SURVIVING THE HOLOCENE
Human Ecological Responses to the Current Interglacial in Southern Valencia, Spain

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For hunter-gatherer groups, the dramatic changes in climate at the end of the last glacial cycle necessitated rearrangement of land use, including shifts in mobility strategies, settlement location, and resource use. We examine these behavioral changes using lithic attribute data as well as spatial distributions of artifacts and features. Using data from intensive survey and excavation, we trace human ecological response through the onset of the current interglacial in central Mediterranean Spain, comparatively far from the margins of the north-temperate ice sheets.

THE ABRUPT END OF THE LAST GLACIAL CYCLE NECESSITATED DRAMATIC ADJUSTMENTS in human behavior. For hunter-gatherer populations, these adjustments often included a new organization of land use, including shifts in resource use and mobility strategies. Although this topic is closely related to the question of the source of the Neolithic in Iberia, this paper does not assume any specific explanation for the origin of the Neolithic. Whatever its origins, people of the Neolithic faced unique environmental conditions with the beginning of the Holocene. Sixteen years of collaborative archaeological research in a small area of Mediterranean Spain offers a window into the human responses to the Pleistocene-Holocene transition. The analyses presented here trace these changes through the onset of the Holocene within this region.

CLIMATE

The onset of the current interglacial instigated many climatic changes. Data extrapolated from ice cores indicate that dramatic temperature spikes occurred, sometimes as quickly as within decades (GRIP 1993). Although the Mediterranean region did not experience the same kinds of environmental shifts that were seen in glaciated and periglacial zones to the north, environmental fluctuations seem to have been equally abrupt, and their effects were amplified by probable population packing because this region served as a refugium for Late Glacial human groups (sensu Jochim 1987; Barton et al. 1994). The Last Glacial was marked by aridity and climatic variability in many places. But, as Richerson, Boyd, and Bettinger noted in 2001, the onset of the Holocene marked a shift toward warmer, wetter climate with increased stability. That stability may be the driving force behind Neolithic intensification.

The past climate specific to the Valencia region can be modeled using macrophysical climate modeling developed by Reid Bryson at the University of Wisconsin (Bryson and DeWall 2007). These models can be used to retrodict annual and monthly climate patterns at individual weather stations for the past 40,000 years at a resolution of 100 years. Figure 1 presents the results of such modeling for a weather station located in the city of Alcoi, southeastern Spain (Figure 2). On the same temporal scale, overall precipitation is contrasted with changes in rain event intensity. January precipitation remains relatively stable over time, but it does increase gradually, particularly in the second half of the Holocene. July precipitation, by contrast, varies dramatically. From the end of the Pleistocene into the Holocene, July precipitation fluctuated rapidly. However, beginning at approximately 8,500 years ago, the July precipitation stabilized for nearly three millennia. After that period of stability, oscillations resumed and the overall amount of July precipitation decreased. The period of constancy and pursuant instability are recognizable in rain event intensity as well. From approximately 9,000 to 5,000 years ago, precipitation intensity in September was limited; rainfall occurred throughout the year with a degree of constancy. However, beginning around 5,000 years ago, agriculturalists would have been faced with intense September storms. It is apparent that agriculture began its dominance not long after the onset of climatic stability in Mediterranean Spain. Social complexity, including risk minimization strategies, boomed in the years after the return of climatic instability, which likely caused a jump in erosion. This point also marks the onset of the regime currently known as the typical Mediterranean climate.

ARCHAEOLOGICAL DATA

The archaeological data examined in this study come from systematic, intensive (albeit limited) surveys and a few excavations in eight valleys in the central Mediterranean coast of Spain: the Polop Alto, Middle Río Serpis, Penaguila, Alcalá, Gallinera, Gorgos, and the Upper Ceta and Famorca (Figure 2). This survey region transects an altitudinal gradient of ca. 900 m and covers an area of ca. 1,800 km^2. The lithic sample sizes from this survey range from 1,100 to 3,800 artifacts per valley. Our study area contains evidence of human occupation as early as the Lower Paleolithic with relative continuity through historic periods. Although these valleys cover only a small portion of the Iberian Peninsula, their long duration of occupation and density of artifacts make them useful for understanding land use in this region. We focus on the Late Upper Paleolithic through the Neolithic, spanning the Terminal Pleistocene into the mid-Holocene, in four of these valleys: the Polop Alto, Middle Río Serpis, Penaguila, and Alcalá. For the purpose of this analysis, the Middle Paleolithic is considered to range from 250,000 to 40,000 BP, the Upper Paleolithic from 40,000 to 14,000 BP, the

