

Thinking outside the box: a new perspective on diet breadth and sexual division of labor in the Prearchaic Great Basin

Robert G. Elston and David W. Zeanah

Abstract

The archaeological record of the Pleistocene/Holocene transition (PHT) demonstrates that the technology and mobility of Prearchaic hunter-gatherers differed dramatically from later Holocene foragers, suggesting a hunting-oriented subsistence. However, meager PHT faunal assemblages imply a generalized, broad-spectrum diet. Ethnographic analogy fails to provide a behavioral framework for understanding this discrepancy because the resource structure of the PHT differed utterly from the ethnographic present. Palaeoenvironmental data alone are incapable of retrodicting ancient diets without an understanding of foraging costs in extinct resource landscapes. This paper reviews recent studies using behavioral ecology as a theoretical framework for simulating foraging behavior in a PHT resource landscape. The simulation for Railroad Valley, Nevada, suggests the explanation for the diversity of subsistence remains in PHT records lies in different foraging strategies for men and women, rather than risk aversion alone. Furthermore, the simulation suggests that Prearchaic hunter-gatherers enjoyed a narrower diet breadth than later foragers, prompting the mobility and technological profiles evinced in the PHT archaeological record.

Keywords

Great Basin; Pleistocene/Holocene transition; foraging behavior; simulation; sexual division of labor.

Introduction

The North American Great Basin (Fig. 1) is renowned for its rich ethnographic record documenting the ecological relationships of hunter-gatherers and the arid setting in which they lived. Informed by ethnographic analogy, over fifty years of archaeological research has demonstrated the existence of similar, although variable, 'Archaic' lifeways through much of the Holocene (Jennings 1957, 1964; Willey and Phillips 1958). More problematic is the pattern characterized by dramatically different technological organization and site

distribution in the Great Basin during the Pleistocene–Holocene transition (PHT), roughly between 11,200 and 8,000 BP. Understanding the nature of PHT adaptive strategies is an enduring problem in Great Basin prehistory (Beck and Jones 1997; Grayson 1993; Simms 1988; Willig and Aikens 1988). This task is complicated by PHT environments utterly unlike any of historical times, leaving Great Basin archaeologists without valid ethnographic analogs to assist interpretation of PHT material culture.

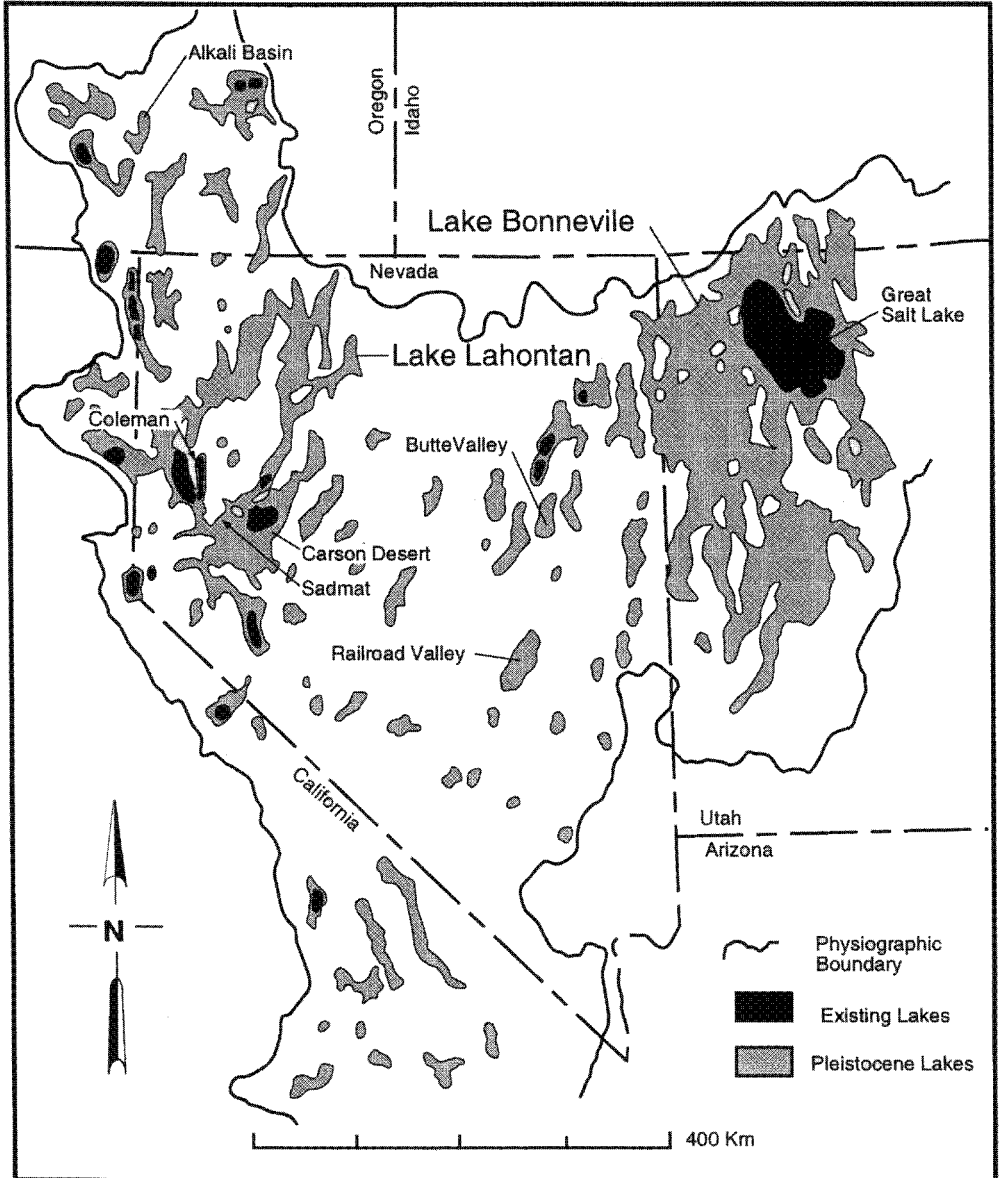


Figure 1 Physiographic Great Basin showing maximum extent of Pleistocene lakes, existing lakes (after Benson et al. 1972) and research areas mentioned in the text and in Fig. 4.

The significance of differences between PHT foragers and later hunter-gatherers divides archaeologists. Early assemblages contain an array of large projectile points and formal flaked tools resembling those of Great Plains and Southwestern Palaeoindians, but few ground stone tools, while middle to late Holocene assemblages contain smaller points, fewer formal flaked tools and abundant ground stone. These contrasts suggest PHT foragers emphasized hunting more than subsequent hunter-gatherers. However, lack of PHT megafauna hunting or butchering sites, or evidence that such animals survived in the Great Basin after 11,300 BP (Grayson 1993), obviates specialized big-game hunting similar to that in Palaeoindian models (Madsen 1982; Tuohy 1974). Moreover, direct subsistence evidence retrieved from coprolites (Eisalt 1997; Fry 1970, 1976; Napton 1997), and from a growing number of faunal assemblages (Beck and Jones 1997; Delacorte 1999; Pinson 1999), reveals a diet that included seeds, fish, and small animals.

Thus, many archaeologists see in the PHT the roots of later broad-spectrum hunting and gathering, using the terms Palaeoarchaic or Initial Archaic for PHT foragers (Beck and Jones 1997; Jones and Beck 1999; Pinson 1999), or eschewing categories altogether (Madsen 1999; Simms 1988). Nevertheless, while many aspects of technology and subsistence appearing in the PHT persist through the later Holocene, we, and others (Basgall 1988; Elston 1982, 1986a; Jennings 1986; Zeanah et al. 1995), emphasize the unique features of PHT archaeology with the term *Prearchaic*.

The problem concerns more than cultural-historical classification, going to the root of long-held notions about cultural ecology and Great Basin adaptive change. If Prearchaic adaptive strategies differ only in degree from ethnohistoric broad-spectrum adaptations, how can we explain the dramatically different technologies and settlement patterns manifested in the archaeological record? On the other hand, if we let the archaeology guide us to an inductive reconstruction of an extinct, specialized subsistence adaptation, how do we reconcile subsistence evidence that seems out of sync with the material culture?

