapped at the suboptimal time-minimizing equilibrium if time minimizers initially constitute more than 66.7% of the population. I have cast this problem in terms of whole strategies, that is, energy maximizing versus time minimizing, but it applies with little or no modification at the tactical level, to territoriality, sedentism, and storage. Note that this outcome—the possibility of being trapped at the lesser of two equilibria—does not hinge as much on the specific payoff values as on the assumption that the relative attraction (payoff) for a strategy increases as it becomes more common (Schelling 1978). It is merely the order of the endpoints—time minimizer superior at the left, energy maximizer superior on the right—that dictates this outcome. There would still be these two equilibria, for instance, if the payoff for becoming a time minimizer were 400 rather than 100 at the right, when the rest of the population is all energy maximizers.

The suboptimal time-minimizing equilibrium gives this situation the flavor of what Schelling (1978) terms the multiperson prisoner's dilemma (MPD). As Schelling notes, however, in MPD there is just one suboptimal equilibrium, whereas in this case there is a second, optimal equilibrium. The problem is to get from the suboptimal to the optimal equilibrium, in this case, from time minimization—which keeps the population low, to energy maximization—which makes the population grow (see also Bettinger, 1980; Bettinger and Baumhoff, 1982). As argued earlier, this is beyond the power of individual rational choice. It requires a multiperson coalition, one more than 33.3% of the total regional population, that shifts together from time minimizing to energy maximizing. Since this coalition makes the energy-maximizing payoff superior, once they shift, all the remaining energy maximizers will shift, moving the population rapidly to the optimal energy-maximizing equilibrium (100% energy maximizing), which is also an ESS. The members of any smaller energy-maximizing coalition, however, end up worse off than before, and no additional members will join them, since the time-minimizing payoff remains higher than the energy-maximizing payoff. Thus the regional population tends very strongly to either of two self-enforcing states, all time minimizing or all energy maximizing. Intermediate mixtures are unstable and transitory.

That something like this obtains in the real world of hunter–gatherers is suggested by the trajectory of the shift to energy maximizing in California, the Great Basin of North America, and Australia. In these places, populations remained at a time-minimizing equilibrium for most of the Holocene, moving just recently, and then very rapidly, to an energy-maximizing equilibrium. This is in accord with the more general consensus (Keeley, 1988; Rosenberg, 1998) that energy-maximizing behavioral shifts (e.g., sedentism, territoriality, complexity) tend to be quite rapid (contra Smith, this volume). The question is how, in such cases, the change itself occurs.

The spread of energy maximizing is easier to explain than its origin. The rapid transition to energy maximization across broad stretches of western North America and Australia strongly suggests that it simply expands from one locality to the next as a wave. Since energy maximizers reproduce faster and are more densely settled than time minimizers, energy maximizing will spread as a chain reaction, with or without population replacement. In the preceding example, for instance, expanding energy maximizers need only constitute 33.3% + 1 of the regional population to cause the remaining majority to make the shift to energy maximizing. This is easy to see with the San because their energy-maximizing transition was brought about not by hunter–gatherers but by pastoralists whose incursion had the same effect. Given a payoff schedule that now favored energy maximizing, the San simply adapted existing technology and behavior to that reality. In cases where expanding energy maximizers are hunter–gatherers who have already worked out the necessary behaviors and technology, however, substantial borrowing is likely. The original population persists but becomes behaviorally indistinguishable from the advancing energy maximizers. Thus the technologies and behaviors of energy maximization may spread far beyond their point of origin without any real change in local personnel. On the other hand, if the energy-maximizing coalition is an ethnic unit that is large enough and good enough at energy maximizing, and the original population is slow to learn energy maximizing, large-scale replacement may occur (Young and Bettinger, 1992). In this way, energy maximizing can spread with the same vigor Bellwood (e.g., 1996) reserves for agriculture.

Once a region is beyond the intersection at which energy maximizing is the superior choice, the coalition—ethnic or otherwise—becomes superfluous to the ensuing transition. An energy-maximizing ethnic coalition, however, will likely not disintegrate because the coalition is obviously united by something other than energy maximizing. That is, one must assume the spreading energy maximizers had long passed the threshold at which energy maximization was self-enforcing, requiring no coalition, which exists for other reasons (Bettinger and Baumhoff, 1982). This makes population replacement by ethnic energy maximizers more likely for reasons having nothing to do with energy maximization but with whatever holds the ethnic coalition together and likely caused it to develop in the first place. In the last analysis, it is the initial formation of the coalition that accounts for the origin of energy maximizing and requires explaining.