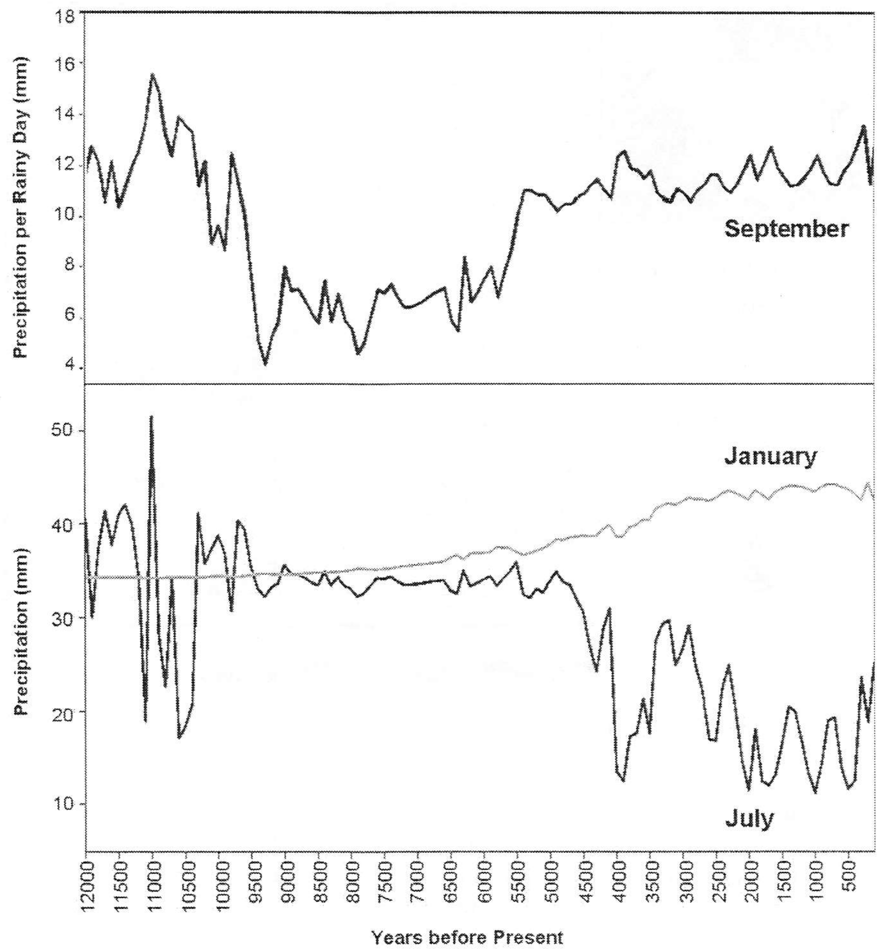

Figure 1. Climate model for the past 12,000 years in Alcoi, Spain.

The top graph indicates rain event intensity for the month of September. The lower graph presents rainfall quantities for January and July.

Late Upper Paleolithic/Mesolithic from 14,000 to 5,600 BP, the Early Neolithic from 5,600 to 4,500 BP, and the Late Neolithic from 4,500 to 2,300 BP.