The dilemma calls for a research strategy that lets us think 'outside the box' imposed by Great Basin cultural history and culture ecology. Some aspects of this research strategy concern purely methodological issues of locating buried PHT deposits in the Great Basin, developing chronologies, extracting subsistence data from surface assemblages and so forth (Beck and Jones 1997; Grayson 1993; Pinson 1999; Willig 1988). However, induction alone can succeed only in identifying ancient archaeological patterns unexplainable by reference to ethnography (O'Connell and Elston 1999). A theoretically based approach is required, one more informative of behavior than induction, and independent of ethnographic models. We are presently developing such an approach to be used in future archaeological tests.

Almost twenty years ago, behavioral ecology was nominated as a suitable theoretical approach to the Prearchaic (O'Connell et al. 1982). In this paper, we describe salient features of PHT environment and Prearchaic technological adaptation, discuss development of behavioral ecology (BE) as a research strategy for investigating Prearchaic adaptations, examine three applications of BE and discuss its implications for interpreting likely hunter-gatherer ecology in PHT resource landscapes. We concentrate on the interval 10,500–8,000 BP to which most extant archaeological data pertain.

Environments of the Pleistocene–Holocene transition

The Great Basin of North America is a region of internal drainage, broken into many mountain ranges and intervening valleys (Fig. 1). Great Basin environments responded to global climate changes (Fig. 2) of the PHT, although climatic effects varied from place to place (Benson 1999; Benson *et al.* 1995; Madsen 1999, 2000; Thompson *et al.* 1993). Plant species continually shifted range, location and abundance, forming communities with no modern analogs. High biodiversity and species turnover (Grayson 2000; Nowak *et al.* 1994) suggest a dynamic landscape in which climax was rarely approached. Nevertheless, some environmental generalizations are warranted.

After the cold and relatively dry last glacial maximum (LGM), a warmer and wetter climate produced shrinking glaciers and rising valley lakes (Madsen 2000; Thompson *et al.* 1993). Between 14,000 BP and 13,000 BP, lakes achieved their maxima (Fig. 1), but regressed rapidly after 12,000 BP, perhaps to desiccation. The last records of Pleistocene megafauna in the Great Basin occur about 11,300 BP (Grayson 1993). The Younger Dryas (YD) was an abrupt global return to glacial climate between 11,200 BP and 10,100 BP, briefly refilling lakes (Madsen 1999, 2000). The first well-dated signs of human occupation (Beck and Jones 1997; Grayson 1993) appear with its onset.

The early Holocene (EH) began with an abrupt return to a warming climate, 2–3°C cooler and moister than present, with greater seasonality. After the extreme variability of the late Pleistocene, EH climate was much more even (Fig. 2). Valley lakes regressed after the YD, but many basins contained shallow lakes and marshes until after 8,000 BP (Grayson 1993; Madsen 1999). In the northern Great Basin, a cool steppe comprised of sagebrush, mesophilic shrubs, perennial forbs and grasses extended from lake/marsh margins into the surrounding mountain ranges with stands of juniper, mountain

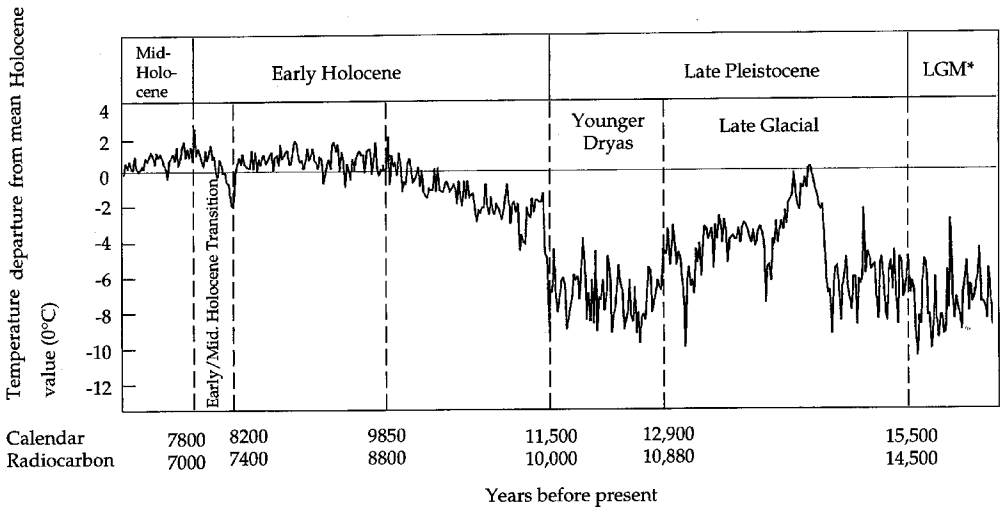


Figure 2 Late Pleistocene–Early Holocene global temperatures based on GISP2 data (from Pinson 1999, used with permission).

mahogany and riparian aspen (Madsen 1999; Nowak et al. 1994; Rhode 2000). Increasing desert scrub species in pollen records reflect the gradual desiccation of basins between 9,000 and 8,000 BP.

The relatively cool, even EH climate, abundant surface water and complex steppe vegetation created productive habitats for a rich biota of fish, waterfowl and mammals (Broughton 2000; Grayson 1993, 2000, Hockett 2000; Livingston 2000). In the northern Great Basin, many small mammal species (e.g. pygmy rabbits, woodrats, marmots, pikas) occurred at lower elevations than present (Grayson 2000). While early fossil and, especially, archaeological records of ungulates are rare, elk and bison infrequently occur in northern Great Basin sites (Bedwell 1973; Dansie 1987; Jennings 1957). Somewhat more numerous records of deer, mountain sheep and antelope suggest these animals were probably present in about the same relative proportions throughout the Holocene (Livingston 1999). To help assess their abundance in the EH, consider that Great Basin brushy steppe today supports large numbers of domestic cattle, wild horses and ungulates (Burkhardt 1995). Because there is a direct positive relationship between annual precipitation and plant biomass and animal productivity (Coe et al. 1976; Zeanah et al. 1995), grazing capacity in the cool, moist EH should have been greater than later in the Holocene. Bio-diversity, which also influences grazing capacity, remained high through the EH (Grayson 2000). For example, a fossil woodrat midden in the Lahontan Basin (Nowak *et al.* 1994) contained many more taxa of shrubs, forbes and grasses used as forage by various animals at the PHT than are now present at the site (Table 1).

Large magnitude, high-frequency climatic fluctuations of the PHT (Fig. 2) have been implicated in possible reduction of ungulate populations and food plants, with resulting stress on human populations (Madsen 1999; Pinson 1999). However, little evidence supports this contention. If numbers of radiocarbon dates are a crude measure of human abundance, Great Basin foragers appear to have flourished between 10,500 BP and 8,500 BP (Fig. 3).

Table 1 Forage plant taxa (shrubs, forbes and grasses) in a fossil woodrat nest in the Lahontan Basin (data from Nowak et al. 1994).

	<i>Numbers of forage plant taxa</i>		<i>Percentage increase</i>
	<i>Present*</i>	<i>Fossil**</i>	
Antelope	8	5	38.5
Mule deer	10	9	47.4
Mountain sheep	12	8	40.0
Rabbit/hare	13	6	31.6
Ground squirrel	7	6	46.2
Woodrat/marmot	3	2	40.0

Notes

* taxa present in both fossil and modern flora at site.

** taxa present only in fossil record or modern flora at higher elevation.

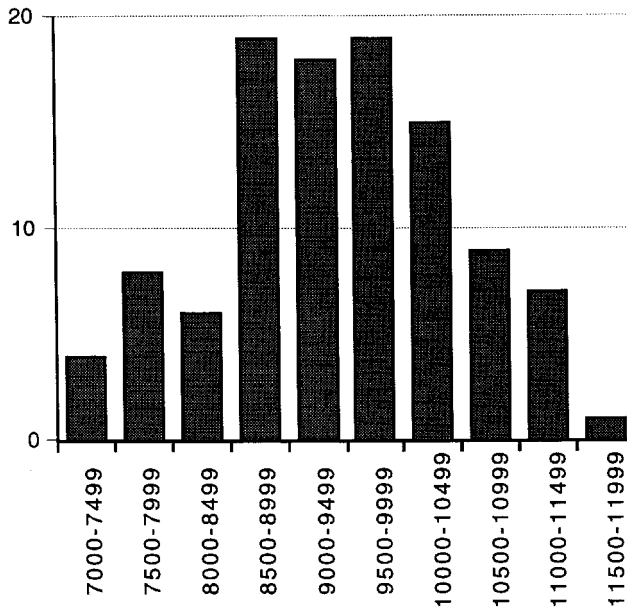


Figure 3 Numbers of Great Basin radiocarbon dates by 500-year interval (charcoal or organic items only – no bone or bulk dates).

