A behavioural ecological approach to a proposed middle Holocene occupational gap

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Abstract

Relative to other periods, there are very few recorded sites of middle Holocene age in Mendoza Province, Argentina. This analysis weighs the preliminary results of a regional study in Mendoza against three possible explanations for the small number of middle Holocene sites: poor visibility, reduced population density and behavioural adaptation. While changes in visibility and population density cannot be dismissed, evidence suggests that the scarcity of mid-Holocene sites in Mendoza reflects changed patterns of land and resource use triggered by climate change. Archaeological data from the region fit the predictions of Charnov's marginal value theorem and a cost-benefit model of lithic procurement, and suggest that hunter-gatherer groups curtailed their mobility during the middle Holocene, producing a more cryptic archaeological record.

1 Introduction

Archaeological and palaeoenvironmental data indicate that the middle Holocene (between 8000 and 4000 BP) was a time of warmer, more arid conditions in many parts of the world (Albanese & Frison 1995; Anderson et al 2007; Antevs 1948; Butzer 1957; Nuñez & Grosjean 1994; Sandweiss et al 1999). Indigenous populations living in areas affected by this trend appear to have been impacted by resultant changes in resource availability (Antevs 1948; Deacon 1974; Grayson 1993; Humphreys & Thackeray 1983; Meltzer 1999; Sheehan 1994). Researchers in southern Mendoza Province, Argentina (figure 1) report a local expression of this larger phenomenon, most notably a conspicuous scarcity of archaeological sites dating to the middle Holocene (Gil et al 2005; Markgraf 1989; Nuñez & Grosjean 1994). (NB: *Mendoza* is the name of both the province and its capital city. Hereafter, *Mendoza* will be used to refer to the province. Thus, 'southern Mendoza' is the southern part of Mendoza Province, between approximately 34–37° south latitude.)

The perceived gap in the Mendoza record resembles gaps reported for other parts of the western Hemisphere during the middle Holocene (Antevs 1948; Gil et al 2005; Grayson 1993; Humphreys & Thackeray 1983; Markgraf 1989; Meltzer 1999; Nuñez & Grosjean 1994; Sheehan 1994). The apparent similarity of responses across so vast and varied an expanse inspired a session devoted to middle Holocene adaptations at the 2008 Annual Meeting of the Society for American Archaeology in Vancouver, British Columbia (Garvey et al, this issue). The project described here is still in its earliest stages and the data are consequently few, but the Mendoza study serves as a vehicle for a broader discussion of theoretical and methodological approaches to the middle Holocene.

Two concepts guide the present research. First, occupational hiatus at scales detectable in the archaeological record have profound implications for our understanding of human adaptive capabilities and it is correspondingly critical that we rule out non-behavioural factors whose expression can mimic abandonment or population diminution before interpreting the significance of perceived gaps. Second, behavioural ecological models offer a powerful means of exploring the relationships between people and their environments and of predicting responses to changing resource availability during the middle Holocene. Testing archaeological data against these models'

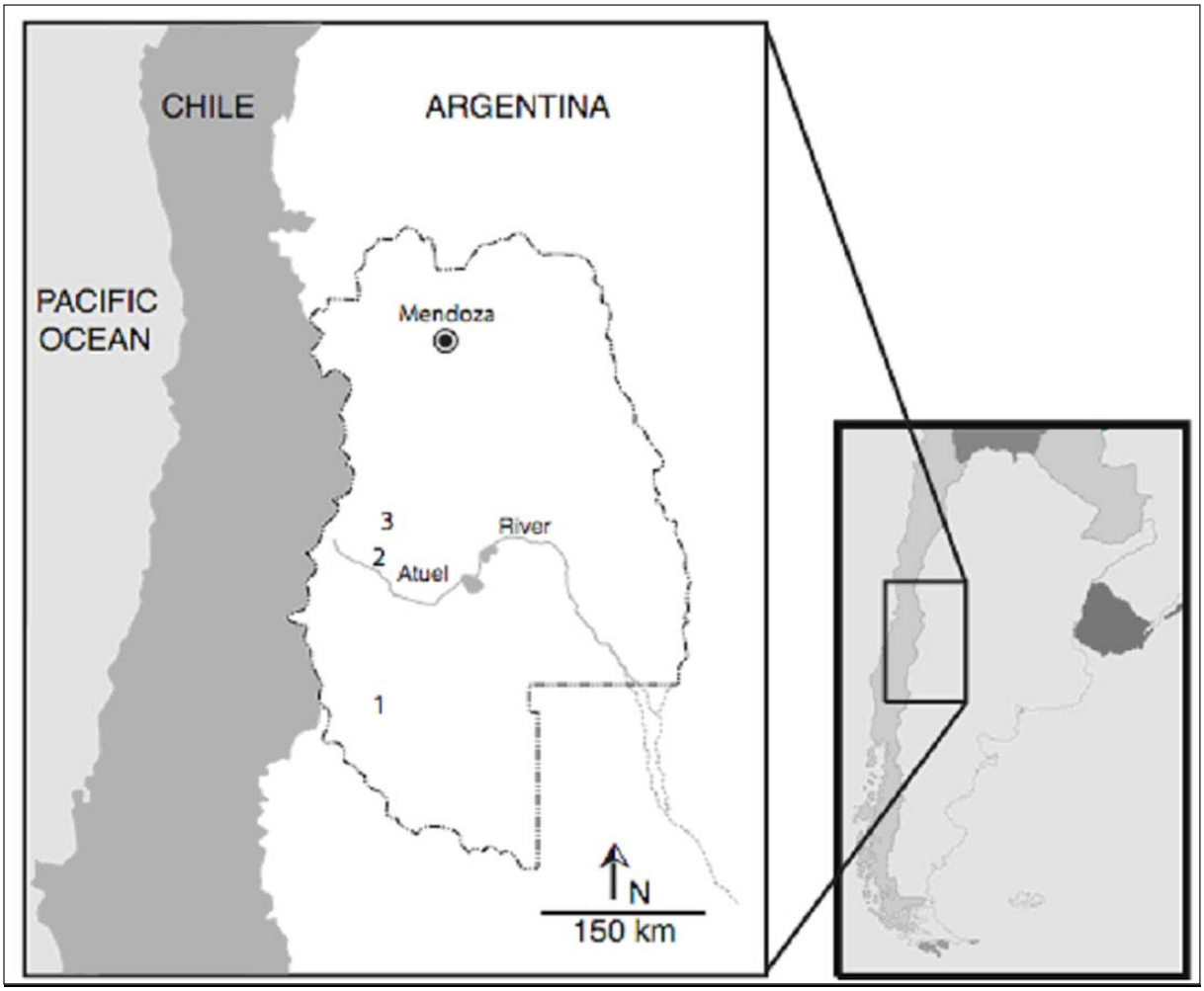

Figure 1 Mendoza Province, Argentina and the locations of sites mentioned in the text: 1 Gruta El Manzano; 2 Arroyo Malo-3; 3 El Mallín

predictions can vastly improve our understanding of both specific behavioural reorganisations and of larger trajectories of human adaptive change.

2 Interpreting archaeological gaps: an example from Argentina

Archaeologists in Mendoza report 206 radiocarbon dates associated with cultural materials spanning the millennia between ca 11,000 BP and European contact (Gil et al 2005). The middle Holocene accounts for over 36 per cent of the time since initial occupation, yet only 6 per cent (N=13) of the reported dates fall within this period (Garvey, in press). The small number of middle Holocene sites has traditionally been explained in terms of local population dynamics – rising death rates and falling birth rates – or regional abandonment. These explanations imply that populations simply expand and contract in response to environmental change. Human behavioural flexibility and decision-making, however, are important and powerful counters to resources scarcity. When local conditions deteriorate, hunter-gatherers can make adjustments in settlement, subsistence and technology in order to target new resources and use previously-targeted ones differently. According to this view, the hunter-gatherers of Mendoza may simply have responded to middle Holocene conditions in ways that made them less archaeologically visible, giving the misimpression of abandonment.