In a series of publications (1999, 2002, 2004), Barton and colleagues described a method for establishing chronological control over surface artifact assemblages. For each collection area, a Temporal Index (TI) was assigned based on the composition of artifact assemblages. Proportions of key artifact types, as well as presence/absence of diagnostic types, form the basis for estimating the probability that a given assemblage dates to a certain period. The Settlement Intensity Index (SII), based on the Temporal Index, is weighted by artifact densities and serves as a surrogate for occupational intensity across the landscape when scaled for the time span for artifact accumulation in each chronological period. SII values

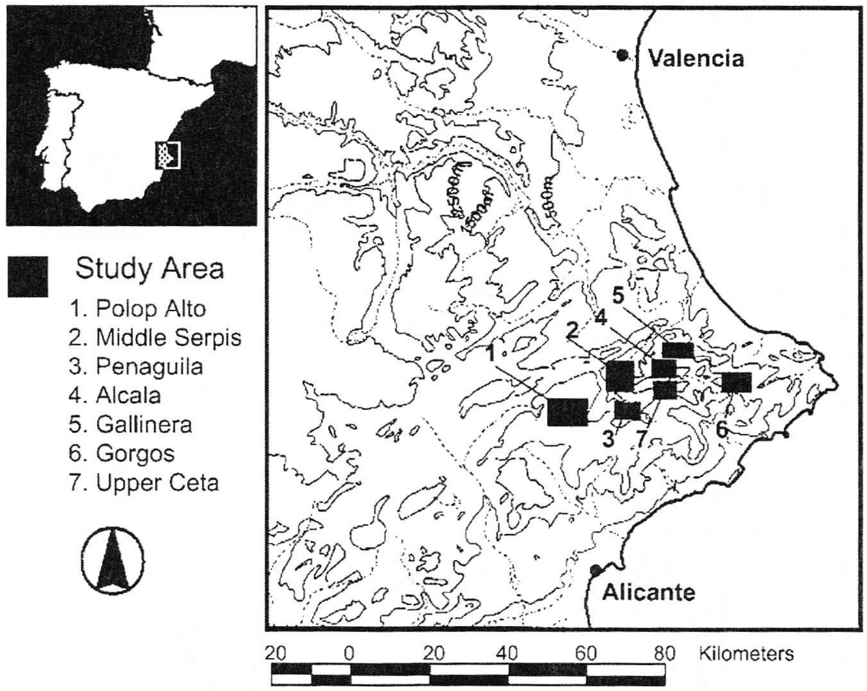

Figure 2. Map demonstrating surveyed areas in Mediterranean Spain (from Barton et al. 1999).

allow us to isolate and analyze the most intensively used areas in each valley for each time period. While this system of indices may appear to abstract the data, in actuality it quantifies the decisions that archaeologists typically make concerning survey assemblages and their temporal context.

Settlement Intensity

As is expected, Neolithic land use appears more intensive than Paleolithic land use (Figure 3). Considering the scaling of time spans, this indicates that artifact accumulation rates were considerably more rapid during the Neolithic than in the Paleolithic. However, the spatial configuration of land-use patterns varies as well as the intensity. For example, even though evidence of Neolithic occupation in the Penaguila Valley becomes increasingly common through time, the total area of most intensive land use decreases from the Early to Late Neolithic. In other words, Paleolithic land use is more dispersed whereas Neolithic land use is more clustered.

Local Density Analysis (LDA), following the work of Johnson (1984) and then Kintigh (1990), serves to summarize land-use dispersion across the valleys and time periods considered here. Figure 4 shows the local density patterning for the Polop Alto, Penaguila, Alcalá, and Muro valleys. The relative heights of the curves in each graph indicate the degree of clustering, while the size of clusters is indicated by the rapidity with which a curve declines. Because the local density