Prearchaic–Archaic contrasts in technology, settlement and land use

Prearchaic foragers of the Great Basin behaved differently from Archaic folks, even though both employed many of the same components of material culture, including cordage, baskets, mats, bags, fishnets, atlatls and darts, woven fur robes, fiber sandals, skin moccasins, milling stones and flaked stone tools (Beck and Jones 1997). In part, we can understand these behavioral contrasts by reference to middle-range theory and the economics of resource procurement in PHT and later Holocene environments.

People tend to locate themselves in places most convenient to resources they pursue; however, environmental change may create or eliminate resources, or change their abundance or distribution (Binford 1977, 1979; Pinson 1999; Raven and Elston 1989; Zeanah *et al.* 1995). During the EH, roughly similar foraging opportunities pertained from valley to valley: highly productive shallow lakes and marshes on the valley floors (Fig. 1), brushy steppe from shoreline to the tops of most mountains, riparian woodlands along streams and juniper woodland with a brushy or herbaceous understory on ridges. The marsh-steppe ecotone was convenient to both marshes and piedmont; hence, a good choice for bases from which to forage in a variety of low to mid-elevation habitats (Pinson 1999). Extensive valley marshes offered foragers seeds, shoots, pollen, birds and bird eggs, shellfish, fish and small mammals. Moreover, large animals may have found marsh-side forage and cover attractive. Lower to mid-elevation steppe and riparian woodland provided high-quality habitat for ungulates (Grayson 1993; Jones and Beck 1999) comparable to

modern upper montane habitats (historically best for hunting large game). The most extensive Prearchaic sites often lie in what now are poor habitats where later Archaic sites are rare, but which in the PHT were prime for exploiting lake/marsh resources and hunting in mid- to low-elevation steppe. These include lowland settings (beach bars or lunettes) associated with pluvial lakes or marshes, elevated old surfaces on valley margins or Pleistocene river and stream terraces (Basgall 1988: 104; Beck and Jones 1994, 1997; Elston and Bullock 1994; Elston et al. 1977; Jones et al. 1996; Pinson 1999; Rusco and Davis 1979; Willig 1988; Zancanella 1988). Fewer Prearchaic sites occur in upland-montane locations where most are small lithic scatters and isolates.

Several lines of evidence indicate low population density and high residential mobility for Prearchaic foragers. Prearchaic sites are relatively few and, while sometimes spatially extensive (e.g. Graf 2001), artifacts are usually sparse. Prearchaic lithic assemblages exhibit little variability, suggesting minimal functional differentiation between sites. Sites lack midden accumulations or evidence of stored food. Very few residential structures date to the EH; none represents long-term occupation (Connolly and Jenkins 1995; Harrington 1957; Pinson 1999). Toolstone distributions from known sources suggest either more extensive social networks or operation over larger territories than in the Archaic (Basgall 1989; Beck and Jones 2001; Graf 2001) (Fig. 4). With low population density, little competition for resources, and similar sets of resources valley to valley, people might have employed a land-use pattern similar to the megapatch strategy proposed by Beaton (1991) where it would pay to pick off high-ranked resources in short-term occupations and then move on to the next patch offering similar opportunities. Frequent residential moves (especially on the predominant north-south axes suggested by toolstone distributions) may have helped avoid seasonal shortages and the need for food storage (Basgall 1989; Elston 1986b).

The few studies of EH coprolites and other archaeological residues indicate that Prearchaic people made use of plants, small mammals, birds, fish and shellfish, as well as large ungulates such as antelope, mountain sheep, elk and bison (Beck and Jones 1997; Dansie 1987; Delacorte 1999; Eisalt 1997; Fry 1970, 1976; Napton 1997, Pinson 1999). The range of items in this diet is similar to Archaic diets. However, Prearchaic and Archaic lithic toolkits suggest greater investments in opposite ends of the diet spectrum. Prearchaic assemblages are rich in formal, hafted flaked stone tools (points, bifaces and scrapers) good for hunting and processing large animals (Fig. 5). Although light duty milling stones are occasionally present in Prearchaic assemblages, evidence of intensive seed processing and storage characteristic of the Archaic is rare. Seeds were as surely in the Prearchaic diet as large game, but seed harvesting received less investment and hunting greater investment in Prearchaic technology than in Archaic technology.

In the warmer, dryer climates of the early Middle Holocene (MH) and later, overall biological productivity was lower, sources of surface water became more scarce and less equably distributed as lakes and marshes in most valleys disappeared (Grayson 1993). Some valleys continued to offer abundant resources, while others were deserts dominated by bare playas. MH environmental heterogeneity and patchiness increased further by northward spread of pinyon pine across the Great Basin. The degree to which people operated logistically from fixed bases or frequently moved camp (Binford 1977, 1979) was increasingly influenced by local resource structure and population density (Elston 1982).