To interpret gaps in archaeological records, we must be able to distinguish human behaviours from non-behavioural factors whose expression can give the false impression of population diminution or regional abandonment**.** In addition to reduced population density, two plausible explanations might account for the small number of middle Holocene sites currently known in Mendoza: poor archaeological visibility and behavioural adaptation. The material signatures implied by these three explanations are not necessarily mutually exclusive. Nonetheless, the most likely explanation for any archaeological gap may be determined by considering broad patterns among the

material signatures in a region (Garvey et al, this issue).

2.1 Visibility

Archaeological visibility is determined by three things: preservation, site formation and sampling. Preservation affects site visibility proportionate to the quantity of organic remains that comprise an assemblage and the force of destructive agents in the deposition environment. Low visibility due to poor preservation can be diagnosed using proxies for increased reliance on organic implements, such as an increased proportion of stone tools designed to work bone or wood, and indicators of a destructive environment. In Mendoza, analyses are underway that will clarify the degree to which preservation contributes to the lack of middle Holocene sites in the region. These include palaeoenvironmental reconstructions, detailed analyses of trans-Holocene trends in bone weathering stages (eg, Behrensmeyer 1978), and stone tool analyses that will detect changing frequencies of bone- and woodworking tools. Even at this early stage, however, evidence suggests that poor preservation cannot fully explain the gap in the Mendoza record, namely, the few known middle Holocene components in the province contain both stone and bone artefacts. At Gruta El Manzano, a cave site in the eastern Andean piedmont (figure 1), none of the 63 bones deposited during the middle Holocene was modified and stone tools are the dominant artefact type (table 1). At Arroyo Malo-3, a cave site in the Andes (figure 1), bone artefacts outnumber stone artefacts by more than 2:1, but none of them has been fashioned into a tool. This analysis is coarse and permits multiple interpretations, yet it provides evidence that stone technologies remained important and that at least some bone survived the middle Holocene. If the sparsity of middle Holocene sites in Mendoza were attributable to poor preservation, we would not expect either of these findings.

Natural site formation processes (Schiffer 1983, 1987) can bias archaeological visibility because they are governed by geologic, hydrologic and climatic factors that are subject to fluctuation through time. Datable episodes of deposition and erosion should be visible in river cutbanks, lake cores and archaeological excavation units, and these can help to determine the effects of site formation processes on middle Holocene deposits. In Mendoza, climate changes during the middle Holocene are likely to have influenced site formation. The province is transected by a number of major fluvial systems whose discharge is largely governed by snowfall in the Andes (Gil et al 2005). Although the middle Holocene is characterised by a net decrease in precipitation, periods of glacial readvance and subsequent meltwater discharge during and after the middle Holocene (Stingl & Garleff 1985) may have scoured or deeply buried any middle Holocene archaeological deposits that existed along waterways. Elsewhere in the region, increased aridity may have exacerbated topsoil erosion. Aeolian soil migration could have caused both site deflation and increased sedimentation in particular microenvironments.

Stratigraphic evidence from Gruta El Manzano suggests that site formation was affected by the middle Holocene climate. When the site was first excavated in 1978, organic materials from the four lowest culture-bearing levels inside the cave returned standard ^{14}C dates of 7330±150 BP (GAK-7259), 7110±180 BP (GAK-7530), 7190±130 BP (GAK-7531), and 7070±170 BP (GAK-7532) (Gambier 1985:141). Recently, archaeologists from the Museo de Historia Natural de San Rafael (MHN) returned to Gruta El Manzano to assess its condition and collect material for a more systematic dating of the site (Gustavo Neme & Adolfo Gil, personal communication 2006). Two additional dates from upper strata, 2100±70 BP (LP-1663) and 1300±50 BP (LP-166), confirm continued use of the cave after the middle Holocene (table 2).

This refined stratigraphic sequence also shows that the first part of the middle Holocene, between ca

		total bone	total stone	bone:stone	bone tools	stone tools
Late Holocene	**Manzano**	15	281	0.05:1	3	60
	AMA-3	424	198	2.14:1	0	5
Mid-Holocene	**Manzano**	63	1209	0.05:1	0	158
	AMA-3	546	207	2.64:1	0	1

Table 1 Bone and stone counts at Gruta El Manzano (Manzano) and Arroyo Malo-3 (AMA-3) during the middle and late Holocene

Stratum	^{14}C Date (cmbs)	potential time span	approx thickness of deposit
B	1300±50 (50-60)	~800 years	60 cm
D	2100±70 (110)	~5000 years	30 cm
E	7330±150 (140-155)	~500 years	75 cm
E	7110±180 (155-175)	-	-
E	7190±130 (175-195)	-	-
E	7070±170 (195-215)	-	-

Table 2 Dated excavation levels from Gruta El Manzano. Note the difference in thickness between deposits of differing age and duration

7500 and 7000, was a time of rapid sediment accumulation, when at least 75 cm of fine sand were deposited inside the cave. The subsequent five thousand years, between ca 7000 and 2000 BP, are represented by a comparatively very thin deposit (approximately 30 cm; table 2). More detailed reconstructions of site formation processes at Gruta El Manzano have been proposed and will help to clarify the degree to which middle Holocene archaeological visibility has been affected by these phenomena. Scientists affiliated with MHN are currently working to understand the region's complex geomorphological history (Sergio Diéguez, personal communication 2008).

Sampling procedures also determe what is 'visible' in archaeological records. Disproportionate focus on particular environment types can distort interpretations of landscape use, for example. The mid-Holocene archaeological record of southern Mendoza currently reflects an overrepresentation of cave sites in the Andes. Prehistoric hunter-gatherers exploited a wide range of resources that were available at different times and across diverse environmental zones (eg, O'Connell & Hayward 1972). The preponderance of cave sites is likely skewing our understanding of prehistoric land use in Mendoza. An on-going, regional surface survey is designed to distinguish sampling biases from the natural or behavioural factors currently limiting archaeological visibility (Bettinger 1977; Thomas 1973). It will do this by testing randomly in many more environment types than have been tested previously, from the Andes, east across the piedmont to the plains (figure 1), thereby providing a sample suitable for addressing alternative explanations of the observed occupational gap in Mendoza. Since January 2008, seven previously unrecorded open-air sites have been located by this method.

2.2 Population density

Temporal gaps reported in southern South America and elsewhere in the western hemisphere have traditionally been explained in terms of decreased population densities due to death or abandonment (Antevs 1948; Barrientos 2001; Gil et al 2005; Grayson 1993; Guráieb 2004). Such explanations imply that people were unable to adapt to middle Holocene heat and aridity, or that environmental *refugia* were available to receive displaced populations. A gap due to population reduction can be distinguished from one caused by poor visibility only when factors that affect visibility can be ruled out. An argument of this kind would be bolstered by fine-grained evidence of simultaneous, severe environmental degradation. Additionally, because not all organisms are affected equally by changes in climate (FAUNMAP Working Group 1996), determining which of a region's resources are limiting to humans and how these were affected by middle Holocene conditions will help to determine the likelihood of reduced population density.

Camelids, especially guanaco (*Lama guanicoe*), are frequently reported to have been the primary subsistence resource among hunter-gatherers in southern South America through much of prehistory (eg, Borrero 1990; Neme 2007; Neme & Gil 2002). Zooarchaeological data show that this trend is also borne out in southern Mendoza (Neme & Gil 2008). If, all else being equal, body size can be taken as a reasonable proxy for resource rank (Lyman 1994; Madsen & Schmitt 1998; Munro 2004; Winterhalder 1981), guanaco can be considered the highest-ranking prehistoric resource in Mendoza, at an average adult body weight between 100 and 120 kg (de Nigris 2004).