The problem basically is that while the coalition ends up making energy maximizing rational for individuals, it is unlikely to form with that in mind. For one thing, it is altogether questionable whether knowing these payoffs would motivate everyone to participate. Women, for instance, might well see their share as the short end of the bargain. In addition, making coalition participation dependent on payoffs substantially increases the size needed to make it attractive. In Figure 5.12, for example, an energy-maximizing coalition must constitute more than 66.7% of the population, to be competitive with the time-minimizing equilibrium, which is twice the size of the coalition needed (33.3% + 1) if payoffs are not the motive for participation. Payoffs, however, are not only the problem. Were payoffs paramount, people would always cooperate and reach optimal equilibria, and there would be no prisoner's dilemma at all. People often do not cooperate, however, because even when a coalition will increase individual payoffs, the individuals in the coalition all have to be convinced that the others are going to change when they do. Without that, none will change. Payoffs, then, are not only what matters; what also matters are perceptions regarding what others are going to do.

For all these reasons, energy maximizing seems most likely to evolve as an unintended consequence, arising from the action of a coalition that forms for other reasons. Since a coalition is involved, anything that causes these individuals to think or act in the same way can produce the result. Contributing to the public good is an unlikely rallying point, of course, for all the reasons revealed in the prisoner's dilemma. Self-interested competition between individuals is a more probable catalyst, partly because competition implies a coalition: it requires that the competitors agree on at least some basic ground rules, even when the motivations vary by individual. It does not matter whether one plays blackjack for financial gain or the thrill of winning; the rules of play and scorekeeping are the same. What then might be the basis for individual competition among energy-maximizing and time-minimizing hunter–gatherers?

Of all the possibilities, competition for mates and prestige seems particularly likely. Knauft (1987) argues that it is contests over women—not property, food, or land—that is behind the unusually high level of homicidal violence that characterizes simple hunter–gatherers, including the !Kung and Hadza. Although Knauft discounts its importance, prestige in some form is surely involved, even among those groups that are said to ridicule men who seek prestige openly (Lee, 1979). Indeed, such ridicule only reinforces the suspicion that prestige seeking is both common and problematic among the !Kung. It is clear, in any case, that !Kung men strive, however subtly, to distinguish themselves as individuals, particularly in the realm of hunting (e.g., Weissner, 1983). Among the Aché (Hill and Kaplan, 1988) there is a more overt connection between prestige in the form of hunting success, on the one hand, and mating and reproductive success, on the other, that is surely not lost on either sex. This is perhaps not surprising since game makes up something like 80% of the Aché diet (Hawkes et al., 1982). The surprise is that good hunters are regarded as good mates almost universally among hunter–gatherers, even where meat is a relatively minor component of the diet (Hawkes, 1990; Steward, 1938:253; Wallace, 1978). I have noted this is likely the result of a form of cultural transmission that Boyd and Richerson (1985) term *indirect bias* (Bettinger, 1991b:202–203). A common form is when individuals acquire multiple behaviors by choosing a social model on the basis of a generalized (e.g., prestige) or specific (e.g., number of mates) measure of success. If hunting proficiency translates as prestige among the Aché, and if young Aché males use prestige to chose social models, then young Aché hunters will end up acquiring (or trying to acquire) the full set of behaviors that characterize the most successful Aché hunters. This would include not just hunting technology and tactics, but a whole range of behaviors—preferences for different foods (large game versus small game, meat versus plants) and activities (hunting, gathering, child care), mate choice, and so on.

Since successful Aché hunters enjoy prestige partly as a consequence of mating success, Aché females must evaluate mates by the same criteria that young Aché males choose social models. In this case, using hunting success as a generalized gloss for male success exaggerates the importance of hunting relative to other activities. It forms the basis of a stable, energy-maximizing coalition as an unintended consequence of indirect bias and the competition for mates among men and women (for a related argument about the Aché, see Hawkes, 1991; for hypothetical examples in more contemporary settings see Orlean, 1988; Schelling, 1978; Sugden, 1986). Since earlier accounts suggest gathered food was formerly more important than game (Clastres, 1972:153), the Aché coalition may have developed recently, as the Aché expanded to exploit new resource opportunities as the population of competing Guarani horticulturalists—and native population in general—shrank as the result of diseases and slave raiding (Hill and Hurtado, 1996:468). Alternatively, it may have evolved much earlier with the development of Guarani horticulture that compressed the Aché in the same way that pastoralism compressed the San in South Africa. Either way, one suspects that hunting prestige was involved in establishing the equilibrium. Hunting prestige also seems to have been involved in the shift to energy maximizing in California and the Great Basin, which is presented in the following section as an instance of the general process.