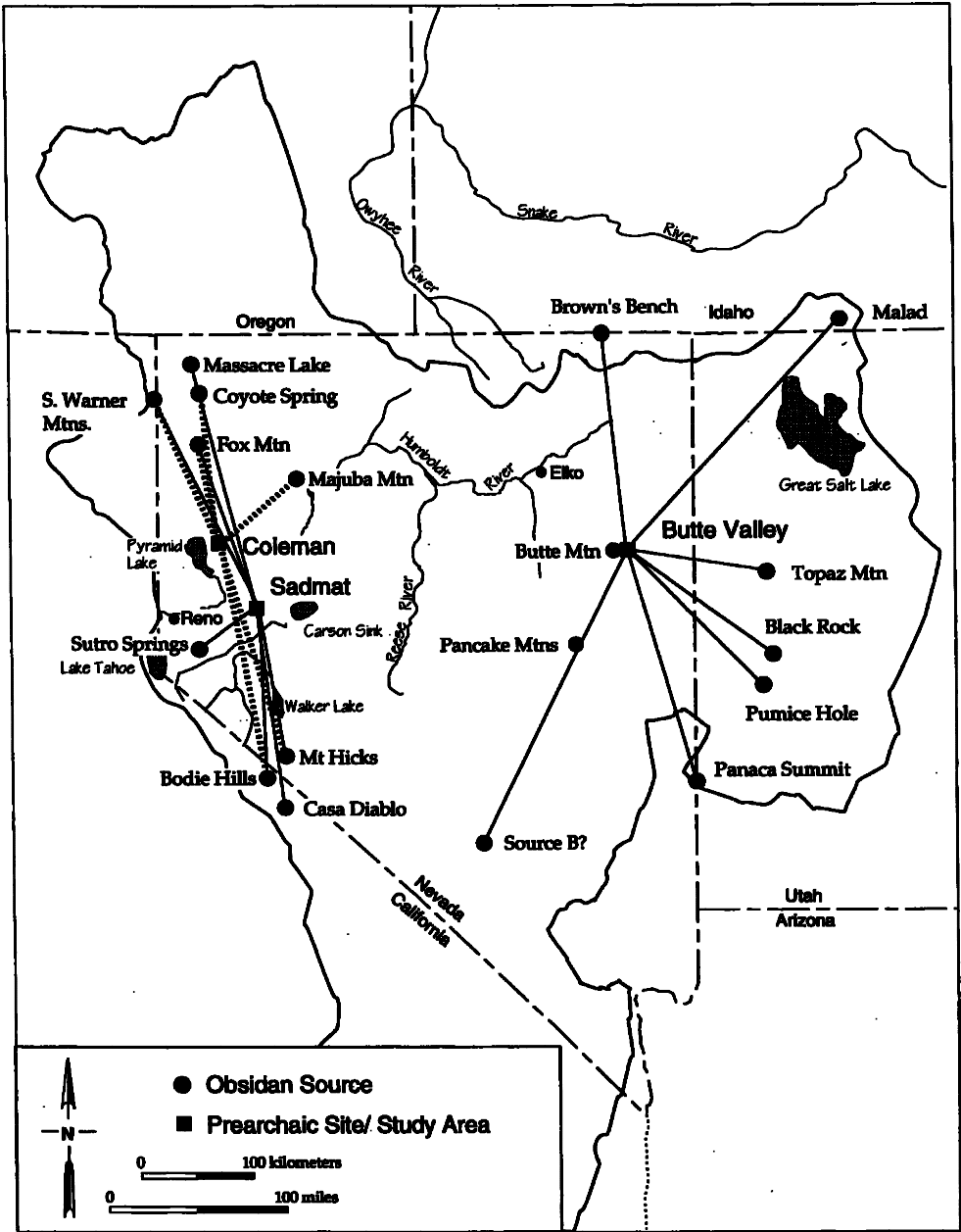


Figure 4 Obsidian sources for Prearchaic lithic assemblages from the Sadmat and Coleman sites in western Nevada (Graf 2001), and from Butte Valley, eastern Nevada (Beck and Jones 2001).

From the MH, Great Basin people foraged in many lowland and upland settings, resulting in a more complex archaeological record where sites display higher assemblage variability. Some sites were short-term camps or task sites, while others assumed a residential character, with middens, substantial structures and storage features (Elston 1986a). Along

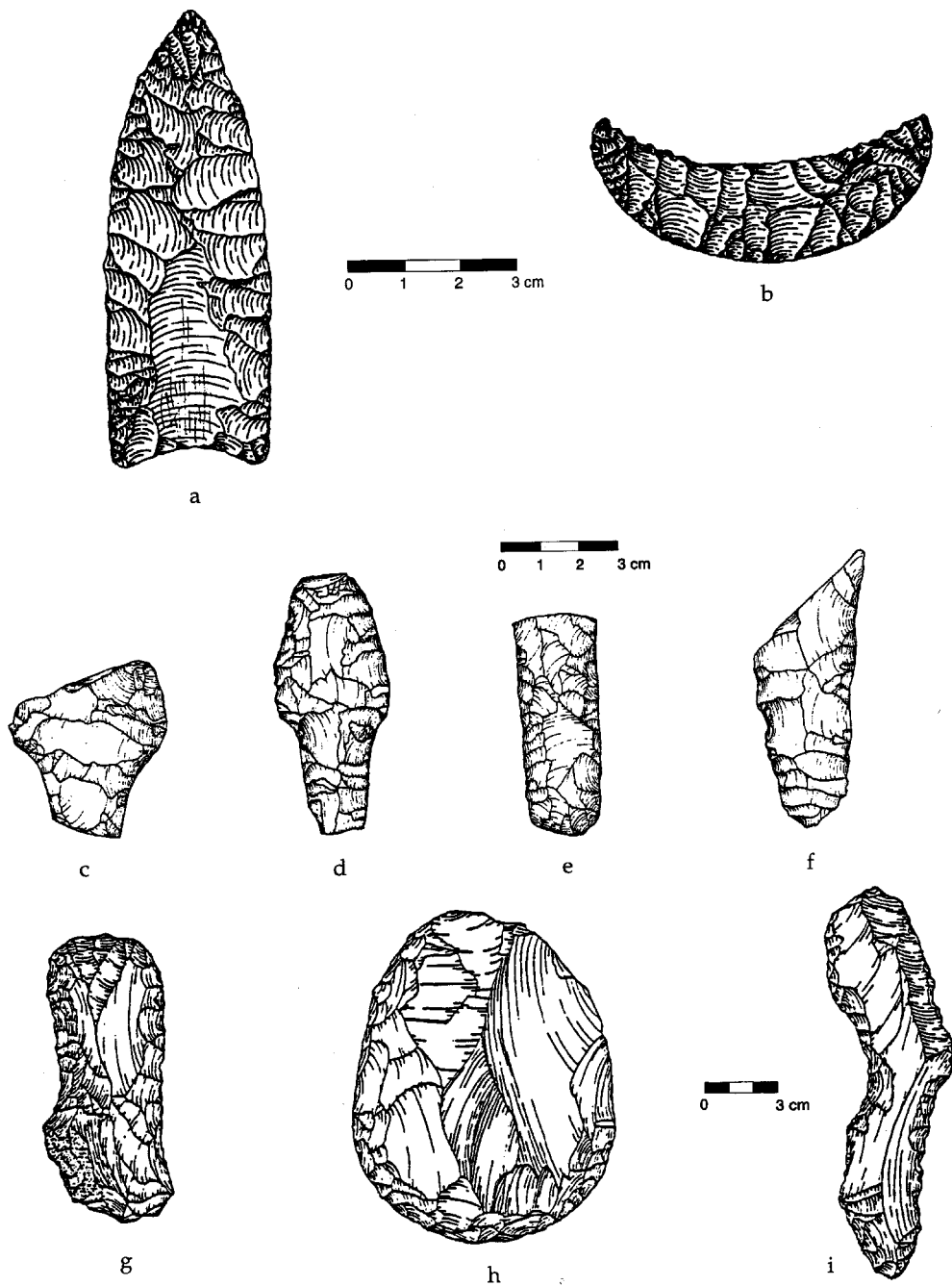


Figure 5 Prearchaic lithic tools: a) fluted point; b) crescent (after Fagan 1988); c-f) stemmed points; g-i) unifacial scrapers (after Davis and Rusco 1987).

with storage, heavy-duty seed-milling equipment became abundant. However, the seasonal Archaic pattern (also observed ethnographically) of living in winter camps on stored food (especially seeds), and becoming more mobile during the remainder of the year, seems to have begun in the MH. With the passage of time, Great Basin foragers operated in smaller territories, became more sedentary, invested more in storage, harvesting and milling equipment and less in formal flaked stone tools (e.g. Bettinger 1999).

Theoretical perspectives of Prearchaic subsistence based on behavioral ecology

Before 1982, archaeologists lacked a guiding theoretical context capable of garnering insights from extant data to guide future research or refine subsistence-settlement models. A lack of suitable ethnographic analogies for EH foraging adaptations hindered investigations of the Prearchaic. Middle range theory helped interpret functional and technological variability in sites and artifacts, but did little to explain it. Big-game hunting proponents eagerly awaited discoveries of kill and butchery sites, but were unable to reconcile mounting evidence for use of a broader array of resources. Advocates of generalized foraging were unable to accommodate the hunting-oriented technology, or evidence of extensive mobility, into their notions of adaptive continuity.

In this context, O'Connell et al. (1982: 234–35) advocated behavioral ecology (BE) as a theoretically coherent approach for predicting prehistoric subsistence patterns where suitable ethnographic models do not apply. Such attempts have drawn three modeling tools from the theoretical arsenal of BE: diet breadth, patch choice and risk. In this section, we trace the development of a behavioral ecological research strategy for investigating Prearchaic adaptations, and discuss the implications such models have for interpreting EH forager ecology.

Models of Prearchaic diet breadth

O'Connell and colleagues (1982) used the diet breadth model (DBM) to explain the rarity of EH milling stones. The DBM ranks resources according to the ratio of calories to handling time, assuming that foragers take encountered prey only if it yields higher caloric returns than those offered by searching for higher-ranked resources. Two DBM predictions are that the abundance of high-ranked resources determines whether lower-ranked resources fall into the optimal diet, and that fewer encounters with higher-ranked prey can expand diet breadth to include lower-ranked resources (Schoener 1971). High-ranked resources in EH environments were presumed to have been sufficiently abundant for Prearchaic foragers to bypass low-ranked seeds. As climatic changes diminished the abundance of higher-ranked prey, Archaic foragers added seeds to their diets and milling equipment to their technological repertoire. This hypothesis relied on a reasonable assumption that seeds ranked lower than most other Great Basin foods (i.e. medium and large-sized game, roots and fish).