Encounter rates with guanaco may have been reduced during the middle Holocene due to shrinking and shifting plant communities and unreliable water sources on the eastern plains, by glacial readvance in the Andes and increased snowfall in the foothills. The fact that guanaco remained the predominant prey species throughout the middle Holocene requires explanation. One hypothesis is that human population densities decreased along with those of guanaco, such that their proportions remained relatively unchanged. However, studies of modern guanacos' feeding behaviour in various microenvironments indicate

that they are drought-tolerant 'generalist herbivores, adapted to utilize a wide range of forage types in a range of habitats' (Raedeke & Simonetti 1988:200). As such, guanaco population densities may not have been affected by middle Holocene conditions. Biogeographic reconstructions of shifting middle Holocene plant communities may assist geographic information systems-based modelling of archaeological site locations, which may have shifted in response to a key resource's adjustment to changed conditions.

Another test of whether the perceived occupational gap in Mendoza is owing to regional abandonment is to track population densities in areas less severely impacted by middle Holocene climate change. That is, if people left Mendoza during the middle Holocene, potential *refugia* should reflect concomitant increases in population density (Hildebrandt & McGuire 2008). Archaeological records in parts of North America indicate that some groups came to rely more heavily on fish and waterfowl during the middle Holocene, perhaps as a response to reduced availability of larger game (Sheehan 2002). The hunter-gatherers of Mendoza may have responded in a similar way. Chilean researchers report continued occupation of Pacific coastal areas through the middle Holocene (Méndez & Jackson 2006). Many of these sites contain tools made of non-local stone, which can be analysed and compared with a growing database of chemically-identified stone in Argentina (Durán et al 2004; Méndez & Jackson 2006). The hypothesis that Mendozan hunter-gathers moved to the coast during middle Holocene droughts will be supported if the foreign stone in Chilean coastal deposits can be traced to eastern Andean sources.

2.3 Behavioural adaptation

At this early stage of inquiry in Mendoza, poor visibility and decreased population density remain plausible explanations for the perceived occupational gap. Nonetheless, preliminary evidence from a multifaceted regional study suggests that changes in land and resource use may be giving the *misimpression* of an occupational gap. If hunter-gatherer groups in Mendoza substantially reorganised their settlement and subsistence behaviours to adjust to changes in resource availability, the archaeological record they left may be cryptic and difficult to detect.

By their very nature, occupational gaps are hard to approach from a behavioural perspective. Historically, adaptive behavioural alternatives to abandonment or death have received little attention in the literature on occupational hiatus. Microeconomic models of human behaviour offer a powerful means of exploring hypothesised relationships between prehistoric people and their environments, and of predicting responses to changing middle Holocene conditions. The behavioural ecological approach is based on the assumption that humans seek to maximise benefits relative to costs. The models designed to test this assumption are intentionally reductionist. By reducing complex prehistoric behaviours to a subset of simpler, well-defined variables, archaeologists can isolate that which is central to a problem (Friedman 1953:36; Winterhalder & Smith 1992). Models can be used in concert to triangulate on specific adaptive decisions. The marginal value theorem and a model of lithic raw material procurement are applied here to predict alternative responses to middle Holocene changes in the Mendozan environment, generating explicit hypotheses that are tested against archaeological data.

The marginal value theorem predicts the optimal point of departure from a resource patch (figure 2; Charnov 1976). Because the amount of energy available in a patch decreases as foragers consume its resources, after a critical point the optimising forager should move to a fresh patch or suffer diminishing returns. This critical point – the *optimal departure time* – is determined by the amount of energy potentially available in the environment as a whole, that is, the energetic returns from all possible patches relative to their distributions. When potential environmental energy is high, ie, when resources are everywhere abundant, the optimal departure time is relatively low; foragers very quickly deplete patches to the point beyond which they stand to improve returns by moving to a fresh one. However, in this situation, optimising foragers find only small amounts of inter-patch travel acceptable. When resources become scarce, the optimal departure threshold is raised and foragers should remain in a given patch longer but be willing to travel farther to get to a new one (Bettinger 1991; Charnov 1976; Garvey in press).

According to the predictions of the marginal value theorem, foragers in Mendoza should have become less residentially mobile (*sensu* Binford 1980) when resources grew scarce during the middle Holocene. This would be reflected in a shift during the middle Holocene from fairly uniform, short-term residential

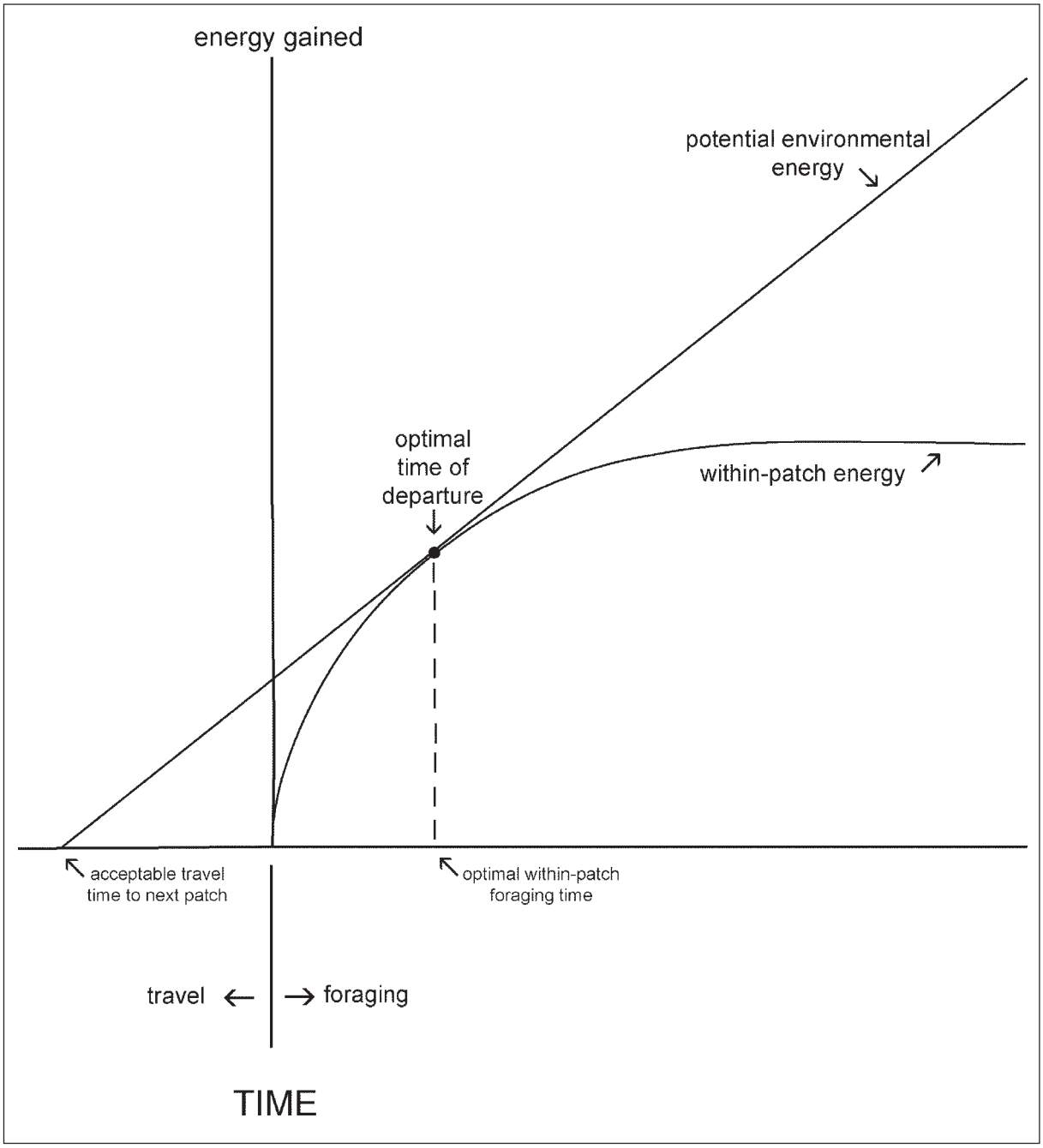

Figure 2 Graphical representation of the marginal value theorem (adapted from Bettinger 1991; Charnov 1976)

bases to greater site variability, including longer-term residential sites and logistical camps (Bettinger 1991; Binford 1980). Less frequent moves during the middle Holocene would have required eventual moves to more distant locales because, given the impoverished environment, the next patch of resources rich enough to offset the cost of moving would have been farther away. In light of this, the proposed occupational gap in Mendoza may not reflect reduced population density, per se, but rather a reduction in the overall number of sites, each occupied for a longer duration.

