Journal of Archaeological Method and Theory, Vol. 11, No. 3, September 2004 (© 2004)

Long-Term Socioecology and Contingent Landscapes

C. Michael Barton,[1,3] Joan Bernabeu,[2] J. Emili Aura,[2] Oreto Garcia,[2] Steven Schmich,[1] and Lluis Molina[2]

Long-term social and natural processes reciprocally interact in spatially and temporally dynamic socioecosystems. We describe an integrated program of patch-based survey and subsurface testing aimed at studying long-term socioecology, focusing especially on the transition from foraging to farming in Mediterranean Spain. Measures of landuse ubiquity, intensity, dispersion, and persistence trace late-Pleistocene through mid-Holocene socioecological trajectories in four upland valleys. Although farming replaced foraging in all four valleys, the timing and nature of this transition varied because of cumulative interactions between social and natural processes. These processes continue to structure modern landscapes and landuse in these valleys.

KEY WORDS: socioecology; landscape; landuse; ecology; origins of agriculture; Spain; Mediterranean; GIS.

INTRODUCTION

In the last decade, ecology has discovered a past; and in many cases this has turned out to be a human past. The spaceless, timeless, linear relationships that specified the flows of matter and energy among organisms are giving way to a realization that ecosystem configuration and process is dynamic in time and space, and contingent on the history of a system in a particular place. Furthermore, humans are coming to be recognized as significant, active members of terrestrial ecosystems for hundreds of millennia in the Old World and since the late Pleistocene throughout the New World. This recognition of temporal and spatial dynamics in

[1]Department of Anthropology, Arizona State University, Tempe, Arizona.
[2]Departament de Prehistòria i d'Arqueologia, Universitat de València, Valencia, Spain.
[3]To whom correspondence should be addressed at Department of Anthropology, P.O. Box 872402, Arizona State University, Tempe, Arizona 85287-2402; e-mail: michael.barton@asu.edu.

ecology and the importance of the human role in ecosystems goes under a variety of names depending on academic discipline, including the new ecology, historical ecology, environmental history, political ecology, and reliance theory (Balée, 1998; Butzer, 1996; Crumley, 1994; Holling, 2001; Pyne, 1997; Sheridan, 1995; Zimmerer, 1994).

These various perspectives share the common realization that humans cannot be viewed either as passive consumers or rapacious exploiters of ecosystems; conversely, ecosystems are more than a backdrop for human agency or a larder to fuel human economies. "Pristine" ecosystems have not existed anywhere for millennia, and humans and cultural systems have played an integral role in the development and maintenance of ecosystems world wide. Yet humans—even in the context of complex society—are still subject to a wide variety of ecological constraints. This means that human society is constantly reshaping the intertwined cultural and natural components of the socioecological landscape on which its members and their descendents must operate.

An appreciation of the history of such inclusive socioecosystems (Barton *et al.*, 2001) is fundamental to understanding their operation. This broader ecological dynamic—one that includes culture as well as nature—operates over varying, but often long time periods as was recognized decades ago by Braudel (1980) in the humanities and Butzer (1982) in the natural sciences. Very often the environmental consequences of human action only are apparent over the course of many generations. Historical disciplines, and especially archaeology with its overt focus on long-term cultural change and human–environmental interaction, are essential for understanding the temporal dynamics of socioecosystems (McGlade, 1995, 1999; Redman and Kinzig, 2003). Similarly, socioecological processes operate at varying spatial scales. As human interaction and social organization varies both across space and at different spatial scales (e.g., household, community, state), so do the ways in which humans interact with the nonhuman aspects of the environment. Hence, the state of a socioecosystem at any particular place is equally a product of spatial-dependent as well as time-dependent processes. Moreover, while human societies operate and change within the framework of general evolutionary processes, we cannot expect a cultural system to follow any particular, linear developmental trajectory. Instead, the outcomes of social evolution will be strongly contingent on socioecological history and geography (Bintliff, 1999; Gould, 1989).

RESEARCH SETTING

Over the past decade, we have been working to better understand the long-term temporal and spatial dynamics of socioecosystems in eastern Spain, building regional datasets for modeling prehistoric landscapes and their changes. This ongoing research project is located in Alicante Province of the País Valenciano.