Simms (1987) tested this assumption by experimentally harvesting an array of Great Basin plant resources, estimating animal return rates from historical, ethnographic and wildlife management sources. Seeds ranked lowest, although their return rates varied

widely by species, harvest timing, procurement mode and abundance. Game proved among the highest-ranked resources, with rank correlating roughly with body size.¹ Given DBM predictions, it seemed reasonable to infer that Prearchaic and Archaic foragers took large game whenever available, but harvested seeds only when higher-ranked resources were scarce. However, Simms could not demonstrate that diminished encounters with large game and consequent diet breadth expansion accounted for intensified seed usage during the MH. Estimating nineteenth-century encounter rates, he calculated the diet breadth of ethnohistoric foragers, predicting that women should have bypassed lower-ranked seeds under all conditions, including the absence of large game. Clearly, the DBM contradicts the ethnographic record documenting Great Basin women harvesting and storing small seeds. Because the DBM fails to predict ethnohistoric small-seed harvesting, even in the absence of large game, it also fails to predict seed usage by either Prearchaic or Archaic foragers. Consequently, the MH proliferation of milling stones cannot reflect the inclusion of seeds into MH diets because of declining large game encounters. Noting this predictive failure, Simms (1987: 82–3) speculated that intensified MH seed use might have resulted from seed storability, rather than short-term foraging efficiency; gatherers stored seeds anticipating seasonal food shortages.

In contrast to the predicted exclusion of seeds from all prehistoric diets, Simms (1987: 88) calculated that Prearchaic encounters with large game would have had to have been as much as twenty-five times greater than ethnohistoric encounter rates to bump small game and higher-ranked plants out of men's optimal diets. Simms concluded that these middle-ranked resources were firmly ensconced in Prearchaic diet under any plausible scenario of large game abundance. Based on this assessment, Simms (1987: 98) conceded that Prearchaic folk may have taken large game more often than Archaic foragers did, but argued that EH game could not have been abundant enough to support a specialized big-game hunting adaptation. Fluctuations in resource abundance demanded that Prearchaic foragers make frequent adjustments to diet breadth, ranging from broad-spectrum seed harvesting to big-game hunting on a daily, seasonal or yearly basis. This notion of Prearchaic adaptive flexibility accounted for occasional Prearchaic milling stones, coprolite evidence that Prearchaic foragers ate seeds and the persistence of some Prearchaic point types into the MH (Simms 1988).

Models of Prearchaic patch choice

The DBM merely ranks resources by relative returns while assuming that resources are randomly distributed. However, foragers face a more complicated world. Observing that Simms' modeling exercise did not consider the spatial and seasonal distribution of resources in EH environments, Intermountain Research (IMR) used the patch choice model (PCM) to simulate Prearchaic subsistence and settlement (Elston et al. 1995). The PCM predicts foraging choices in patchy environments by ranking resource patches according to caloric return. Foraging in a patch is economical if the returns for seeking and handling resources within that patch exceed the overall returns for traveling to and foraging within higher-ranked patches. The PCM predicts that foragers prefer the most profitable patches, and that a change in resource abundance may alter the array of patches selected (MacArthur and Pianka 1966).

Estimating the composition and distribution of biotic habitats by soil type, IMR simulated the nineteenth-century resource landscape of the Carson Desert in western Nevada, classifying the biota associated with each soil as a patch and modeling patch choice decisions by seasonality and sexual division of labor (Raven and Elston 1989; Zeanah et al. 1995; Zeanah 1996). This landscape served as a baseline against which palaeoenvironmental data could be compared to approximate EH resource distributions and Prearchaic foraging decisions.

IMR assumed that higher EH precipitation fostered abundant small and large game, as well as plant foods around lowland wetland communities in distributions dramatically contrasting with discrete nineteenth-century upland, desert and wetland patches. IMR calculated the optimal diet of Prearchaic men and women (Fig. 6) for an array of wetland and terrestrial prey types reasonably presumed available within foraging distance of an EH lowland camp. IMR used Simms' (1987) return rate estimates for the ethnohistoric Great Basin, but increased his encounters with game by 75 per cent, corresponding to the greater densities of forage expected for the EH Carson Desert.

Like Simms, IMR's simulation predicted that Prearchaic women would have bypassed most seeds in favor of the highest-ranked plants and small game. The optimal diet of men always included medium and large game but, unlike Simms' estimates, excluded smaller game. Unlike ethnohistoric foragers, Prearchaic men should have achieved higher return

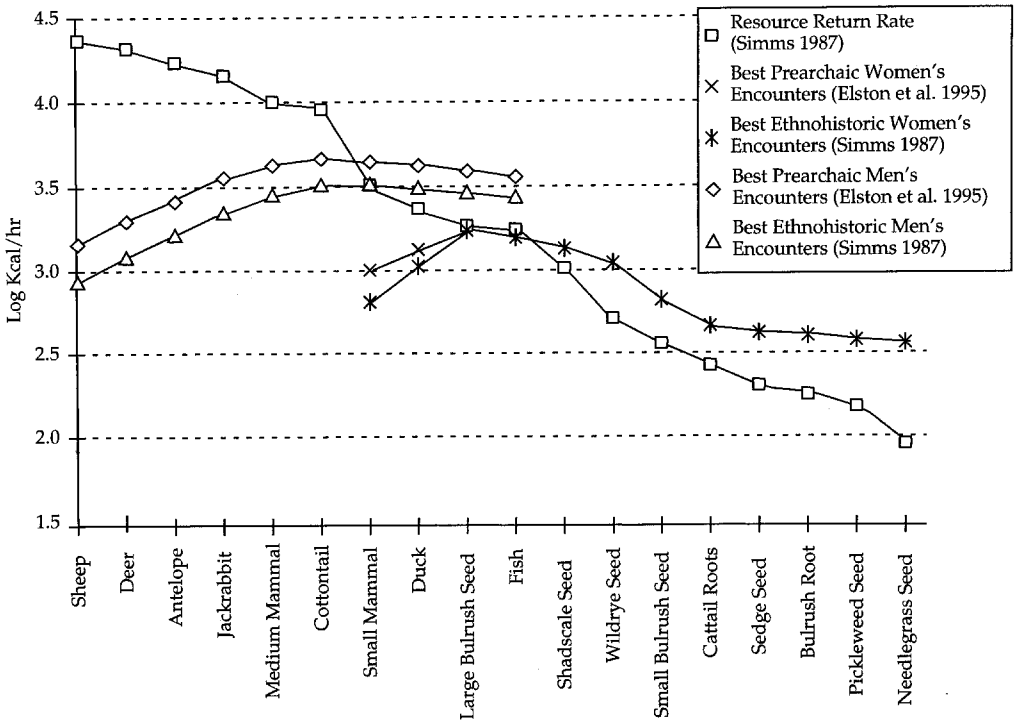


Figure 6 Simulated autumn foraging returns for men and women foragers in early Holocene wetlands.

rates than women, with both men's and women's foraging best in lowland patches. IMR proposed that this encouraged a residentially mobile adaptation in which men's hunting opportunities determined residential movements and women's foraging opportunities determined site location. Although Prearchaic foragers could not be stereotyped as 'big-game hunters', the EH ecological setting prompted a hunting-oriented adaptation significantly different from later hunter-gatherers. IMR argued that this perspective best accounted for specialized Prearchaic lithic assemblages, point distributions and evidence for high residential mobility.

A model of Prearchaic risk sensitivity

A third application of BE to model Prearchaic foraging used the Z-score model (ZSM) to consider foraging risk in EH environments (Pinson 1999). The ZSM predicts forager choices when return rates vary stochastically by considering the mean and variance of resource return rates. It assumes that acquisition of a minimum quantity of food within a limited period is critical. If average foraging returns exceed a critical threshold (i.e. starvation, reproductive success), pursuit of low-variance resources minimizes the risk of falling short. If foraging means fall below the threshold, gambling on high-variance resources maximizes chances that foraging returns will exceed minimum requirements (Stephens and Charnov 1982).

Pinson's (1999) hypothesis is that starvation risk imposed a minimum threshold for Prearchaic foragers. Pinson assumed variance in return rates correlates with prey size,² and that Simms' (1987) resource ranking correlates with mean return rates. Prearchaic hunter-gatherers should have been either risk-averse or risk-prone.³ Risk-prone foragers followed predictions of the DBM and PCM, preferentially pursuing large ungulates over smaller game and foraging in habitats where encounters with large game were most likely. In contrast, risk-averse foragers preferred lower-ranked, but predictable, small mammals, fish and fowl, foraging in locations offering access to multiple habitats. Pinson did not consider the effects of sexual division of labor on resource choice or risk sensitivity.