Multiple lines of reasoning from preliminary regional data suggest that Mendozan sites were occupied longer during the middle Holocene than during other periods of prehistory. For example, lithic artefacts from Gruta El Manzano suggest long-term occupation during the middle Holocene. If artefact frequencies can be taken as reasonable proxies for intensity of use (Adams 1998), extended occupation is supported by the fact that artefacts were deposited in significantly higher numbers during the first part of the middle Holocene than at any other time (figure 3). The composition of the middle Holocene component is also consistent with this hypothesis (table 3),

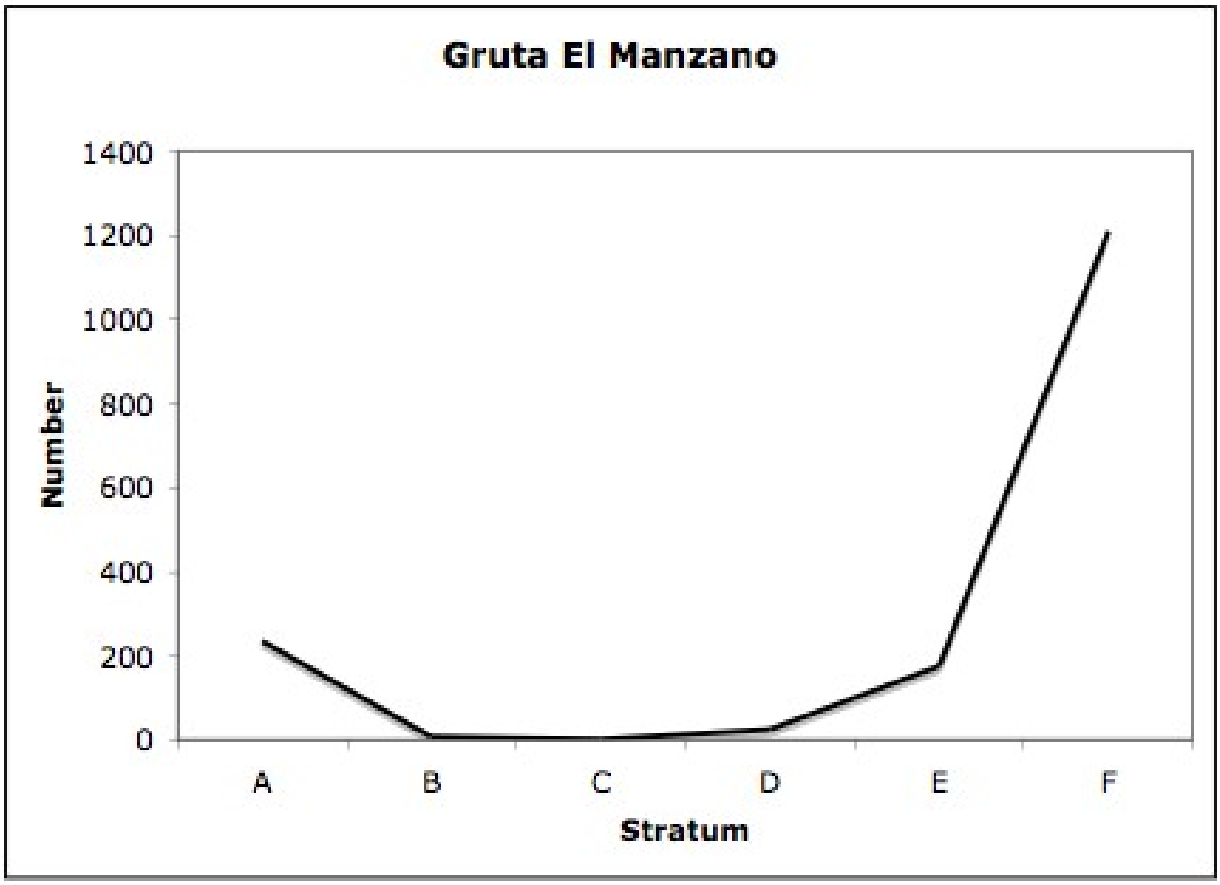

Figure 3 Raw counts of lithic artefacts per natural stratum (as described by Gambier 1985) at Gruta El Manzano. Stratum F (140-215 cmbs) dates to ca 7500-7000 BP. The average artefact count per 10-centimetre level within this stratum is 161.2. This more than 2.5 times higher than the next largest count (Stratum A, 0-40 cmbs, N=235, average of 58.5 per 10 centimetre level), and nearly 50 times higher than the lowest, non-zero count (Stratum B, 40-60 cmbs, N=7, average of 3.5 per 10 centimetre level)

	Number	Per cent
local material	753	62
informal tools	97	61
informal/local	62	64
non-local material	456	38
formal tools	61	39
formal/non-local	19	31
biface thinning	28	3
thinning/non-local	18	64
all tools	158	13
all debitage	1051	87

Table 3 Counts and percentages of raw material and tool types at Gruta El Manzano during the middle Holocene

namely, it is dominated by local materials and informal tools, or ones that show little production effort (Andrefsky 1998). Formal tools are less common and are frequently made of non-local obsidian. The majority of the bifacial thinning flakes, of which there are very few, are also of non-local obsidian. Finally, the middle Holocene deposit is characterised by a tool-to-debitage ratio of 0.15:1. Similar trends in local versus non-local materials, formal tool production and use, and tool:debitage ratios have been associated with long-term occupation (Andrefsky 1994, 1998; Kuhn 1991; MacDonald 1991; Parry & Kelly 1987).

A pattern observed at El Mallín, a cave site in the Andean foothills along the Río Diamante (figure 1), also supports extended middle Holocene occupation, as predicted by the marginal value theorem. Here, artefact frequencies differ dramatically between units inside the cave and out, as well as through time (figure 4). In middle Holocene levels, there are far fewer lithic artefacts inside the cave than there are outside, while the opposite is true of late Holocene deposits. This suggests extended occupation and a consequential preference for a well-maintained interior living surface during the middle Holocene. Late Holocene artefact distributions suggest stays of shorter duration, with less incentive to expend effort in floor cleaning during that time.