Within a region of over 1800 km^2, we have conducted a program of intensive survey and excavation in eight valleys of the rugged uplands that border the Mediterranean littoral: the Polop Alto, Penaguila, middle Serpis, Alcalá, Gallinera, Ceta, Gorgos, and Canyoles valleys (Fig. 1). The study area comprises the northern end of the Baetic mountain system that lies between the interior plateau of the southern Meseta and the Mediterranean along Spain's southeastern margin. Here, elevations range from around 200 m to over 1500 m. Elevations of individual valleys surveyed are 200–350 m for Gorgos, 300–500 m for Gallinera, 300–600 m for Canyoles, 350–500 m for the middle Serpis, 500–800 m for the Ceta, 550–750 m for the Penaguila, 600–700 m for the Alcalá, and 700–900 m for the Polo Alto valley. Dry farming is practiced throughout the region, with rainfall measuring 600–900 mm per year.

Human occupation within the study area extends back into the Middle Pleistocene, and has been more or less continuous at least since the early Upper Pleistocene. Because the regional prehistory recently has been reviewed in detail elsewhere (Aura and Pérez-Ripoll, 1995; Barton *et al.*, 1999; Bernabeu and Juan-Cabanilles, 1994; Villaverde *et al.*, 1998), we provide only a brief summary here. A record of human presence in the Middle Pleistocene is found at the site of Bolomor (with TL dates of ca. 250 kya), a short distance north of the Gorgos valley (Fernández Peris, 1993; Fernández Peris *et al.*, 1997). Upper

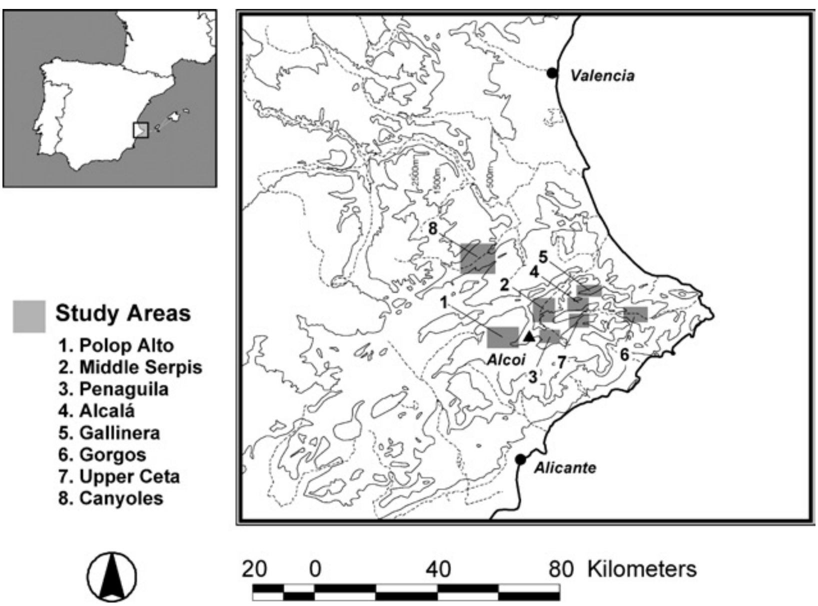

Fig. 1. Research area in eastern Spain.

Pleistocene, Middle Paleolithic occupations are documented at cave/rockshelter sites of Cova del Salt, in the Polop Alto (Barton, 1988; Galvan, 1992); Cova Negra, near Xátiva and a little to the north of the study area (Villaverde, 1984); and Cova Beneito, in the middle Serpis valley (Doménech Faus, 1999; Iturbe *et al.*, 1993). Beneito also has a long Upper Paleolithic sequence, beginning at ca. 34,000 bp. Late Upper Paleolithic industries appear ca. 14,000 bp in the regional Magdalenian at sites like Tossal de la Roca rockshelter, at the western edge of the Alcalá valley (Cacho *et al.*, 1996), and the open-air locality of Encantada in the middle Serpis valley (García Puchol and Barton, 2001). These Upper Paleolithic industries, and the way of life they represent, continue into the Holocene until the appearance of the Geometric Mesolithic at about 8000 bp, exemplified locally at Tossal de la Roca and Cova de la Falguera shelter, in the Polop Alto (Barton and Clark, 1993; Cacho *et al.*, 1996; Doménech, 1990; García Puchol, 2002).