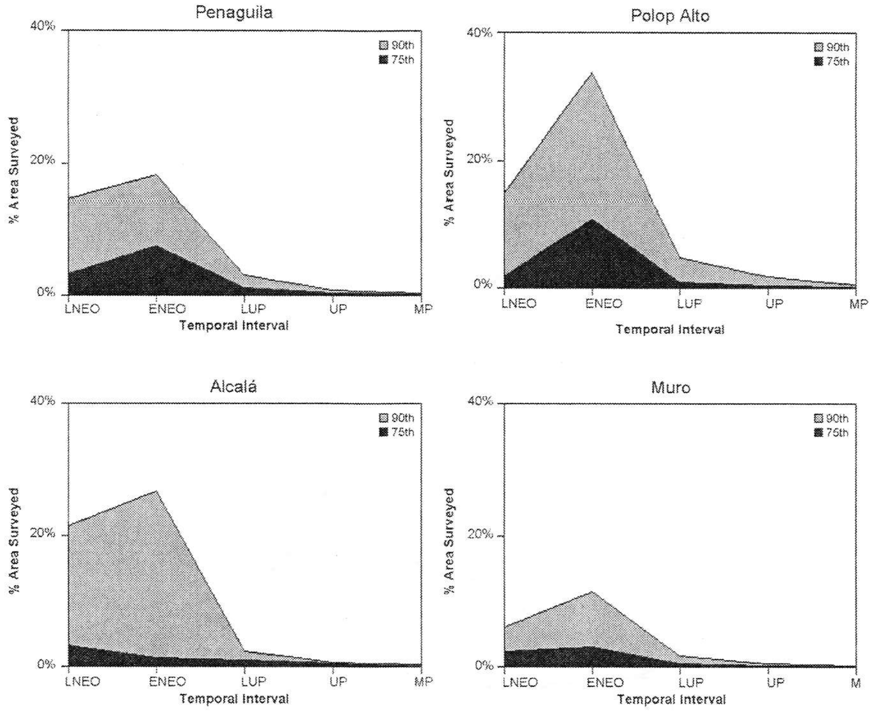

Figure 3. For each time period in each of four valleys, the percent of surveyed area demonstrating SII values in the 75th percentile and above and in the 90th percentile and above.

coefficient values are affected by the particular spatial parameters of each area analyzed, they are not directly comparable across the different survey areas. It is the overall shape of the curves and variation among the curves of the temporal phases within each valley that are of importance here.

For the Alcalá Valley, the LDA curves do not display much difference per time period. However, in the Polop Alto there is a marked change with the onset of the Late Neolithic. The Paleolithic and Early Neolithic periods show a low degree of clustering over continuously varying neighborhood sizes. However, the Late Neolithic displays a higher peak that declines across larger neighborhood radii, those 400 m and above, which reflects a high density of land use over a large primary area. The Penaguila Valley is similar to the Polop, except that the entire Neolithic follows the strong clustering pattern. In other words, areas of intensive land use were dispersed in the Paleolithic through Mesolithic but changed to a clustered settlement pattern with the Early Neolithic. Finally, in the Muro area of the Middle Serpis, the Paleolithic through Mesolithic shows a similarly dispersed distribution, with the Early Neolithic showing more clustering and evidencing clusters that extend in size over larger neighborhood radii. However, the Late Neolithic curve parallels the more dispersed Paleolithic ones, rather than the Early Neolithic curve.