If middle Holocene Mendocinos were indeed less mobile than their predecessors, we might make predictions about where to find these long-term occupation sites through additional behavioural ecological models. According to the predictions of the central place foraging model of subsistence, middle Holocene base camps should be located close to essential resources with high transport costs

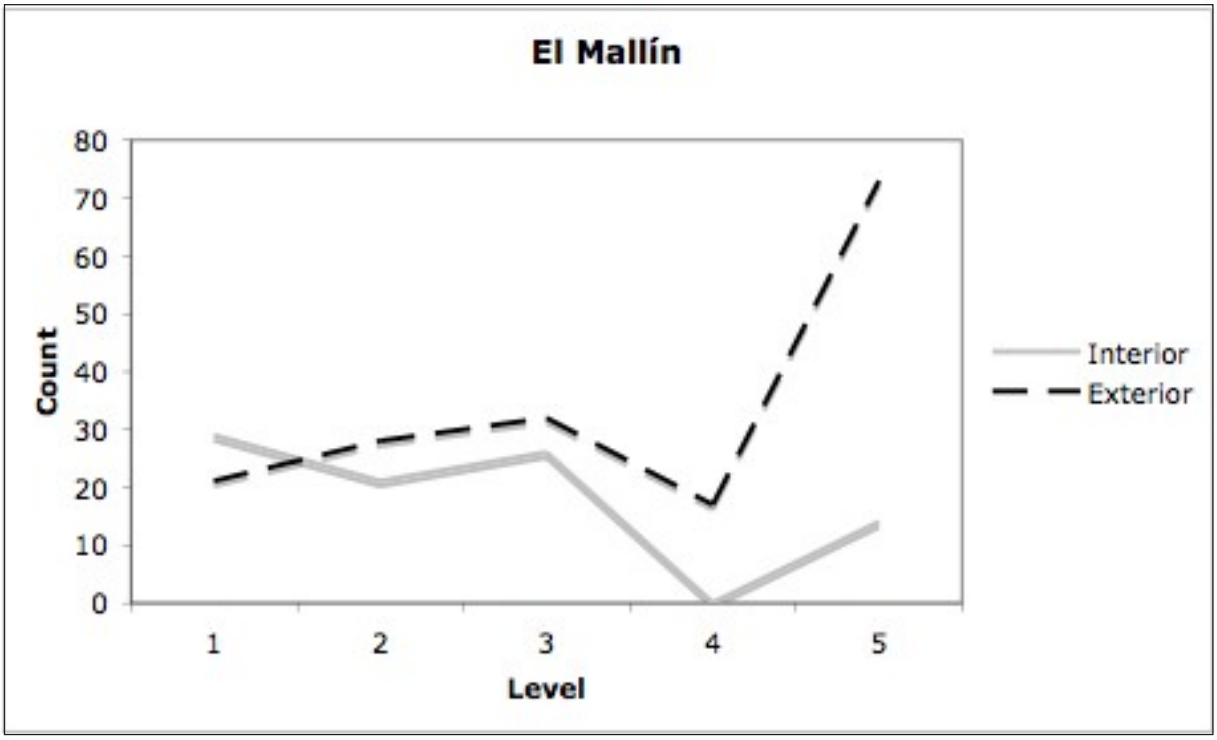

Figure 4 Number of lithic artefacts recovered from the interior versus the exterior of the cave at El Mallín. Level 5 dates to the middle Holocene

(Marlowe 2006; Zeanah 2000, 2002). During the hot, dry middle Holocene in Mendoza, water may have been the resource governing mobility, as it appears to have been in other semi-arid zones of the western Hemisphere (eg, the Great Basin; Jones et al 2003). Indeed, all of the presently known middle Holocene sites in Mendoza are located in upland valleys of major rivers and their tributaries. Because resource biomes are arranged vertically in western Mendoza, changing rapidly with elevation in the Andes, if middle Holocene hunter-gatherers were bound to water sources, they may have tracked seasonally-available resources from the upland river valleys in the west, downstream to the rivers' lower courses to the east, straying little from the river valleys over the course of the seasonal round (Garvey, in press).

2.4 A model of lithic raw material procurement

The marginal value theorem is a simple yet powerful model for predicting behaviours during periods of climate change. The implications of the model extend beyond settlement reorganisation; changes in resource use should likewise be reflected in the archaeological record. An economic model of stone procurement predicts changes in material type frequencies based on the costs of obtaining partiuclar matierals relative to the benefits they afford. Weighing archaeological data against this hypothesis further improves our understanding of potential behavioural adjustments to middle Holocene conditions.

Some have argued that long-term occupation sites should exhibit less variation in lithic raw materials and a greater reliance on local stone than short-term occupation sites (eg, MacDonald 1991; cf Andrefsky 1994, 1998). This prediction stems from the rationale that short-term occupations are associated with mobile groups whose movement across the landscape is likely to bring them into contact with more varied stone sources (Andrefsky 1998). From a behavioural ecological perspective, this phenomenon might have its root in more fundamental aspects of human decision-making.

Bettinger and colleagues (2006; see also Ugan et al 2003) describe a model that formalises the commonsense notion that, as more time is devoted to particular subsistence activities, it becomes increasingly beneficial to invest in more costly strategies that increase returns. That is, technology should track changes in the intensity of resource use. When the currencies and constraints are appropriately defined, this model can be used to predict lithic raw material use. Stone types differ in their costs of procurement, ease of use, and the benefits they afford, just as technologies differ with respect to manufacturing costs and return rates (Garvey, in press). In Mendoza, for instance, basalt appears to be characterised by a modest procurement cost, given that it is