6.1. Transition to Energy Maximizing in California and the Great Basin

I have argued (Bettinger, 1999a,b) that in California and the Great Basin, time minimizing was characterized by an immediate-return system in which meat was highly valued and both hunted and gathered food were public goods. This, and relatively low hunter success rates and the high costs of plant processing, acted as disincentives to intensive individual foraging effort, particularly gatherer foraging effort and food storage, which kept the population low. This equilibrium was disturbed by the introduction of the bow and arrow at 1.4 kya, which both raised hunting returns and diminished their variance, so that the amount of food produced increased dramatically. Large game was more intensively hunted, but there was greater impact on smaller game, whose pursuit costs dropped markedly given the greater accuracy of the bow relative to the atlatl. As the bow increased individual hunter success while reducing its variability, hunting likely became more solitary, and differences in individual hunter success became more stable and visibly apparent.

Good hunters who understood the new technology, and could put it to use most effectively, were likely induced to become major group provisioners by perquisites that increased their reproductive success (e.g., Hawkes, 1990). Perhaps, as Kaplan and Hill (1985:237) speculate for the Aché, the children of good hunters were less subject to infanticide or forced treks to new camps when they were too sick to travel. As these reproductive benefits made them more desirable as mates, the best hunters found it increasingly possible to attract and maintain more than one wife (e.g., Steward, 1938:143; Wallace, 1978:685). Such polygynous mating would have been attractive to females, especially sisters with closely coinciding genetic interests, who would benefit from the resulting economy of scale in female activities, including childcare and plant procurement and processing (cf. McCarthy, 1993). Under these circumstances, it is quite conceivable that, so long as good hunters continued to provide a steady volume of meat, polygynous households may have been extended the minor privilege of hoarding (not sharing) unprocessed plant foods that were less valued by the community at large, especially by monogamous females less capable of processing them. Then, polygynous families that took advantage of this opportunity by actually investing more female labor in plant procurement and processing would have enjoyed a steadier food supply, hence, additional reproductive advantages, causing hunters to compete harder for hard-working gatherers and hard-working gatherers to compete harder for hard-working hunters. Both kinds of foraging intensified as hunters and gatherers continued to compete for mating advantages. However, the greater intrinsic productivity of plant procurement caused it to expand more rapidly and soon greatly overshadow the importance of hunting, even in monogamous households.

Support for this scenario of simultaneous intensification in gathering *and* hunting is suggested by the pronounced sexual dimorphism that typifies Great Basin skeletal populations dating to the centuries immediately following the introduction of the bow (ca. 1.4 to 0.6 kya), which is the highest ever reported for Amerindians (Ruff, 1999). Increased investment of labor by men and women in activities with very different physical demands—

hunting and gathering—is most likely responsible for this. The complete trajectory, in which plant procurement finally eclipsed hunting, however, is perhaps best illustrated in the archaeological record of eastern California. In this region rock art hunting scenes greatly proliferated following the introduction of the bow and arrow (Whitley, 1998), suggesting intensification of the hunting effort. It is precisely at this time that plant processing tools first came to dominate archaeological assemblages, suggesting the simultaneous intensification of gathering (Bettinger, 1999a). Plant processing tools became increasingly abundant subsequently, suggesting the growing importance of plant procurement, but rock art hunting scenes did not, and were essentially absent from a terminal prehistoric cultural repertoire supported by intensive plant procurement.

From this view, the shift to energy maximizing and intensive plant procurement was not the result of resource shortage but rather a technologically induced resource surplus that increased incentives for hunters via a reward structure (polygyny) that happened to make plant procurement and processing attractive to males and females alike. In the last analysis, however, the upward spiral of female investment of labor in plant processing was not driven as much by good hunters as by the self-interested competition among females for mates and labor-reducing social arrangements.