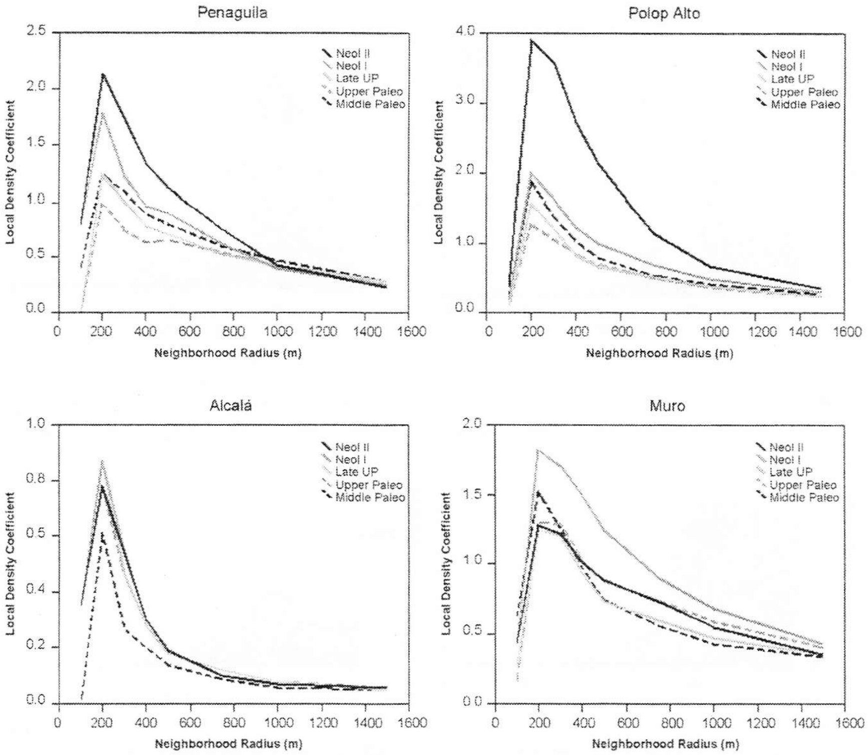

Figure 4. Local density coefficients for increasing neighborhood sizes per time period as calculated in each of four valleys.

Lithic Analysis

Understanding variability in lithic technology can be informative for the explication of settlement systems, human mobility, and raw material procurement (Barton 1990; Kuhn 1992; Shott 1996). Nelson (1991) has also noted that technological organization responds to environmental conditions, including resource predictability, distribution, periodicity, productivity, and mobility. Lithics suggestive of curation were manufactured before their use was required, enabled the economic use of raw material, and were discarded toward the end of their potential use-life; this is evident through tool maintenance and recycling (Bamforth 1986; Nelson 1991; Shott 1996). These factors tend to make curated tools more portable, an advantageous strategy for highly mobile people who need to maintain sufficient cutting edge at a low weight, since curated tools must be carried across the countryside (Kuhn 1992). Expedient tools, at the other end of the continuum, were produced for the task(s) at hand and discarded before their maximum utility was expended. Expedient behavior assumes the presence of abundant raw material, but little time is required to manufacture tools. This is often associated with stockpiling of raw material (Bamforth 1986; Nelson 1991; Shott 1996). Overall, for a given locality, lithic assemblages in which stone curation was important are often characterized by comparatively smaller, more extensively retouched artifacts, less cortex, and lower densities of artifacts discarded at sites. More expedient lithic use tended to generate comparatively larger, fewer retouched artifacts (with less-intensive retouch), with more cortex, and higher quantities of discarded lithics at sites.

Mobility, or the lack thereof, is a major contributing factor to the morphology and use of lithic tools. The strongest connection between mobility and lithic patterning is in the availability of raw material. When people are highly mobile, there is less opportunity to procure raw material. The connection between curation and mobility was originally noted by Binford (1973) and elaborated on and empirically supported by subsequent work (Bamforth and Becker 2000; Kuhn 1992; Nelson 1991; Parry and Kelly 1987; Shott 1996).

Strong differences between Paleolithic and Neolithic settlement make the Penaguila Valley a logical choice for detailed analysis of patterns of curation and expediency in lithic technology to understand changes in mobility patterns across the Pleistocene-Holocene boundary. We follow the method proposed by Barton and Riel-Salvatore (Barton 1998; Riel-Salvatore and Barton 2004), modified for surface assemblages. This strategy is advantageous in that comparisons of stone tool assemblages can be made across temporal and spatial boundaries, despite differences in typological systematics. As originally described, this method compared artifact volumetric density with relative frequency of retouched pieces within assemblages. However, for the surface assemblages in the present analysis it was necessary to use surface area instead of excavated sediment volume. With these modified variables, scatterplots were generated plotting the independent variable of artifact density against the dependent variable of tool frequency. To the extent that mobility practices and site occupation duration are driving variability in lithic artifacts, it is expected that assemblages will be distributed along a continuum from curated (low volumetric density and high retouch frequency) to expedient (high volumetric density and low retouch frequency). If regression coefficients are strong, indicating a close fit with the expected pattern, then retouch frequency alone can be used as a proxy for curation. Size and cortex were also examined as additional evidence of variation in curation patterns.