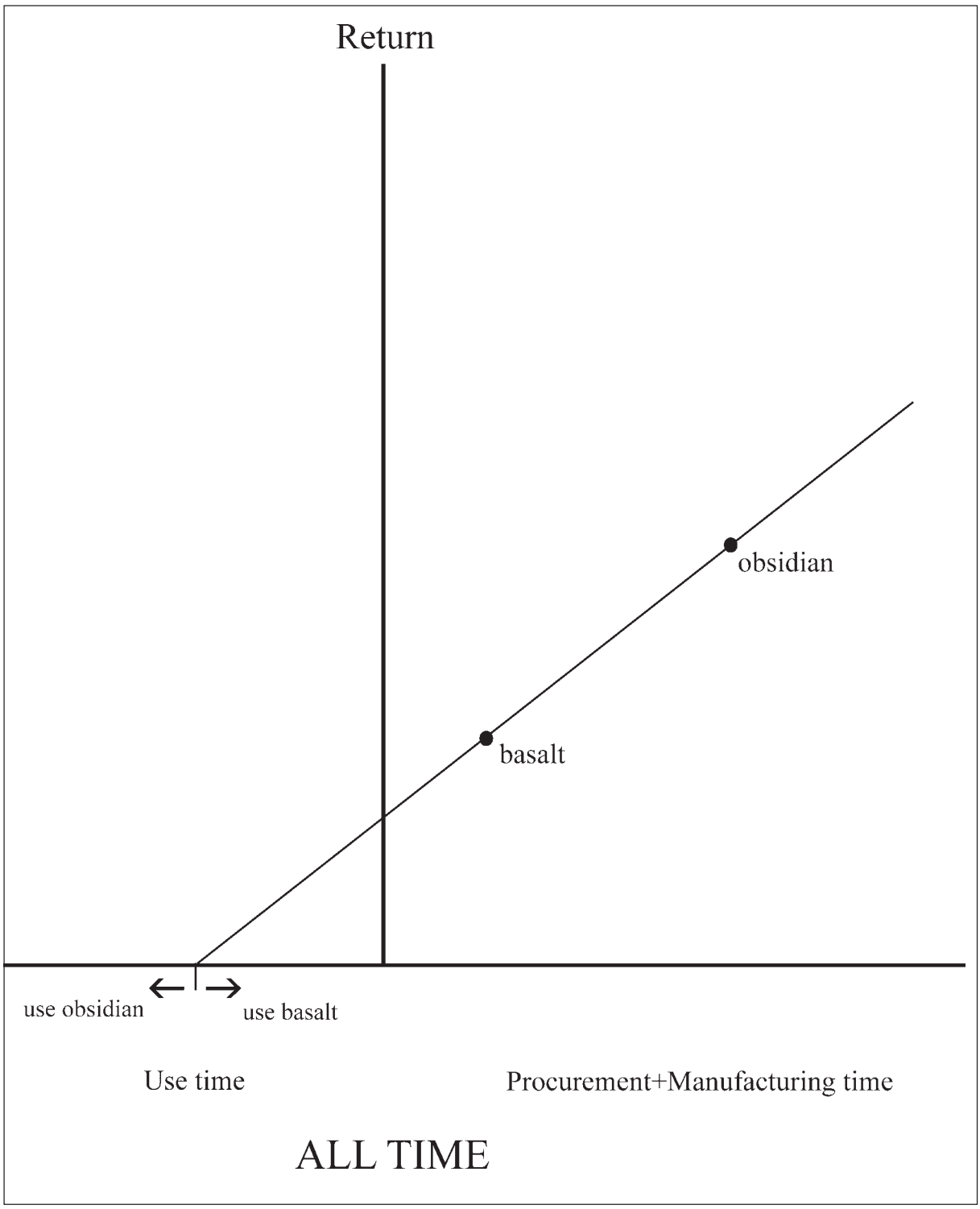

Figure 5 Basic model for establishing the critical use time for raw materials, beyond which threshold a tool user will achieve a higher return rate by switching from lower-cost, lower-quality basalt to higher-cost, higher-quality obsidian. The dimension *time* is divided into procurement plus manufacturing time to the right of the origin, and use time to the left of the origin. Return rates lie along the *y*-axis (adapted from Bettinger et al 2006)

immediately local relative to sites with middle Holocene deposits, but it is a low-quality material with a correspondingly low return. Obsidian, on the other hand, gives a higher return, but its procurement cost is also higher, since obsidians are located at appreciable distances from archaeological sites, often through the rugged terrain of the Andes. The return rates of basalt and obsidian relative to the time it takes to procure and craft tools from each, defines a critical use time (figure 5). The amount of time devoted to a task must exceed this critical threshold for higher-quality, harder to obtain obsidians to be viable in the presence of lower-quality, but readily available basalts.

Given that the marginal value theorem predicts

restricted movement during the middle Holocene, we should expect lower-quality, local basalts to be prevalent the lithic assemblages of this period in southern Mendoza. In part, this is due to the fact that excursions to localised obsidian sources in the Andes would have inflicted both opportunity and absolute costs that may not have been justifiable during the hot, dry middle Holocene. Furthermore, groups staying longer in particular locales are likely to have widened their diet breadth to include low-ranked resources such as small game and plant foods (Garvey, in press; Jones et al 2003). Thus, subsistence may have been too generalised, and specialised tool use times too low, to warrant trips for high-cost, high-return raw materials (Bettinger et al 2006; Garvey, in press). This prediction is borne out by the frequencies of obsidians and basalts at Arroyo Malo-3 where local, lower-quality basalts predominate in middle Holocene component (figure 6). During the late Holocene, basalt use decreases and the use of obsidian increases dramatically. At Gruta El Manzano, basalt and obsidian occur in relatively equal proportions during the middle Holocene (figure 7). However, when all raw materials are considered, local materials constitute the majority of the collection (table 3). Similar to the trend seen at Arroyo Malo-3, use of non-local obsidians increases markedly during the late Holocene (figure 7).

The pronounced shift in stone use after the middle Holocene further strengthens the argument that middle Holocene sites in Mendoza are few because of changed landscape and resource use. At the start of the late Holocene (ca 4000 BP), non-local, high-quality obsidians become more common, eventually coming to dominate lithic assemblages (eg, figure 7). This trend implies either increased mobility, as the marginal value theorem predicts for periods of climatic amelioration, or more specialised tool use resulting from a changed subsistence focus. That is, subsistence resources probably rebounded after the middle Holocene, but human populations appear to have increased substantially as well, which would have created competition and the need to intensify, thereby driving the need for the high-quality raw materials one supposes are needed to manufacture specialised tools (Garvey, in press; Gil et al 2005).

The observed changes in the duration of occupation, site composition, and lithic raw material use through the middle Holocene, are consistent with the behavioural ecological predictions of the marginal value theorem and the model of stone procurement described by Garvey (in press). This suggests that behavioural reorganisation contributes to the perceived gap in the middle Holocene record of southern Mendoza, Argentina.

Figure 6 Trends in obsidian and basalt use at Arroyo Malo-3 through the Holocene

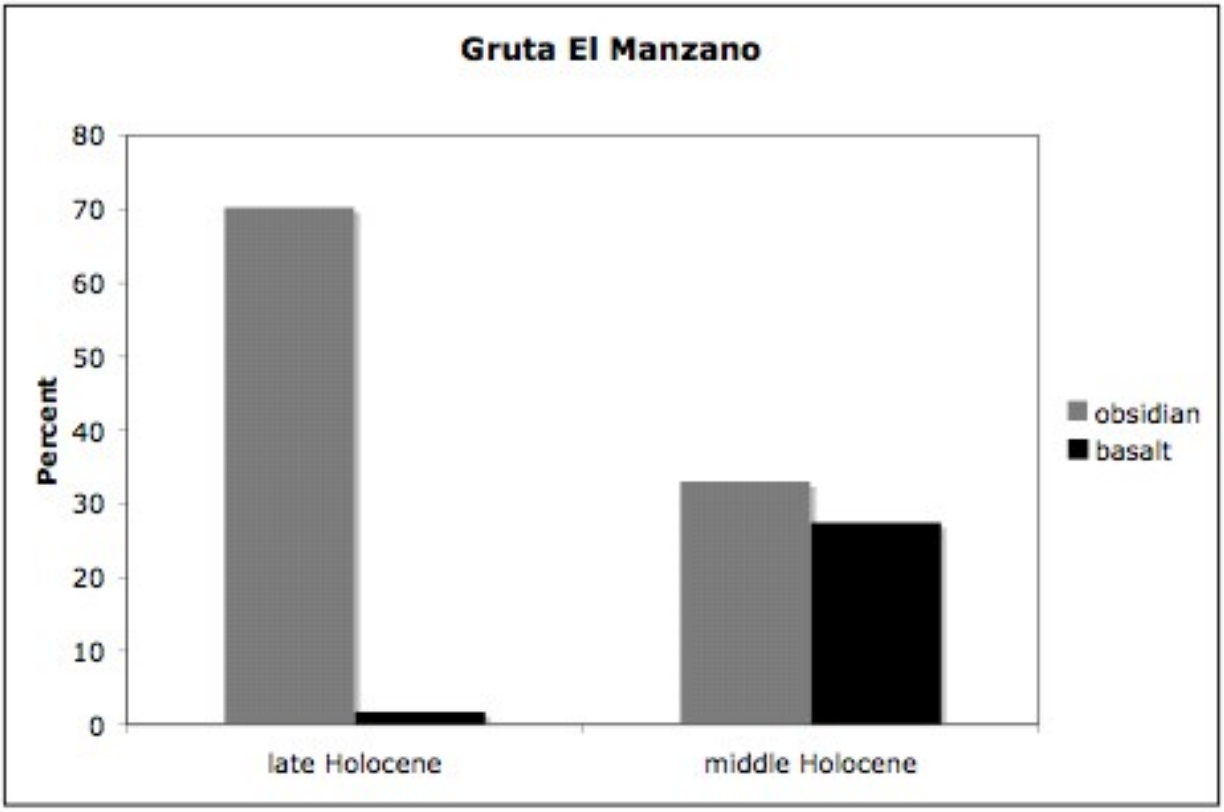

Figure 7 Trends in obsidian and basalt use at Gruta El Manzano in the middle versus later Holocene