The regional Neolithic is divided into early and late phases. The Neolithic I begins by 5600 B.C. and continues until ca. 4500 B.C., representing the earliest clear evidence for the use of domestic plants and animals in the Iberian peninsula. Locally, the Neolithic I is best known from the cave site of Cova de l'Or, in the middle Serpis (Martí *et al.*, 1980) and the open air locality of Mas d'Is in the Penaguila valley (Bernabeu Auban *et al.*, 2003). The Neolithic II is subdivided into three subphases. The Neolithic IIA is dated to 4500–3700 B.C., but poorly represented regionally, whereas the better represented Neolithic IIB dates to 3700–2900 B.C., making it roughly contemporaneous with the "Los Millares" culture of southeastern Spain. The final Neolithic IIC, also called the "Bell Beaker" after the form of characteristic ceramics, is dated to 2900–2300 B.C.. Recently studied Neolithic II sites in the region include the settlements of Niuet (Bernabeu *et al.*, 1994), Alt de Punxó (Barton, personal communication, 2003), and Les Jovades (Bernabeu, 1993; Pascual Benito, 1989), all in the middle Serpis valley. The regional Bronze Age dates to between 2200 and 1200 B.C. and is broadly contemporaneous with the better known "Argaric" culture of southeastern Spain. By 600 B.C., a variety of Iron Age groups, generically known as the "Iberic Culture" occupied the area, interacting with Phoenician, Greek, and Punic traders, until the region became incorporated into the expanding Roman Republic after the Second Punic War.

RESEARCH PROTOCOLS FOR LONG-TERM SOCIOECOLOGY

Conceptual Frameworks

Over the past decade, we have developed a suite of research protocols aimed at addressing the long-term dynamics of prehistoric socioecosystems at regional scales in a systematic fashion (Barton *et al.*, 1999, 2002, 2004; Bernabeu Auban, 1999; Bernabeu *et al.*, 1999, 2000). Although our ultimate interest is in the ecology of interacting human and natural systems, these prehistoric systems are no longer extant and cannot be studied in terms of information, energy, and material flows among organisms that comprise the primary data of ecology any more than the prehistoric social systems can be observed. However, landscapes are the geographical context in which socioecosystems operate and are altered by socioecological processes. In recent years, landscape has become a catchword that embodies a wide variety of concepts (e.g., compare the perspectives in Bender, 1993; Bottema *et al.*, 1990; Bradley, 1991; Crumley, 1994; Fisher and Thurston, 1999; Llobera, 2001; Redman and Kinzig, 2003; Rossignol and Wandsnider, 1992; Ucko and Layton, 1999; Waters and Kuehn, 1996). Here, we use the term broadly to mean the earth's surface and surface sediments, along with its physical, biotic, and social constituents. Social and natural processes that structure and change socioecosystems very often have physical outcomes on landscapes, depositing, rearranging, or removing materials.

Soil, itself a component of a landscape, exemplifies the physical results of the complex relationships among physical, biotic, and social processes. A particular soil and its properties is a product of the deposition and/or weathering of mineral parent materials; the addition, chemical transformation, and translocation of the residues of dead plants and animals (related to the type of vegetation that grows on the soil); rearrangement of soil constituents by plant roots, animal burrowing, and tillage by humans; additions of chemical and natural fertilizers by humans; movement of soil constituents and chemical reactions driven by percolating precipitation and/or groundwater movement; physical and chemical changes to temperature variation; and physical losses due to wind and water erosion (Birkeland, 1999). A further important point is that soil development is a long-term, cumulative phenomenon; the many processes outlined above cumulatively alter the properties of an extant soil rather than creating a new soil or new soil property. This is the case with other landscape components. They, and the landscapes they comprise, are the long-term, cumulative products of a very long history of social and natural processes and their interactions. Hence, landscape studies can serve as a way to get at those no longer observable processes we seek to understand. In order to acquire archaeological data to understand past socioecosystems, we must record cultural and natural characteristics of modern landscapes that are only the most recent manifestation of continuous series of changes.