The scatterplots in Figure 5 were generated to compare retouch frequency with artifact density. For each time period, these variables are reasonably well correlated, with correlation coefficients below −0.5. This means that differences in retouched tool frequency can serve as a proxy for curation behavior.

Figure 6 presents the tool frequency per time period. As is apparent, there is a distinct decrease in retouch frequency (and, hence, in lithic curation behaviors) during the Neolithic. A Wilcoxon signed-rank test confirmed this pattern (Table 1). There are no significant differences within the Paleolithic phases, but each Paleolithic phase is significantly different from each Neolithic phase. When assemblages are combined into Paleolithic and Neolithic groups (Figure 7), the p value is even lower ($p = 0.0000043$), indicating that lithic curation is more characteristic of Paleolithic assemblages than Neolithic ones.

The results of analyses of size and cortex are consistent with the patterns of retouch frequency. Table 2 presents the average lithic size and cortex percentage per survey patch for each time period in the Penaguila Valley. Again,

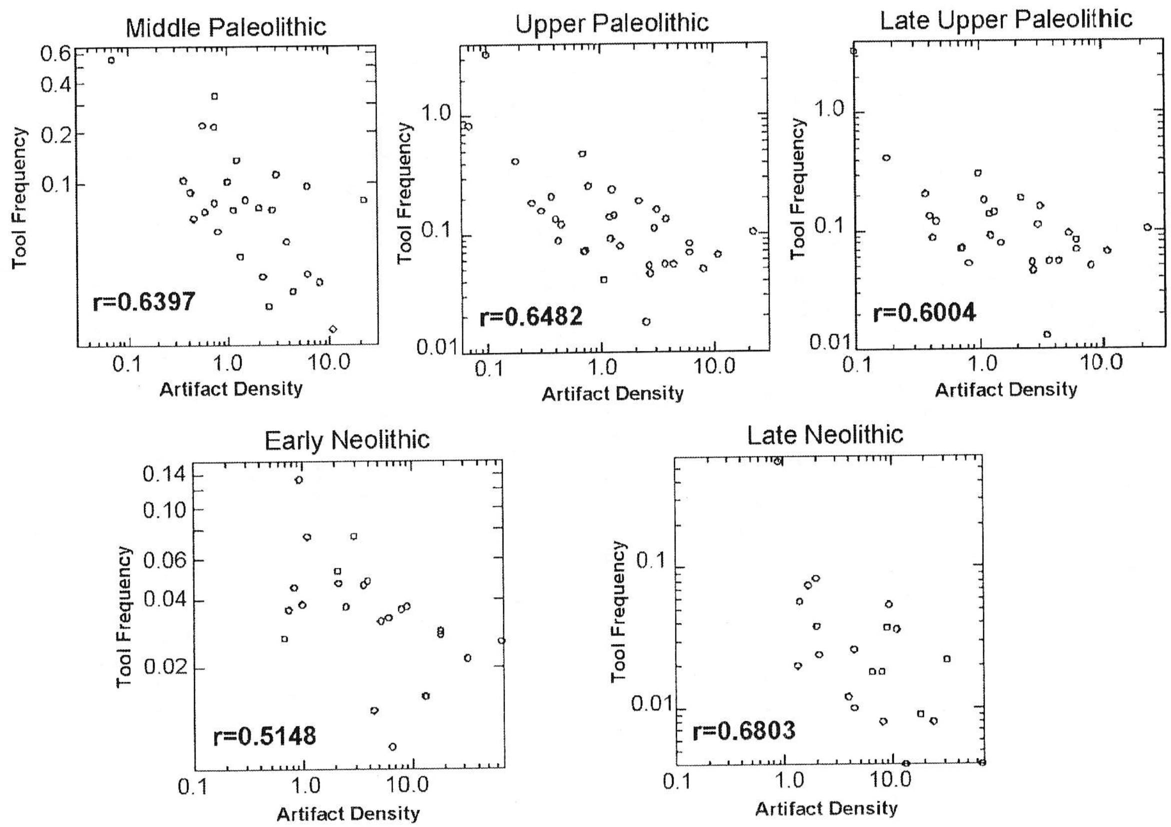

Figure 5. Scatterplots of tool frequency versus artifact density for each time period from the Penaguila Valley on a logarithmic scale.