3 Discussion and conclusions

Granting that the data are currently few which support the hypothesis that the Mendoza gap is due to human behavioural adaptations, the evolutionary framework proposed here provides a number of empirically testable predictions. An on-going regional study will provide the representative sample necessary to address alternative explanations of the observed occupational gap in Mendoza. Artefact frequencies and richness indices, as well as site location and catchment data, will define discrete settlement categories and inform inferences about the subsitsence-settlement systems of which they were part, clarifying land and resource use at different times during the Holocene (Bettinger 1999; Bettinger & Baumhoff 1982; Bettinger et al 1994; Chatters 1987; O'Connell & Hayward 1972; Shott 1986). Geochemical sourcing of obsidians and basalts will make it possible to measure the diversity of stone types among archaeological sites and the distances that these types were transported over the Mendoza landscape, and thereby to infer patterns of mobility and overall foraging radii (eg, Bamforth 1990; Basgall 1989; Eerkens et al 2007; Eerkens et al 2008; Jones et al 2003). Furthermore, determining which resources were limiting to human populations during different periods and how these particular resources were affected by climate change will help define the range of alternatives available to prehistoric Mendocinos. Understanding these relationships and, ultimately, how humans responded to major climatic fluctuations in Argentina will clarify larger trajectories of hunter-gatherer adaptive change worldwide.

The Mendoza project is designed to address both a puzzling and controversial archaeological phenomenon in Argentina and more general aspects of human action and decision-making in the face of resource scarcity. These theses are by no means exclusive to southern South America; similar gaps have been reported for a number of regions throughout the western hemisphere (Antevs 1948; Gil et al 2005; Grayson 1993; Humphreys & Thackeray 1983; Markgraf 1989; Meltzer 1999; Nuñez & Grosjean 1994; Sheehan 1994) and elsewhere in the world (eg, Deacon 1974). Assessing responses to changing climatic conditions using a behavioural ecological framework permits comparison of these far-flung cases while avoiding environmental determinism and ad hoc descriptions. Behavioural models isolate variables that are central to a particular outcome, thereby reducing the unnumbered complexities of reality to a tractable number of abstractions (Friedman 1953; Winterhalder & Smith 1992). Archaeological data can then be tested

against the resulting predictions for a more scientifically rigorous assessment of past behaviours. This rigourous approach has not been applied widely to in the study of perceived occupational hiatus.

True gaps in archaeological records may help to define human adaptive capacity. Identifying real gaps requires a regional approach and careful study of extra-behavioural factors that might also cause sparse archaeological records. Failure to distinguish between natural and cultural causes of sparse records may lead, at best, to an inaccurate reconstruction of a region's prehistory. At worst, concluding that people are incapable of adapting to environmental change, without first testing alternative hypotheses, could lead to a fundamental misunderstanding of human behavioural flexibility.

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References

Adams, B 1998. *The Middle to Upper Paleolithic Transition in Central Europe: The Record from the Bükk Mountain Region*. Oxford: Archaeopress, BAR International Series 693.

Albanese, J & Frison, G 1995. Cultural and landscape change during the middle Holocene, Rocky Mountain area, Wyoming and Montana. In Bettis, EA (ed) *Archaeological Geology of the Archaic Period in North America*. Boulder, Colorado: Geological Society of America, Special Papers 297:1–19.

Anderson, DG, Maasch, KA & Sandweiss, DH (eds) 2007. *Climate Change and Cultural Dynamics: A Global Perspective on Mid-Holocene Transitions*. New York: Academic Press.

Andrefsky, W 1994. Raw Material Availability and the Organization of Technology. *American Antiquity* 59:21–35.

Andrefsky, W 1998 *Lithics: Macroscopic Approaches to Analysis*. Cambridge: Cambridge University Press.

Antevs, E 1948. Climatic changes and pre-white man. The Great Basin, with emphasis on glacial and postglacial times. *University of Utah Bulletin* 30 (20):168–191.

Bamforth, DB 1990. Settlement, Raw Material, and Lithic Procurement in the Central Mojave Desert. *Journal of Anthropological Archaeology* 9:70–104.

Barrientos, G 2001. Una aproximación bioarqueológica al estudio del poblamiento prehispánico tardío del Sudeste de la región pampeana. *Intersecciones en Antropología* 2:3–18.

Basgall, ME 1989. Obsidian Acquisition and Use in Prehistoric Central Eastern California: a Preliminary Assessment. In Hughes, R (ed) *Current Directions in California Obsidian Studies*. Contributions of the University of California Archaeological Research Facility 48:111–126.

Behrensmeyer, AK 1978. Taphonomic and ecological information from bone weathering. *Paleobiology* 2:150–162.

Bettinger, R 1977. Aboriginal human ecology in Owens Valley: prehistoric change in the Great Basin. *American Antiquity* 42:3–17.

Bettinger, R 1991. *Hunter-Gatherers: archaeological and evolutionary theory*. New York: Plenum.

Bettinger, R 1999. From traveler to processor: regional trajectories of hunter-gatherer sedentism in the Inyo-Mono region, California. In Billman, BR & Feinman, GM (eds) *Settlement Pattern studies in the Americas: Fifty Years Since Virú*. Washington: Smithsonian Institution Press:39–55.

Bettinger, R & Baumhoff, M 1982. The Numic Spread: Great Basin Cultures in Competition. *American Antiquity* 47:485–503.

Bettinger, R, Madsen, D & Elston, R 1994. Prehistoric settlement categories and settlement systems in the Alashan Desert of Inner Mongolia, PRC. *Journal of Anthropological Archaeology* 13:74–101.

Bettinger, R, Winterhalder, B & McElreath, R 2006. A simple model of technological intensification. *Journal of Archaeological Science* 33:538–545.

Binford, R 1980. Willow smoke and dogs' tails: hunter-gatherer settlement systems and archaeological site formation. *American Antiquity* 45:4–20.

Borrero, LA 1990. Fuego-Patagonian Bone Assemblages and the Problem of Communal Guanaco Hunting. In Davis, LB & Reeves, BOK (eds) *Hunters of the Recent Past.* Boston: Unwin Hyman: 373–399.

Butzer, KW 1957. Late Glacial and Postglacial Climatic Variation. *Erkunde* 2:21–35.

Charnov, E 1976 Optimal foraging: the marginal

value theorem. *Theoretical Population Biology* 9:129–136.

Chatters, J 1987. Hunter-gatherer adaptations and assemblage structure. *Journal of Anthropological Research* 6:336–375.

Deacon, J 1974. Patterning in the radiocarbon dates for the Wolton/Smithfield complex in southern Africa. *South African Archaeological Bulletin* 27:10–48.

De Nigris, ME 2004. Guanaco and Huemul in Patagonian Hunter-Gatherers Diet. In Mengoni Goñalons, GL (ed) *Zooarchaeology of South America*. Oxford: Archaeopress BAR International Series, 1298.:11–37.

Durán, V, Giesso, M, Glascock, M, Neme, G, Gil, A & Sanhueza, L 2004. Estudio de Fuentes de Aprovisionamiento y Redes de Distribución de Obsidiana Durante el Holoceno Tardío en el Sur de Mendoza (Argentina). *Estudios Atacameños* 28:25–42.

Eerkens, JW, Ferguson, JR, Glascock, MD, Skinner, CE & Waechter, SA 2007. Reduction Strategies and Geochemical Characterization of Lithic Assemblages: A Comparison of Three Case Studies from Western North America. *American Antiquity* 72:585–597.

Eerkens, JW, Spurling, AM & Gras, MA 2008. Measuring Prehistoric Mobility Strategies based on Obsidian Geochemical and Technological Signatures in the Owens Valley, California. *Journal of Archaeological Science* 35:668–680.

FAUNMAP Working Group 1996. Spatial response of mammals to Late Quaternary environmental fluctuations. *Science* 272:1601–1606.