In this sense, the things that we study—whether architecture or artifacts, soils or landforms—are profitably viewed as accumulations that have been deposited at varying rates and preserved differentially. Long-term human landuse is often portrayed as a sequence of occupations, like the pages of a book, but is better conceived of as a repeatedly overwritten manuscript—that is, a palimpsest (cf. Binford, 1981; Zvelebil *et al.*, 1992). Furthermore, the complex causes of deposition, subsequent alteration, and eventual preservation or loss of landscape elements include those social processes that we seek to understand. Although archaeologists often divide such accumulation processes into "cultural" and "natural" (Schiffer, 1983, 1987)—and seek to isolate the cultural for study—such divisions are in reality greatly blurred. For example, artifact discard can be affected by "natural" processes, with vegetation density or rapid accumulation of colluvial sediment during storms affecting the likelihood of artifact loss, and shifting stream courses or changes in the distribution of animals and edible plants affecting the abandonment of settlements and their artifacts. Similarly, "natural" processes such as the accumulation of alluvial sediments, erosion, and soil formation are influenced by human behaviors such as landscape burning (accidental or intentional), forest clearance, tillage, and fertilizing.

Because of the cumulative nature of landscapes—including behavioral residues—and because of the complex intertwining of cultural and natural processes, we take a taphonomic approach to the archaeological record (Barton *et al.*, 1999, 2002). That is, we focus on understanding the suite of processes that are responsible for the accumulations of artifactual and other materials that make up modern landscapes. These processes include not just initial deposition, but subsequent alteration, transport, and loss. Rather than treating all but the first of these sets of processes (i.e., discard or deposition) as noise that distorts the archaeological record, we see all taphonomic processes as potentially informative. In practice, this means that we record landuse and geomorphology along with artifact and feature counts in our survey units, and evidence for transport and other postdepositional alteration is included in our artifact analysis along with technological, functional, and stylistic features. It also means that we treat the archaeological record as a continuous, spatially variable, long-term accumulation rather than a set of imperfect snapshots of the past.

Field Methods

Issues of scale, units, and data collection standards are fundamental to all fieldwork, varying according to the nature of archaeological questions addressed and a researcher's perspective on the archaeological record (although the last is often implicit). Our immediate goal is to evaluate the spatial and temporal variation in the accumulation of cultural and natural residues relevant to understanding aspects of past socioecosystems. At a more inferential level, we have focused especially on tracking changes in subsistence economy, the spatial configuration of human landuse, changes in settlement permanence, and associated changes to biotic communities and surface sediments.

Given these research objectives, our work has taken place at a "meso-scale," intermediate between extensive, site-focused surveys and detailed excavation of particular human settlements. We want to cover large enough areas to encompass most of the normal, day-to-day activities and natural processes that characterize community-level socioecosystems. That is, we endeavor to look beyond the information-rich but geographically tiny window afforded by site-focused excavation. However, we also want to focus on areas small enough so that we are not relegated by logistics to collecting data only at a series of those localities with especially high artifact densities or concentrations of architectural features (i.e., sites). For this reason, we have chosen invest considerable research effort in patch-based survey and extensive subsurface testing rather than long-term excavation of a single or few sites, and to intensively survey in a series of compact valleys rather than extensively across the entire region.

At this meso-scale, we endeavor to collect information about landscapes rather than sites, employing a patch-based methodology. Most archaeological survey uses characteristics of the data sought (i.e., surface density of material culture) to define units for data collection. That is, archaeologists seek out locales with particularly high concentrations of artifacts and/or architecture relative to the background and then collect information about those locales. This strategy serves very well for many archaeological questions and is often the most pragmatic option when very large tracts of land must be covered. However, if we are interested in the interactions between humans and other components of their ecosystems, and seek to identify and explain spatial variation in artifact accumulations across landscapes, we also need to systematically collect data at locales where material culture is rare or absent. This means that we cannot limit our survey units to those locales commonly termed “sites.” The considerable literature on “nonsite” or “off-site” survey encompasses a wide variety of techniques (Dunnell, 1992; Ebert *et al.*, 1996; Foley, 1981; Zvelebil *et al.*, 1992). Rather than describing our field methods in terms of what they are not (i.e., nonsite), we feel it is more useful to describe them in terms of what they are.