These changes in subsistence coincided with a major change in settlement pattern. As the bow increased mean hunting success while reducing its variance, it diminished the advantage of living in large, resource-pooling groups to reduce income variance (Winterhalder, 1986a), so mean size of residential groups probably decreased. Social fissioning, in combination with the more intensive acquisition of smaller game, likely resulted in increasingly intensive use of marginal, but relatively reliable, patches that had previously been used more sparingly and in more specialized ways. Residential use of Great Basin wetlands rich in small package resources susceptible to the bow (fish, birds, small mammals) increased dramatically with the introduction of that technology, for example (Bettinger, 1999c; Hemphill and Larsen, 1999). Without the safety net that large group sharing had previously provided, wetlands may have been especially favored as a means of risk reduction, particularly as refuges during periods of extreme resource shortage. This is because marshes are one of the few environments where at least *some* food can be found throughout the year, even (with considerable scrounging) in the depths of winter, when the problem of food shortage is most acute (Kelly, 1988:18). Coprolite contents from at least some wetlands sites dating to this time speak to a pattern of hardship verging on starvation that is consistent with the use of marshes as such a last resort (Nelson, 1996). As with the subsistence changes described earlier, this settlement change increased the genetic incentive for more intensive foraging. As group size diminished, the degree of relatedness among its members surely increased, so that both hunted and gathered products went increasingly to relatives rather than unrelated camp followers. These subsistence–settlement shifts, in combination with the potential of the bow as a defensive weapon, seem likely to account for the transition from time minimizing to energy maximizing in California and the Great Basin.

6.2. Discussion

The evolution of energy maximization in California and the Great Basin captures what is likely the basic requirement for all such transitions: a profound reshuffling of technology, resources, or population that momentarily creates opportunities for individuals of both sexes to advance their selfish interests through intensified foraging. Large-scale perturbation must be required, for, if small ones sufficed, hunters and gatherers would always be stumbling on the requisite inducements, and, once again, groups would quickly move toward energy-maximizing equilibria. This is why I argued earlier that the incremental technological innovations identified by Hayden (1981) were likely insufficient, and why I singled out the bow as being different in this regard. However, if the bow can have this effect, then so might the atlatl (Davidson, 1989), which is at least worth thinking about in connection with the transition to energy maximizing in Australia and perhaps Eurasia during the late Pleistocene (Davidson, 1989), although much more than that was likely involved. In a somewhat different vein, quite apart from the resource opportunities actually realized, differential access to advanced technology could in theory set the stage for escalated prestige competition leading to energy maximizing through the kind of indirectly biased social transmission described previously for the Aché.

Technological change is surely not the only route to energy maximizing, however. A major increase in resources might have the same effect. Again, the magnitude of increase must be very large and so, the record suggests, must be population to start with. I have in mind here all the transitions to energy maximizing that occurred in the early Holocene, or perhaps in the latest Pleistocene, notably in the Near East, as in the Nautufian (Belfer-Cohen, 1991; Goring-Morris, 1989, 1995; Goring-Morris and Belfer-Cohen, 1998; Henry, 1989), the Far East, as in Jomon Japan (Aikens and Akazawa, 1996) and Mesolithic North China (Elston et al., 1997); and Europe, as in the Ertebølle (Price, 1985, 1991; Rowley-Conwy, 1983, 1998b, 1999)

In all these cases, populations seem to have moved to energy-maximizing equilibria, either immediately with the dramatic changes of environment at the onset of the Holocene, or as soon as local environments stabilized following the retraction of glacial ice. What stands out about the terminal Pleistocene hunter–gatherers in all these places is that their technology seems to have been organized along essentially the same lines as the intensive time-minimizing technologies that preceded the shift to energy maximizing between 4.5 kya and 1.5 kya in South Africa (Wilton), Australia (Small Tool Tradition), and the western Great Basin of North America (e.g., Zvelebil, 1993). By contrast, in these latter places, where energy maximizing is relatively late, terminal Pleistocene technologies suggest nonintensive forms of time minimization. Theory suggests, and the record appears to confirm, that such systems would respond to increasing Holocene resource abundance by reducing foraging effort, that is, by minimizing time, not by maximizing energy.