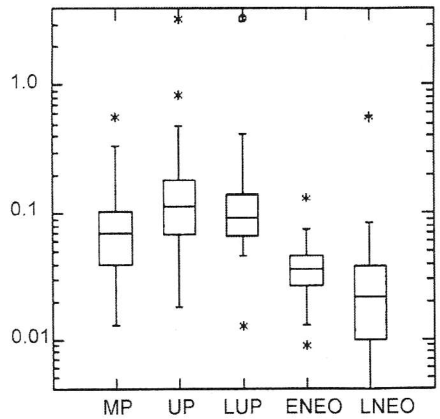

Figure 6. Box plot of retouch frequency of lithic artifacts per time period from the Penaguila Valley on a logarithmic scale.

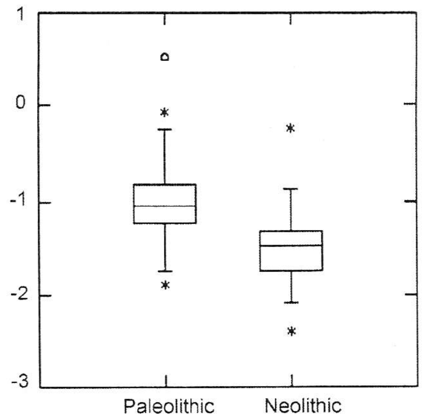

Figure 7. Box plot of retouch frequency of all lithic artifacts from the Penaguila Valley separated into Paleolithic and Neolithic time periods. Frequency plotted on a logarithmic scale with $p = 0.0000043$.

TABLE 1

Two-sided probability from a Wilcoxon signed-rank test for "tool" frequency in each time period. These numbers represent the probability that the two samples being compared derive from the same population.

	Middle Paleolithic	Upper Paleolithic	Late Upper Paleolithic	Early Neolithic	Late Neolithic
Middle Paleolithic	1.00				
Upper Paleolithic	0.18	1.00			
Late Upper Paleolithic	0.12	0.55	1.00		
Early Neolithic	0.02	0.01	0.00	1.00	
Late Neolithic	0.07	0.03	0.02	0.02	1.00

the three Paleolithic time periods (M, EUP, and LUP) resemble each other, whereas a change is apparent with the Neolithic, particularly the Late Neolithic. Neolithic assemblages overall show more cortex remaining on artifacts; they also demonstrate more variety in their locations of discard. Some artifacts were disposed of after having been highly recycled, while others were abandoned early in the use-life sequence. Overall, Neolithic artifacts are larger and retain more cortex than those used by Paleolithic inhabitants of the Penaguila Valley. Again these differences are supported, though less strongly than in the retouch analysis, by Wilcoxon signed-rank tests. Although these results, like those of the settlement intensity analysis, are not surprising, they represent fundamental concepts that needed empirical confirmation.

TABLE 2
Average size and cortex values for lithic artifacts from each time period in the Penaguila Valley.

Time Period	Size (1–4)	Cortex Code (1–3)
Middle Paleolithic	1.45	1.26
Upper Paleolithic	1.46	1.24
Late Upper Paleolithic	1.46	1.24
Early Neolithic	1.42	1.31
Late Neolithic	1.54	1.29

Size was coded as follows: 1 (< 2cm), 2 (2–4 cm), 3 (4–8 cm), 4 (> 8 cm). Cortex was coded 1 (0–10% cortex remaining), 2 (10–50% cortex remaining), 3 (more than 50% cortex remaining). Averaged codes only include materials from survey patches that yielded artifacts solely attributable to that time period.