Our survey units are defined geographically, rather than in terms of material culture density. That is, we identify a series of geographic study units (i.e., “patches”) from which we systematically collect data—including but not limited to information about cultural materials—whether or not artifacts or other behavioral residues are found in the unit. A similar method is employed in fieldwork deriving conceptually from the “new ecology” that seeks to assess spatial variation in ecological parameters and processes. Such geography-based units are called patches in relevant publications (Collins *et al.*, 2000) and we follow this usage here. We generally use the small, terraced fields that are pervasive throughout the Mediterranean to delineate our study patches. In the first surveys conducted in this region (the Penaguila and parts of the Serpis valleys) contiguous areas were completely covered. Subsequently, we have employed a multistage strategy of stratified, random sampling followed by selected sampling to cover larger areas while maintaining the potential for statistical modeling.

Within each patch we record a suite of standardized data about the modern landscape as well as systematically collect prehistoric artifacts. Some of these data, such as landform and surface soil characteristics, provide information about landscape development and past ecology. Others, such as current landuse and surface visibility, help us better assess the accumulation processes that create and alter the archaeological record. For example, artifact density can be measured in two ways, the number of artifacts per unit volume of sediment or the number of artifacts per unit area of the landscape surface. The former varies according to the relative accumulation rates for artifact and sediments at a particular locale; the latter also is strongly affected by processes that bring artifacts to the surface (especially tillage), intensity and entrainment energies of surface erosion (removing artifacts or leaving them on a deflation surface), and the nature of plant cover. The two measures of artifact density are clearly related but not identical. Recording information about landuse and surface visibility can help us to reexpress counts per surface area to more closely approximate density in volumetric terms, and hence accumulation rates. We make extensive use of GIS tools to organize and rescale the data we collect. By using a GIS to map patches, we can overlay aerial and space-borne imagery that provides further information about soils, sediments and geomorphology, and vegetation and landuse. We also use GIS for quantitative analysis and socioecological modeling from patch-based data.

Analytical Approaches

Our perspective that the archaeological record is part of a more inclusive socioecological landscape that has been differentially accumulating across space and time has shaped our approach to analysis of the data we collect. We assume a priori that artifact accumulations are palimpsests rather than cultural snapshots. Furthermore, we recognize at the outset that these accumulations are not simply the result of cultural site formation (sensu Schiffer, 1987), but are also shaped and recorded by the long-term dynamics of landscape formation that are ongoing today.

Distinguishing the changing nature of human use of each patch through time is essential to modeling the temporal dynamics of human ecosystems across space. However, such chronology building is a more complex task for surface assemblages where episodes of greater human activity (and higher artifact accumulation rates) are not separated stratigraphically by sediment that accumulated more rapidly than artifacts during intervals of minimal activity. Commonly, archaeologists estimate the time-span represented in surface artifact accumulations by identifying artifacts whose presence or absence is chronologically sensitive to varying degrees. For simplicity, a locale is generally assigned to a single period, although “multiple occupations” can also be recognized. Our analytical protocols systematize this generally subjective procedure while recognizing the often palimpsest nature of material culture accumulations.

Making extensive use of GIS tools, we use the combined presence and/or absence of a variety artifact forms to estimate systematically the likelihood that artifacts accumulated in a study patch during any of several temporal intervals. Because our intent here is to explore very long-term dynamics at a regional scale, these intervals are the Middle Paleolithic (early Upper Pleistocene), Upper Paleolithic (late Upper Pleistocene), final Paleolithic–Mesolithic (terminal Pleistocene–early Holocene), Neolithic I, and Neolithic II. This also represents the temporal resolution most consistently and reliably identifiable across all the valleys discussed here. Nevertheless, as we have accumulated more detailed information in each valley, we have begun to use a higher resolution chronology in some valleys, especially for the Late Pleistocene and Early Holocene (Bernabeu *et al.*, 2000; Bernabeu Auban *et al.*, 1999). In the future we hope to employ this finer resolution chronology across the entire region.