7. Implications

Early in this century, Sollas (1915) echoed the popular notion that ethnographic hunter–gatherers were Pleistocene relicts, the unevolved representatives of long-extinct Paleolithic peoples and cultures curiously preserved. By contrast, few today would argue that the !Kung, or the Aché, or the Great Basin Shoshoni, or the Inuit are a close match for any Pleistocene hunter–gatherer system. The modern caution derives, in part, from our growing reluctance to draw distinctions between ourselves and the peoples we study and, less self-consciously, from a deeper and more theoretically informed understanding of the panoply of ethnographic hunter–gatherer variation. More pragmatically still, it derives from the knowledge that all behavior is grounded in context (Nelson, 1991), which becomes harder to control the farther one goes back in time and the suspicion that things were much different in the Pleistocene (Wobst, 1978). The evidence presented here shows that our caution is well justified and why.

Pleistocene and Holocene hunter–gatherers are worlds apart in natural setting. Hunter–gatherer adaptive strategies persist only to the extent they succeed in coping with short-run and long-run variability—and both were an order of magnitude larger in the Pleistocene than the Holocene, while overall productivity was substantially lower. If variable, unproductive environments are a hunter–gatherer's nightmare, the Holocene was the hunter–gatherers dream come true. Because of that, the ethnographic hunter–gatherers that have always provided the basic framework for our understanding of prehistoric hunter–gatherers cannot possibly represent the full range of viable strategic options. Despite their impressive outward variability, ethnographic hunter–gatherers—foragers and collectors alike—are all energy maximizers, and for good reason.

As noted at the beginning of this chapter, the Holocene trajectory of hunting and gathering is one of retreat and extinction before spreading waves of agriculturalists, agropastoralists, pastoralists, and imperial nation-states, as well as by hunter–gatherer groups vastly changed and set in motion by these systems. The comparative handful of hunter–gatherers that managed to resist these forces down nearly to the present did so only through energy-maximizing tactics that permitted their persistence in either marginal environments or richer settings so densely settled and culturally unified that agriculture could not penetrate. Prior to this, and until the very latest Holocene in many places, hunter–gatherer subsistence strategies were structured very differently in ways that minimized time rather than maximized energy.

Time-minimizing and energy-maximizing strategies differ in a variety of ways that are crucial to interpreting the archaeological record of hunter–gatherer responses to these challenges of the Holocene. Time-minimizing, traveler strategies are optimal where population density, hence resource competition, are comparatively low relative to available resources. Under such circumstances, hunter–gatherers will be highly selective, both with respect to the resources they use and the patches in which they obtain them. Relatively more time is expended in travel between patches than in foraging within them, and in searching for resources than procuring and processing them. In the presence of such conditions, risk is relatively low, and mobility is highly effective in reducing it. Risk, however, will increase directly as resources diminish or population increases. Time minimizers should respond to such challenges through time-saving tactics, especially in technology. Empirically, increasing rates of tool discard (e.g., Delacorte et al., 1995; Hiscock and Attenbrow, 1998) and stone tool waste (e.g., Belfer-Cohen, 1991:177–178; Gilreath and Hildebrant, 1997) appear to go hand in hand with the appearance of more complex tool forms in a way that is consistent with this expectation (Bettinger, 1999a).

Energy maximizing, on the other hand, entails a completely different set of constraints and expectations. In particular, energy-maximizing, processor strategies are optimal where population densities and resource competition are high relative to available resources, which decreases the opportunities for successful movement between patches. Under such circumstances, hunter–gatherers become less selective, both with respect to the resources they use and the patches in which they obtain them. Consequently, relatively more time is expended in foraging in patches than traveling between them, and in procuring and processing resources than in searching for them. Here, it is the amount of energy that can be extracted per unit of space, rather than per unit of time, that becomes paramount (Belfer-

Cohen, 1998; Bettinger, 1999a). Because reduced mobility increases the opportunities for resource monitoring, and decreases the time constraints on procurement and processing, increased expenditure of labor—especially female labor—becomes the primary means of risk reduction.

The hunter–gatherer transition from minimizing time to maximizing energy is a distinctively Holocene process. The archaeology of Holocene hunter–gatherers tells us that environment, technology, and population all contribute to this transition, but not in a simple deterministic way because time minimization and energy maximization are stable, self-reinforcing, equilibria, that is, they contain a critical social component. The forces of environment, technology, and population contribute to such transitions only if they qualitatively increase the rewards individuals obtain from existing payoff structures and if, in turn, those rewards produce novel social arrangements that change existing payoff structures or create new ones. Ethnography provides only the most general clues about time-minimizing hunter–gatherer behaviors—and essentially nothing about the change from time minimization to energy maximization. Although ethnography will surely remain central to hunter–gatherer research in the next millenium, some of the most interesting problems lie well beyond the "comfort zone" of ethnography. The challenge is to extend our understanding beyond lifeways that are recent and familiar without losing our way entirely in the process. How do we do this?