Friedman, M 1953. *Essays in positive economics*. Chicago: University of Chicago Press.

Gambier, M 1985. *La Cultura de los Morrillos*. Instituto de Investigaciones Arqueológicas y Museo. Facultad de Filosofía, Humanidades y Artes. Universidad Nacional de San Juan.

Garvey, R (in press). A Model of Lithic Raw Material Procurement. In Berg, C & Ward, C (eds) *Strangers No More: Method and Theory in Flaked Stone Studies.* Tuscaloosa: University of Alabama Press.

Gil, A, Zárate, M & Neme, G 2005. Mid-Holocene paleoenvironments and the archaeological record of southern Mendoza, Argentina. *Quaternary International* 132: 81–94.

Grayson, D 1993. *The desert's past: a natural prehistory of the Great Basin*. Washington, DC: Smithsonian Institution Press.

Guráieb, AG 2004. Before and after the hiatus: lithic technology in Cerro de los Indios 1 rockshelter, south Patagonia Argentina. *Before Farming* [online version] 2004/2 article 3.

Hildebrandt, WR & McGuire, KR 2008. Middle Holocene Adaptations on the Central Coast of California: Estuaries and their Influence on the Development of Acorn-Intensive Economies. Paper presented at the 73rd Annual Meeting of the Society for American Archaeology, Vancouver, British Columbia, March 2008.

Humphreys, AJB & Thackeray, AI 1983. *Ghaap and Gariep: Later Stone Age Studies in the Northern Cape*. South African Archaeological Society Monograph Series 2.

Jones, G, Beck, C, Jones, E & Hughes, R 2003. Lithic source use and paleoarchaic foraging territories in the Great Basin. *American Antiquity* 68:5–38.

Jones, G, Grayson, DK & Beck, C 1983. Artifact class richness and sample size in archaeological surface assemblages. In Dunnell, RC & Grayson, DK (eds) *Lulu Linear Punctate: Essays in honor of George Irving Quimby*. University of Michigan Museum of Anthropology Papers 72:55–73.

Kuhn, SL 1991. "Unpacking" Reduction: Lithic Raw Material Economy in the Mousterian of West-Central Italy. *Journal of Anthropological Archaeology* 10:76–106.

Lyman, RL 1994. *Vertebrate Taphonomy*. Cambridge: Cambridge University Press.

MacDonald, M 1991. Technological Organization and Sedentism in the Epipaleolithic of Dakhleh Oasis, Egypt. *The African Archaeological Review* 9:81–109.

Madsen, DB & Schmitt, DN 1998. Mass Collecting and the Diet Breadth Model: A Great Basin Example. *Journal of Archaeological Science* 25:445–455.

Markgraf, V 1989. Paleoclimates in Central and South America since 18,000 BP based on pollen an lake level records. *Quaternary Science Reviews* 8:1–12.

Marlowe, FW 2006. Central place provisioning: The Hadza as an example. In Hohmann, G, Robbins, MM & Boesch, C (eds) *Feeding Ecology in Apes and Other Primates*. Cambridge: Cambridge University Press, Cambridge:359–377.

Meltzer, D 1999. Human response to middle Holocene (Altithermal) climates on the North American Great Plains. *Quaternary Research* 52:404–416.

Méndez, CA & Jackson, DG 2006. Causalidad o concurencia, relaciones entre cambios ambientales y socials en los cazadores recolectores durante la transición entre el Holoceno medio y tardío (costa semiárido de Chile). *Chungara, Revista de Antropología Chilena* 38:173–184.

Munro, ND 2004. Zooarchaeoogical Measures of Hunting Pressure and Occupation Intensity in the Natufian: Implications for Agricultural Origins. *Current Anthropology* 45:S5–S33.

Neme, GA 2007. Cazadores-recolectores de altura en los Andes meridionales: el alto valle del río Atuel. Oxford: British Archaeological Reports International Series: 1591.

Neme, GA & Gil, AF 2002. La Explotación Faunística y la Frecuencia de Partes Esqueletarias en el Registro Arqueológico del Sur Mendocino. In Gil, AF & Neme, GA (eds) *Entre Montañas y Desiertos: Arqueoogía del Sur de Mendoza*. Buenos Aires: Sociedad Argentina de Antropología:141–155.

Neme, GA & Gil, AF 2008. Archaeofaunal Data and Human Occupation During the Middle Holocene in Central-Western Argentina. Paper presented at the 73rd Annual Meeting of the Society for American Archaeology, Vancouver, British Columbia, March 2008.

Nuñez, L & Grosjean, M 1994. Cambios ambientales pleistoceno-holocenicos: Ocupación humana y use de recursos en la Puna de Atacama (Norte de Chile). *Estudios Atacameños*11:11–24.

O'Connell, JF & Hayward, PS 1972. Altithermal and Medithermal Human Adaptations in Sruprise Valley, Northeast California. In Fowler, DD (ed) *Great Basin Cutlrual Ecology: A Symposium*. Publications in the Social Sciences No 8. Reno, Nevada: University of Nevada, Desert Research Institute:25–41.

Parry, WJ & Kelly, RL 1987. Expedient Core Technology and Sedentism. In Johnson, JK & Morrow, CA (eds) *The Organization of Core Technology*. Boulder, Colorado: Westview Press:285–304.

Raedeke, KJ & Simonetti, JA 1988. Food Habits of *Lama Guanicoe* in the Atacama Desert of Northern Chile. *Journal of Mammology* 69(1):198–201.

Sandweiss, D, Maasch, K & Anderson, D 1999. Transition in the Mid-Holocene. *Science* 283:499–500.

Schiffer, MB 1983. Toward the identification of formation processes. *American Antiquity* 48:675–706.

Schiffer, MB 1987. *Formation Processes of the Archaeological Record*. Albuquerque: University of New Mexico Press.

Sheehan, M 1994. Cultural responses to the Altithermal: the role of aquifer-related water resources. *Geoarchaeology* 9:113–137.

Sheehan, M 2002. Dietary responses to mid-Holocene climate change. *North American Archaeologist* 23:117–143.

Shott, MJ 1986. Settlement mobility and technological organization: an ethnographic examination. *Journal of Anthropological Research* 42:15–51.

Stingl, H & Garleff, K 1985. Glacier variations and climate of the late Quaternary in the subtropical and mid-latitude Andes of Argentina. *Zeitschrift für Gletscherkunde* 21:225–228.

Thomas, DH 1973. An empirical test for Steward's model of Great Basin settlement patterns. *American Antiquity* 38:155–176.

Ugan, A, Bright, J & Rogers, A 2003. When is technology worth the trouble? *Journal of Archaeological Science* 30:1315–1329.

Winterhalder, B 1981. Optimal Foraging Strategies and Hunter-Gatherer Research in Anthropology. In Winterhalder, B & Smith, EA (eds) *Hunter-Gatherer Foraging Strategies: Ethnographic and Archaeological Analyses*. Chicago: University of Chicago Press:13–35.

Winterhalder, B & Smith, E 1992. Evolutionary ecology and the social sciences. In Smith, EA & Winterhalder, B (eds) *Evolutionary ecology and human behavior*. New York: Aldine de Gruyter:3–23.

Zeanah, DW 2000. Transport costs, central place foraging, and hunter-gatherer alpine land use strategies. In Madsen, DB & Metcalfe, MD (eds) *Intermountain Archaeology: Selected Papers of the Rocky Mountain Anthropological Conference*. Salt Lake City: University of Utah Press.

Zeanah, DW 2002 Central place foraging and prehistoric pinyon utilization in the Great Basin. In Fitzhugh, B & Habu, J (eds) *Beyond Foraging and Collecting: Evolutionary Change in Hunter-Gatherer Settlement Systems*. New York: Kluwer Academic/Plenum Publishers:231–256.