We assign a rank order probability estimate between zero and one to each patch for each of the five time intervals (Table I). These ordinal probability estimates, that we call Temporal Index (TI), allow us to infer where human activities took place and the relative extent of the landscape used at different times in the past. This is shown graphically in Fig. 2. We further make the reasonable assumption—based on the positive relationship between diversity and sample size—that the time period(s) with the strongest chronological signal (i.e. the highest TI values) most often will be the one during which the greatest portion of an artifact assemblage accumulated. Hence, we also weight a measure of artifact abundance (also a rank-ordered value within each valley) by TI to estimate geographic variation in intensity of landuse within each time interval.

We designated this latter value Settlement Intensity Index (SII). To derive artifact abundance weightings, assemblages from all patches are ranked into six quantile groups according to lithic artifact density in pieces per square kilometer (lithics are used here because they are a material class with consistent taphonomic properties across all time periods): 1.00 for patches with densities in the 91st–100th percentile, 0.90 for patches in the 75th–90th percentile, 0.75 for patches in the 51st–75th percentile, 0.50 for patches in the 26th–50th percentile, 0.25 for patches in the 11th–25th percentile, 0.10 for patches in the 1st–11th percentile, and 0 for patches with no artifacts. For every patch the abundance weighting is multiplied by the TI value for each chronological period to produce a SII value for each time period. In this way a patch can have a high SII value for one or more periods and low values for others; it also can have equally high values (if it has many artifacts and clear temporal signals) or low values (few artifacts and/or ambiguous temporal signals) for all periods.

There are several important considerations for using a measure such as SII for modeling prehistoric landuse. We avoid using raw artifact density in creating

Table I. Calculation of Temporal Index (TI) (After Barton *et al.*, 1999)

Period	Temporal Index					
	0.9	0.7	0.5	0.3	0.1	0
Late Neolithic	Present: Late Neol. tools[a] *or* Late Neol. ceramics	Present: ceramics *or* ground stone	Present: Neol. tools,[b] ceramics *or* ground stone	Present: blade tech.[c]	Present: artifacts	Present: N/A
	Absent: N/A	Absent: backed tools *and* Early Neol. tools[d]	Absent: N/A	Absent: N/A	Absent: N/A	Absent: artifacts
Early Neolithic	Present: (backed tools *and* [ceramics or Early Neol. tools]) *or* Early Neol. ceramics	Present: Neol. tools, ceramics *or* ground stone	Present: backed tools *or* ceramics	Present: blade tech.	Present: artifacts	Present: N/A
	Absent: Late Neol. tools *and* Late Neol. ceramics	Absent: Late Neol. tools *and* Late Neol. ceramics	Absent: N/A	Absent: N/A	Absent: N/A	Absent: artifacts
Late Upper Paleolithic & Epipaleolithic	Present: backed tools	Present: backed tools	Present: backed tools *or* blade tech.	Present: backed tools *or* blade tech.	Present: lithics	Present: N/A
	Absent: Neol. tools *and* ceramics	Absent: ceramic density $<75/km^2$	Absent: ceramic density $<75/km^2$	Absent: N/A	Absent: N/A	Absent: lithics
Upper Paleolithic	Present: U. Paleo. tools,[f] *and* blade tech.	Present: U. Paleo. tools *or* blade tech.	Present: U. Paleo. tools *or* blade tech.	Present: U. Paleo. tools *or* blade tech.	Present: lithics	Present: N/A
	Absent: backed tools, Neol. tools, *and* ceramics	Absent: backed tools, Neol. tools, and ceramics	Absent: ceramic density $<75/km^2$	Absent: N/A	Absent: N/A	Absent: lithics