These predictions found support in analyses of faunal assemblages and point distributions in the Alkali Basin of southeastern Oregon. EH faunal assemblages have relatively low ratios of artiodactyl to lagomorph bone compared with later Holocene assemblages,⁴ and EH projectile points cluster in locations offering access to multiple biotic habitats. Pinson interprets this as evidence that Prearchaic foragers avoided starvation risk by emphasizing small-game procurement at the expense of large-game hunting.

Evaluation of Z score and patch choice models of early Holocene adaptation

Given that three attempts to model Prearchaic adaptations have been made in the twenty years since BE was introduced to Great Basin archaeology, it is worth considering whether BE has contributed any meaningful insight. Prospects seem bleak at first glance since the three applications make contradictory inferences about Prearchaic foraging

behavior, claiming to retrodict broad-spectrum foragers, big-game hunters and small-game specialists. However, all three agree that *specialized* big-game hunting is ecologically untenable in EH Great Basin environments, expecting that Prearchaic foragers procured a more generalized array of prey. Of contention is whether Prearchaic adaptations were categorically different from later Archaic patterns; if so, what roles did large-game hunting and generalized foraging play in determining the distinctive strategies? We have seen that DBM alone is useful for ranking resources, but that patch choice conditions diet breadth, in turn conditioned by environment. Therefore, in the following discussion we evaluate the ZSM as applied to the North Alkali Basin, Oregon (Pinson 1999), and the PCM (in which the DBM is included) in Railroad Valley, Nevada (Zeanah et al. 1999).

The ZSM in North Alkali Valley, Oregon: risk-averse pursuit of low-ranked resources

Pinson (1999) interprets the prevalence of small game in EH faunal assemblages of south-eastern Oregon as evidence that starvation promoted a distinctive, risk-averse, Prearchaic foraging strategy. The Oregon faunal profile is consistent with coprolite evidence from the Bonneville and Lahontan basins for generalized diets (Eiselt 1997; Fry 1976), and is duplicated by EH faunal assemblages from south-eastern California (Delacorte 1999). These findings do not contradict DBM and PCM simulations (Elston et al. 1995; Simms 1987) that predict such resources to have been regular prey of Prearchaic women. The real question is whether the scarce remains of large ungulates in the faunal record demonstrates that Prearchaic foragers avoided risk by shunning large game.

Pinson (1999: 109–13) proposes that EH foraging risk was induced by local variations in water budget, precipitation, watershed catchment and so on, causing lake basin productivity to vary unpredictably. When moving into a new basin, Prearchaic foragers could not anticipate the abundance of prey based on previous encounter rates, and, thus, avoided starvation risk by procuring the most dependable resources. Yet Prearchaic foragers must occasionally have entered basins where foraging returns proved unlikely to surpass the starvation threshold. The ZSM predicts that such foragers should choose *higher*-variance resources over alternatives that are more predictable: risk-averse strategies should characterize only situations where mean foraging returns are securely above the starvation limit. If risk was the primary constraint of Prearchaic adaptations, there should be evidence for both specialized large-game hunting and small-resource procurement rather than consistent evidence of generalized foraging.

Pinson's scenario does not address why, if foragers are risk-averse, they should even bother to move from one basin to another. EH lowland environments supported abundant and diverse populations of fish, small mammals and waterfowl that should have been resilient to over-exploitation by Prearchaic foragers (cf. Winterhalder et al. 1988). Late prehistoric and ethnographic foragers exploiting such patches tended to stay put, moving out only when extraordinary resource opportunities became available elsewhere or in response to catastrophic environmental failures (Fowler 1990, 1992; Raven 1992; Raven and Elston 1989). If EH environments were really as patchy and unpredictable as proposed by Pinson, Prearchaic foragers should have employed land-use strategies similar to those of the Archaic, generating similar archaeological residues. We agree that EH ungulate abundance was probably sensitive to hunting pressure, and, as well, varied with

seasonal migrations (cf. Winterhalder *et al.* 1988). But, in fact, there seems little reason for Prearchaic hunter-gatherers to move from basin to basin *except* to maximize large-game encounters in the more homogeneous and productive EH environments we envision. Such a strategy would account for the hunting orientation and evidence of high mobility in Prearchaic lithic assemblages.

One constraint of the standard ZSM is that risk-averse foragers forgo the opportunity to seek higher-return prey by pursuing low-variance resources. Making this assumption of Prearchaic foragers fails to consider the role of sexual division of labor in alleviating scheduling conflicts. The Hadza of eastern Africa provide a useful analogy (Hawkes 1990; Hawkes *et al.* 1991). Hadza men pursue big game to the exclusion of smaller prey even though many days of failure separate hunting successes. Women and children avoid starvation by procuring small game, roots, berries and nuts. A similar division of labor likely characterized Prearchaic foraging strategies:⁵ men pursued high-return but high-variance large game, while women procured more secure, but lower-ranked resources. Therefore, Prearchaic foragers would not have had to abandon hunting in order to provision themselves daily with smaller resources.

We propose that small seed usage is a more likely example of risk-averse foraging than small-game procurement. Both Simms (1987) and IMR (Zeanah *et al.* 1995) predicted the exclusion of small seeds in optimal diets of Prearchaic through ethnohistoric hunter-gatherers.⁶ Obviously, ethnographic and archaeological data demonstrating that seeds were a critical food resource after the Prearchaic challenge this prediction.

Noting this predictive failure, Simms (1987) first suggested that Archaic women stored seeds to avoid over-winter food shortages. Although expensive to process for consumption, seeds can be stored with relatively little effort, allowing gatherers to defer high processing costs for future periods of scarcity (Bettinger 1999). If so, seed storage qualifies as risk-averse foraging, because Archaic women were, by definition, forgoing opportunities to pursue higher-ranked prey to create a predictable food patch by stockpiling food resources too low ranked to enter their optimal diet.⁷ If risk aversion rather than energy maximization accounts for Archaic seed usage, then there should have been less of a need for food storage in the EH than in later periods.

Patch choice and EH and MH foraging ecology in Railroad Valley

To contrast EH and MH foraging strategies, it is instructive to consider IMR's (Zeanah *et al.* 1999) simulation of foraging ecology in Railroad Valley, eastern Nevada, using similar techniques for estimating biotic habitats by soil type that were employed in the Carson Desert. However, more detailed regional palaeoenvironmental data, better information on the productive capacity of modern soil types and improved GIS (Geographic Information System) capabilities permitted a more finely tuned reconstruction of prehistoric foraging landscapes than was feasible in the Carson Desert.

Annual herbaceous biomass productivity (Fig. 7) was estimated for EH and MH foraging landscapes in Railroad Valley by putting an EH lake on the modern playa and altering the modern productivity of soil types to reflect expected EH and MH parameters of precipitation, water table and erosion. These resource mosaics formed the setting for simulating the optimal diet breadth of male and female foragers randomly encountering

prey in each habitat by season. Obviously, these palaeoenvironmental reconstructions and foraging simulations must be cautiously regarded as only tentative, rough approximations. However, they allow us to gauge the effects of palaeoenvironmental change on foraging behavior in a theoretically consistent manner.

Mean and standard deviation of simulated men's foraging returns by season for the fifteen most productive Railroad Valley habitats are shown in Figure 8. The figure also shows the thresholds under which lower-ranked seeds and small game begin to enter optimal diets. Compared to the EH, hunting returns of MH men diminish as much 75 per cent in all seasons, suggesting that hunting was much less productive in the MH. Women's MH foraging returns (Fig. 9) lessen much less dramatically, with autumn returns increasing slightly (due to arrival of pinyon as a new resource). During summer, autumn and early winter, women's foraging returns were too high to allow small seeds into optimal diets under both EH and MH climatic scenarios. However, MH women experience a 60 per cent reduction in late winter-spring foraging returns that should allow even the lowest-ranked seeds into the diet, but in the season when most small seeds are unavailable. This diminution of women's foraging opportunities reflects the desiccation of lakeside wetlands in Railroad Valley, removing fish, waterfowl, eggs and wetland small mammals from women's springtime prey opportunities.