One answer is obvious: we need to do more archaeology, but not just any kind of archaeology. Despite the call of the 1960s and 1970s for programs of regional archaeology (e.g., Binford, 1964; Mueller, 1975; Thomas, 1969), there remain many places around the world where, at the end of this millennium, we simply have no clear picture of regional subsistence–settlement systems during any part of the Holocene (or any earlier time). We are unlikely to unfold the complexities of hunter–gatherer adaptive change in the coming millennium unless this is done. Until we can say with some confidence where a group of hunter–gatherers was living in the winter and in the summer, and what they were doing at these times, and where they were living and what they were doing in the times in between, speculation about the basic nature of their adaptive strategy, or in what direction it might have been changing, is a fairyland exercise.

A second area where work is likely to prove beneficial in the coming millennium is the bioarchaeological analysis of skeletal remains. The major thrust of this research has typically been documenting changes in quality of life and diet associated with the shift to agriculture (e.g., Coltrain, 1993; Larsen, 1982; Schoeninger and Moore, 1992), but there is increasing interest in applications that deal with shifts in hunter–gatherer adaptation (Hemphill and Larsen, 1999; Pate, 1998; Sealy, 1986; Sealy and van der Merwe, 1988; Woodborne *et al.*, 1995). Such work should be particularly revealing of the major changes in hunter–gatherer adaptive strategy discussed here.

A third area that is likely to further our understanding of Holocene hunter–gatherers is the development of large, comparative sets of archaeological data. Such data are the very foundation of evolutionary and ecological human biology (Hawkes et al., 1998; Roberts, 1953), of course, and it is hardly a secret that our current understanding of hunter–gatherer behavior was greatly advanced by the development of large, comparative sets of ethnographic data that served as a laboratory for a variety of interesting experiments (Binford, 1980; Keeley, 1988, 1991, 1992; Kelly, 1983, 1995). Such samples are only occasionally available in archaeology (e.g., Fellner, 1995; Goring-Morris, 1987), however, and seldom, if ever, cover more than a single region. An ambitious world survey of archaeological "traditions" is underway (Peregrine and Ember, 1997). Unfortunately, it evidently will not present basic quantitative data on archaeological assemblages, which is essential to understanding fundamental shifts in hunter–gatherer behavior during the Holocene. In many places, the technological signature of the shift from time minimizing to energy maximizing is quantitative rather than qualitative, involving changes in the relative frequencies of the same tool types (e.g., Bettinger, 1999a; Hiscock, 1994). Further, it is not just formal tools that matter. To understand these changes one needs to know about the ratios between formal and informal tools, between tools and tool waste, and so on. This point would seem obvious, yet, even today, published accounts of hunter–gatherer lithic assemblages seldom include a tally of lithic waste. It is perhaps not so surprising, then, that archaeologists have not gotten very far in operationalizing such basic concepts as risk in terms that can be meaningfully applied to archaeological assemblages (for one good attempt, see Bamforth and Bleed, 1997).

The point I am driving at here, is that, although hunter–gatherer archaeology has accomplished a good deal in the past half century, it has not quite kept pace with hunter–gatherer theory, and that we are badly in need of some good old-fashioned pattern recognition. Theory is all well and good, but at some juncture all theories inevitably seem to point in two equally plausible, but mutually contradictory, directions. Such an impasse cannot be "thought out." It has to be confronted with critical data to decide in which of the two directions one ought to proceed (Kuhn, 1962:29). Since the theories we are working with are meant to be generalizing, that is, about hunter–gatherers worldwide, the development of cross-cultural archaeological data sets is clearly indicated. Many of the patterns in which we are interested will likely emerge only on a global scale (e.g., Keeley, 1988:395). In the last analysis, however, this approach is perhaps most crucial because the ethnographic record provides very few reliable clues about how we should go about modeling time-minimizing hunter–gatherer systems (Wobst, 1974). The models will have to come from theory, and many of them will undoubtedly be wildly wrong. Only a global archaeological perspective can provide the framework necessary for testing these models and discarding the ones that make sense in theory but not in fact. For students of hunter–gatherers, this is the challenge of the new millennium.

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