Middle Paleolithic	Present: M. Paleo. tools[g]	Present: M. Paleo. tools	Present: M. Paleo. tools	Present: M. Paleo. tools or flake tech.[h]	Present: lithics	Present: N/A
	Absent: U. Paleo. tools, backed tools, Neol. tools, blade tech., and ceramics	Absent: backed tools, Neol. tools, and ceramics	Absent: ceramic density $<75/km^2$	Absent: N/A	Absent: N/A	Absent: lithics

[a] Late Neolithic lithic tools include bifacial projectile points and denticulated sickle blades. The latter also occur in Bronze Age contexts, but are only found in association with other Neolithic artifacts in our collections from the Polop Alto; hence they are used here as a marker for the Late Neolithic.
[b] Neolithic tools (Early and Late) include plain (i.e., undenticulated) sickle blades and bifacial drills (taladros).
[c] Besides prismatic blades, evidence for blade technology includes crest blades, blade cores, and blade core face and platform rejuvination flakes.
[d] Early Neolithic tools are finely retouched (utilized) bladelets. Backed tools include backed bladelets, backed points, and geometric microliths.
[e] This is an empirical figure for "background" ceramics derived from examining density histograms of ceramics for the entire Polop Alto survey area.
[f] Upper Paleolithic tools include endscrapers, burins, truncations, and perforators.
[g] Middle Paleolithic tools include sidescrapers (including transverse and déjéte scrapers), notch/denticulates, and Mousterian points.
[h] Flake technology includes flakes and flake cores—both prepared (e.g., discoid and levallois) and amorphous.

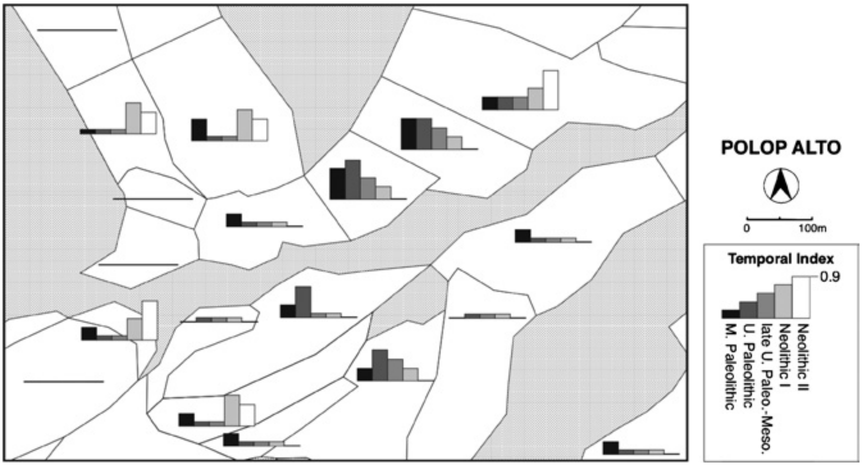

Fig. 2. TI values for each temporal interval for survey patches (white) in a section of the Polop Valley.

SII to reduce variance due to a few extreme density values, to scale SII between 0 and 1, and to increase comparability at regional scales where there is likely to be variation in artifact density due to taphonomic processes. Nevertheless, because considerable variation is likely for artifact accumulation rates during different time periods (e.g., Paleolithic vs. Neolithic), it is inappropriate to compare raw SII values across time periods (i.e., an SII value of 0.5 has a different meaning in terms of landuse intensity for the Middle Paleolithic than for the Neolithic II). Rather, we again rank SII values within each time period and compare the spatial distributions (and other characteristics) of patches with equivalent rankings of SII for each time period. For example, we compare below distribution patterns of patches in the upper quartile for each time interval. We also focus primarily on high SII values (i.e., above the median) for several important reasons. Very low SII values derive from low TI values and low artifact densities, indicating ambiguous temporal signals and the possibility that modern landuse (and attendant surface visibility) has affected spatial patterning. Slightly higher to moderate values of SII result from either low TI values (ambiguous temporal signal) and high artifact densities, or high TI values and low artifact densities. In the first case, we can document intensive landuse but cannot say with confidence when it occurred. In the second case, human presence is documented at a particular time, but landuse intensity is minimal. Also, since only a few artifacts are represented, the possibility that they may be redeposited from their discard location is higher. More detailed descriptions of the way in which these indexes are calculated and discussions of taphonomic and social factors that can affect them are found in Barton *et al.* (1999, 2002) and Bernabeu *et al.* (1999).