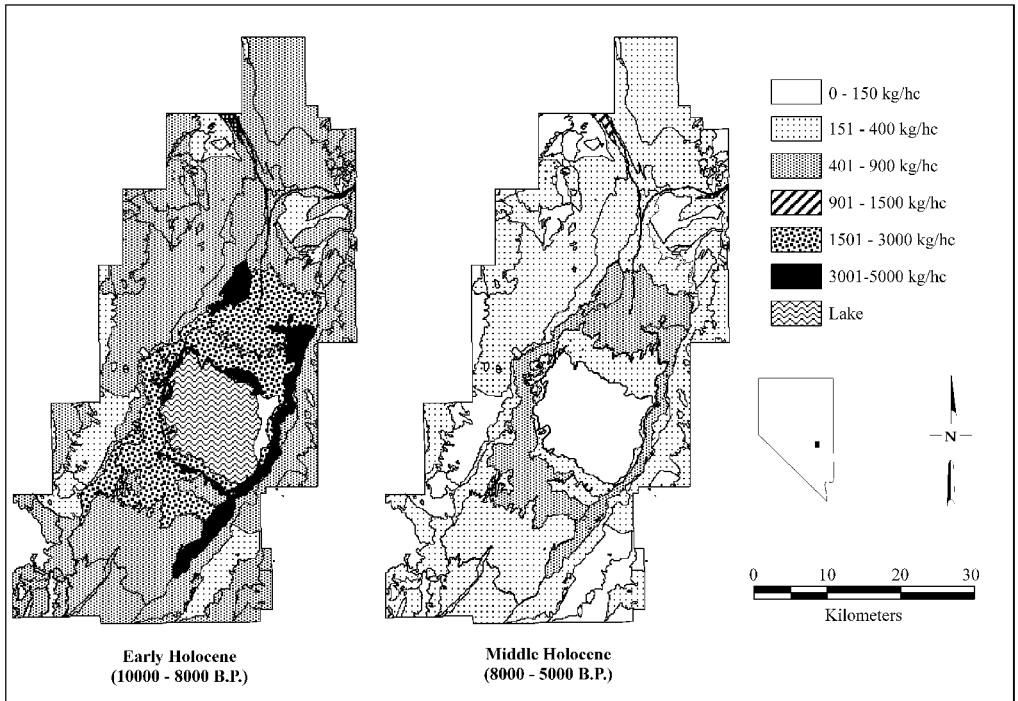


Figure 7 Above-ground annual herbaceous biomass estimated for early and middle Holocene Railroad Valley, Nevada.

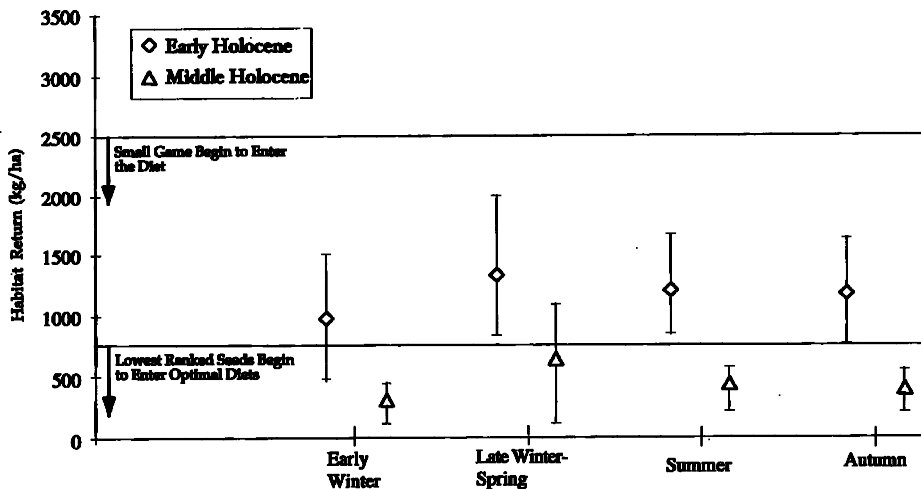


Figure 8 Men's foraging returns (mean and standard deviation) by season for the fifteen highest-ranked habitats in Railroad Valley, showing thresholds at which different resource classes enter the diet.

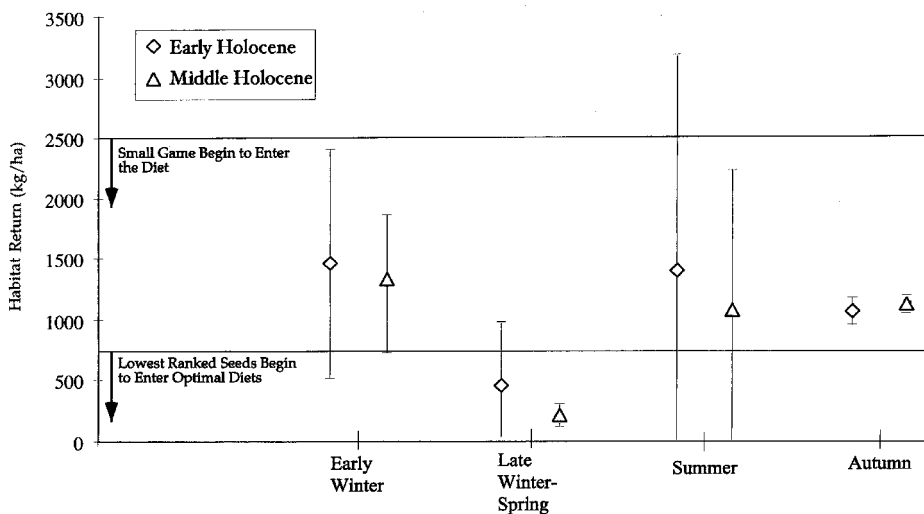


Figure 9 Women's foraging returns (mean and standard deviation) by season for the fifteen highest-ranked habitats in Railroad Valley, showing thresholds at which different resource classes enter the diet.

Conclusion

If broad-spectrum foraging and sexual division of labor were always components of Great Basin foraging strategies, what accounts for the Prearchaic–Archaic contrast in the archaeological record? We propose that Prearchaic technology and settlement

pattern are responses to low human population amid a unique landscape and resource structure. Our simulations point to key ecological differences between Prearchaic and Archaic subsistence strategies in the Great Basin. Large animals should have been relatively abundant in low to mid-elevation brushy steppe from fall to spring where they could have been hunted from lowland bases. EH wetlands provided a relatively secure late winter-early spring foraging patch for women where they could take small game, waterfowl and fish from the same sites. The abundance of expansive wetlands, and lack of competition throughout the Great Basin, allowed Prearchaic foragers high mobility that maximized men's encounters with large game without sacrificing women's foraging interests.

If lithic technology and tool morphology are adaptively significant, the function of Prearchaic lithic assemblages is clear. In addition to flake tools and choppers, these assemblages include bifaces, projectile points, steep-edged end- and side-scrapers, bifaces, fine graters and awls, and crescents, but they rarely contain milling stones (Basgall 1988; Beck and Jones 1997; Davis and Rusco 1987; Elston 1986a; Willig 1988). Flaked stone tool preforms are frequently blades or blade-like flakes; tools are notable for their large size. Stemmed bifaces are often multipurpose, serving variously as points, knives and scrapers (Jones and Beck 1999). The large size and abundance of formal tools in Prearchaic lithic assemblages reflect both mobility and the importance of capture and processing tasks for which the tools were used (Bleed 1986; Elston 1990, 1992; Goodyear 1979; Kelly 1988, 1992; Kelly and Todd 1988; Tomka 2001; Torrence 1983, 1989; Ugan and Rogers 2000). Bifaces provide a means for mobile foragers to transport toolstone in a useful form far from toolstone sources, and are reliable, maintainable and flexible (easily converted to another form). These qualities, and the ability to predict tool-use life, are enhanced in bifaces and other formal tools by use of high-quality toolstone, large tool size, standardized symmetrical form and standardized maintenance techniques. Such a formal, standardized lithic technology is more expensive to master and maintain than expedient approaches (Elston 1992). However, the pay-offs are enhanced tool reliability and work efficiency (Bleed 1986; Tomka 2001).