EXCAVATED SITE COMPARISON

In-depth studies at five prehistoric settlements provide a more detailed picture of the organizational shifts that characterized human response to Holocene environmental changes. Occupational histories at sites located within the survey valley margins can confirm and enhance analysis of the survey data. Cova Beneito, Encantada, and Alt del Punxó are located in the Serpis Valley; Cova de la Falguera is in the Polop Valley; and Mas d'Is is in the Penaguila Valley. Cova Beneito and Cova de la Falguera are rockshelter sites; the others are open-air localities. These sites display variable occupational persistence across multiple time periods, but none have evidence of continued occupation from the Terminal Pleistocene into the mid-Holocene.

Cova Beneito is a small shelter in the Sierra Benicadell that marks the northern margins of the Serpis Valley. Its long occupational sequence spans much of the Upper Paleolithic, but evidence of occupation following the Late Pleistocene is minimal (Barton 1988; Doménech Faus 2005; Iturbe et al. 1993).

Encantada, located on a high terrace above the confluence of the Barranc de la Encantada and the Río Serpis, has an intensive Terminal Pleistocene occupation (Barton et al. 2004; García Puchol et al. 2001). Human use of the locale extended into the early Holocene as evidenced by a Mesolithic assemblage. However, this was followed by an occupational hiatus that may have lasted until post-Roman times, although there are Chalcolithic or Bronze Age materials in a rockshelter above the site (but these may be from a burial, rather than representing an occupation). Also in the Serpis Valley, the site of Alt del Púnxo, located on an old alluvial fan of the Río de Agres, lacks evidence of Late Paleolithic use even though the surface has been stable since the Middle Pleistocene at least. It has limited early Holocene occupation, followed by a hiatus. Following this, there is evidence for more or less continuous use from the Late Neolithic (ca. 4,200 cal BC) onward (Barton et al. 2004; García Puchol and Molina Balaguer 1999; García Puchol et al. 2008).

Cova de la Falguera, in the middle reaches of the Barranc de Coves canyon, opens onto the Polop Valley. The rockshelter was initially occupied by Mesolithic hunters. With a few, brief interruptions, the site continued to be occupied by Neolithic and Chalcolithic herders (García Puchol 2005; García Puchol and Aura Tortosa 2006). There is no evidence of Pleistocene human presence at Mas d'Is, although evidence of Mesolithic occupation was recently discovered nearby. This occupation was founded at the beginning of the Neolithic, and the site continued into the Bronze Age (Barton et al. 2004; Bernabeu Auban et al. 2003, 2006; Bernabeu Auban and Orozco Köhler 2005). Although some especially favored cave and rockshelter sites evidence repeated human use across the Pleistocene-Holocene transition, from the Late Paleolithic well into the Neolithic, these seem to have been more the exception than the rule. Most localities with evidence of especially intensive human use (probably campsites, farms, and hamlets) were either occupied in the Pleistocene—with use extending into the Early Holocene occasionally, as at Encantada—or in the Holocene, with significant human use beginning with the Mesolithic or Neolithic. This shift in landscape use seems more to do with adjustments to the new environmental circumstances of the Holocene than the subsequent socioeconomic transition from foraging to farming, though the latter had equally significant consequences for land use (Barton et al. 2004; Bernabeu et al. 2006; García Puchol 2005).

CONCLUSION

Although Mediterranean Spain was far from the glacial landscapes of northern Europe, the Pleistocene-Holocene transition seems to mark a significant change in its human ecology. While the trends determined by this analysis are at times unspecific, they are broad in their implications. Some changes, such as decreases in lithic curation and increases in lithic accumulation rates, may be a result of reduced mobility accompanying the appearance/adoption of farming. However, most of the observed changes seem more closely associated with responses to the onset of global warming that we call the Holocene. The fact that humans were organized in small groups, the landscape was sparsely populated compared with the present, and (initially at least) humans continued to subsist on wild plants and animals across the Pleistocene-Holocene transition makes the shifts in land-use patterns seen in the archaeological record all the more dramatic. Human populations in this region today (and throughout most of the globe) are much higher and more densely packed, precluding the kinds of land-use reorganization that characterized early Holocene response to environmental change. In this sense, our options for responding to the climatic changes that we face in the coming century appear much more limited. We would do well to study and heed the lessons of the people of Mediterranean Spain who survived the Holocene crisis.

NOTE

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