Although one could use this tool kit to capture and process fish, small mammals, and plants, it seems more appropriate for use on larger prey. Indeed, Tomka (2001) argues that proportions of formal and standardized tools (particularly knives and scrapers) in lithic assemblages relate directly to intensity of large-animal processing. He suggests that the long-term trend in North America toward greater reliance on expedient tools, noted by Parry and Kelly (1987), is better explained as a decreasing reliance on strategies of high-volume animal hunting and processing than as decreasing residential mobility.

Extirpation of Great Basin wetlands during the MH removed women's critical foraging patches from most basins, creating significant risk of food shortages. Residential sites were established at perennial springs and associated wetlands (Fagan 1974; O'Connell 1975; Elston 1982). By accumulating seed stores during periods of seasonal abundance, MH women minimized resource variance, decreasing the chances of falling short of food during the winter. Dependence on storage tethered Archaic foragers to their seed caches, reducing their overall mobility and spawning a profound reorganization of tool production, toolstone procurement and hunting strategies (e.g. Eckerle and Hobey 1999). Men

continued to hunt, but more and more in logistical forays from relatively fixed bases. As men's and women's diets increasingly overlapped, men invested less in hunting equipment, while women invested more in plant-processing tools. Mass large-game procurement techniques occurred too infrequently for investment in specialized formal processing tools to pay off. This explanation accounts not only for the MH disappearance of formal chipped stone tool industries and the proliferation of milling equipment, but also the appearance of storage features and prolonged duration residential base camps (Bedwell 1973; O'Connell 1975; Hattori 1982; Schroedl and Coulam 1994).

We cannot base contrasts between Prearchaic and Archaic foragers in the Great Basin on either diet breadth or risk-sensitivity alone. Broad-spectrum foraging spans at least the Late Palaeolithic (Stiner et al. 2000), and was always a feature of Great Basin foraging. Moreover, Great Basin foragers continued to hunt existing large game through the mid-Holocene and into the ethnohistoric period. Starvation was a risk faced by hunter-gatherers throughout Great Basin prehistory, moderated by a complex of tactics, including variable diet breadth and mobility, and sexual division of labor (Zeanah n.d.), although the implications of the latter for Great Basin foraging strategies have been little appreciated. Great Basin men's and women's diets overlapped somewhat, but like male foragers elsewhere (Hawkes 1996), men tended to pursue more high-ranked but highly variable resources such as large game, while women focused on lower-ranked, less variable resources such as waterfowl, fish and seeds that require little processing. This division allowed Great Basin foragers to have it both ways: women saw to it everyone had something to eat, while men brought home the occasional high-return prey. Therefore, men invested heavily in hunting technology, while women had no need to invest in equipment for intensive plant processing.

We have built a case that a BE theoretical approach has yielded meaningful insight into Prearchaic foraging adaptations, and that DBM and PCM simulations better account for the Prearchaic archaeological record than the ZSM alone. However, our theoretical expectations must be borne out by further archaeological investigations. In large part, the objectives of future research have already been laid out, and involve continued search for buried PHT deposits, and extraction of subsistence and chronological data from surface assemblages (Beck and Jones 1997). Our BE approach adds testable expectations to this research strategy. Our simulations suggest that the known Prearchaic record is biased toward sites positioned primarily to access women's resources, but bearing a technology reflecting men's subsistence and mobility strategies. If we are correct, evidence of men's high-variance foraging behavior lies buried in valley piedmonts and passes, away from the wetland settings where the most extensive Prearchaic sites are usually found. Effective search for such evidence must combine geo-archaeological identification of sediment exposures of suitable age, with theoretical simulations of EH large game habitat and Prearchaic hunting behavior.

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Silver City, Nevada

Notes

- 1 A correlation between body size and resource ranking seems well supported ethnographically (O'Connell and Hawkes 1981; Winterhalder 1981; Hawkes *et al.* 1982), and often serves to rank prey items relatively (Broughton 1994). However, this assumption is violated when smaller resources occur in unusual abundance, returning exceptionally high caloric yields. For example, grasshoppers obtained from windrows along margins of lakes provide higher caloric return rates than large-game hunting (Madsen and Kirkman 1988). Brine fly larvae, bulrush and pickleweed seed and fish are also known to occur occasionally in windrows and can be expected to return similarly fantastically high caloric return rates (Raven and Elston 1988; Bettinger 1993; Barlow and Metcalfe 1996; Madsen and Schmitt 1998). Similarly, mass capture technologies and communal hunting tactics can provide higher caloric returns for hunting small and medium-sized mammals than encounter hunting of large mammals (Simms 1987). Therefore, the ranking of any particular prey item varies depending on mode of procurement.
- 2 Like the DBM assumption that prey size correlated with resource ranking, this assumption seems ethnographically justified (Hawkes 1990, 1991) and is likely to be generally true. However, mode of procurement may allow smaller resources to be harvested, unpredictably, at fantastically high return rates. In addition, many small and medium-sized animals are prone to periodic, catastrophic population declines induced by climatic change, disease and overcrowding (e.g. Zeanah 1996; Kelly 2001). Therefore, in many short-term circumstances, the return garnered from smaller game may actually be more variable than the returns from large game.
- 3 Pinson (1999) characterizes possible risk strategies as risk-sensitive or risk-indifferent. However, risk-sensitive foragers can be either risk-prone (variance-maximizing big-game hunters) or risk-averse (variance-minimizing small-game gatherers) depending on circumstances. Because the outcome of risk-indifferent foraging is the same (variance-maximizing) as risk-prone foraging, we refer to the dyad 'risk-prone-risk-averse' for the sake of simplicity.
- 4 Pinson's (1999) analysis does not consider other factors that might contribute to low artiodactyl index values, such as processing tactics to minimize transport costs when kill sites and residential bases were in different locations (e.g. Metcalfe and Barlow 1992; O'Connell *et al.* 1990).
- 5 This may appear to contradict our initial assessment of ethnographic analogies as incapable of providing insight into Prearchaic adaptations. However, our conviction that sexual division of labor was likely a critical aspect of Prearchaic foraging strategies is based on homologous rather than analogous reasoning, and is theoretically justified from a BE perspective. Sexual division of subsistence labor is nearly universal among ethnographic hunter-gatherers, and most anthropologists perceive sexual division of

labor as fundamental to hunter-gatherer subsistence organization (Ember 1975; Hiatt 1978). In addition, current evolutionary models see sexual division of labor as a significant trend in hominid evolution selected by conflicting responses of males and females to the risks of successful reproduction (Bird 1999; Hawkes 1996). Ethnographers observed a division of subsistence labor by gender among Great Basin foragers (Kelly 1932: 79; Steward 1938: 44, 1941: 312–13; Stewart 1941: 406). Moreover, a growing body of bioarchaeological evidence builds a compelling case for sexual division of labor among Archaic hunter-gatherers in the Great Basin (Hemphill 1999: 285; Larsen and Hutchinson 1999; Rhode et al. 2000: 55–6). We are, therefore, confident that sexual division of labor was practiced by Prearchaic foragers; models of Prearchaic adaptation that ignore this factor cannot be complete.

- 6 Critics point out that this finding hinges on the use of foraging experiments to replicate prehistoric resource return rates (Bettinger 1994), and are skeptical that modern scholars can reproduce the expertise of prehistoric foragers or judge circumstances under which they chose to take resources. However, many estimates have been replicated by independent experiments (Larralde and Chandler 1981; Simms 1987; Jones and Madsen 1991; Bullock 1994; Barlow and Metcalfe 1996) and are comparable to return rates procured by ethnographic hunter-gatherers who take similar arrays of food (O’Connell and Hawkes 1981; Cane 1987). More important, the experimental replications would have to be wrong by several orders of magnitude to change DBM predictions (Simms 1987: 49, 53).
- 7 Obviously, food storage also incurs risk in that caches may be lost to spoilage and theft. However, we agree with many previous biological and anthropological models that consider food storage to be a strategy for minimizing variability in foraging returns (Testart 1982; Vander Wall 1990; Winterhalder 1990; Winterhalder et al. 1999).

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