In essence, we have simply systematized the more subjective chronological assessments that archaeologists commonly make in survey projects. However, we do these assessments for each landscape patch we study, rather than only for sites. Furthermore, while there is nothing inherently wrong with more subjective chronology building, especially by an experienced archaeologist, our analytical protocols are more consistently replicable, hopefully reducing interinvestigator variation in the interpretation of archaeological materials. So far, subsurface testing has borne out these chronological assessments derived from surface data.

Because they are quantitative and linked with spatially defined data collection units, measures such as TI and SII also can more easily be incorporated in other forms of paleolandscape analysis. For example, this framework has served as a platform for examining the differential effects of erosion on artifact accumulations through time, assessing temporal variation in artifact transport, monitoring temporal changes in evidence such as artifact density and morphology for settlement permanence, and modeling spatial aspects of past socioecosystems (Barton *et al.*, 1999, 2002; Bernabeu *et al.*, 1999, 2000). The systematic nature of the data produced by these analytical protocols also facilitates comparisons across regions. Here we focus on such comparative study, examining temporal and spatial dynamics in the evolution of Neolithic socioecosystems and their long-term consequences in four of the valleys where we have worked: the Penaguila, Polop Alto, Alacalá, and middle Serpis.

At the outset of this discussion, we want to make clear that we are not implying that each valley coincides with the range of a distinct prehistoric social group. In reality, of course, a single forager community could easily have used all four of the valleys discussed here, and even more sedentary Neolithic communities probably made use of areas larger than one of these valleys. Or more likely, each valley formed only a part of the territory of one or more distinct groups, and territorial boundaries shifted through time. However, the real social groups that actually existed in the past and the lands they actually occupied regularly at a particular point in time are extremely difficult to identify in the archaeological record. By focusing on landuse within observable geographic units, rather than social groups that disappeared millennia ago, we endeavor to build more accurate models of prehistoric human ecology and its dynamics in space and time.

LONG-TERM DYNAMICS IN FOUR VALLEYS

Neolithization, in effect, is the replacement of forager socioecosystems with one dependent on mutualistic relationships between humans and domestic plants and animals, especially where humans manage the reproduction and environment of domesticates (sensu Rindos, 1980, 1984). Given that neolithization began in many different regions across the globe in the first half of the Holocene and led to the replacement of virtually all forager socioecosystems in the second half, there would clearly seem to be some very general processes at work. This has encouraged archaeologists to seek principles that would explain the origins of food production on a worldwide scale. However, numerous archaeological studies also indicate that the transition from foraging to food production has taken place at different rates and in different ways in different parts of the world. As Flannery (1986) and Rindos (1980, 1984) point out, this process can be complex and indirect involving a changing web of task scheduling and associated costs and benefits of using different suites of wild and domestic resources. Both authors also note that the implications of neolithization for other aspects of human society can be as indirect as they are far reaching.

Building on this work, we agree that general evolutionary processes drive neolithization but that the outcomes of these processes are highly contingent on the socioecological contexts in which they operate (Bettinger, 1991, pp. 213–224). The transition from foraging to food production always takes place in the context of specific human societies with a history of use of particular landscapes that have their own suite of physical and biological characteristics that, in turn, are shaped in part by human societies. With marked environmental diversity over small distances, a very long and varied human history, and single suite of domestic plants and animals during the initial spread of agro-ecosystems, the Mediterranean is an excellent region in which to evaluate the extent to which historical and spatial contingency affect the outcomes of the processes of neolithization and of socioecological change more generally.

Landuse Ubiquity

In order to establish a baseline for monitoring the Neolithic transition in geographic and historical context, we examine changing aspects of the spatial configuration of human activities across four valleys from the Middle Paleolithic through the Neolithic II. One measure of spatial configurations of socioecosystems is the ubiquity (or total spatial extent) of landuse through time. We assess this by looking at the amount of land area with artifact accumulations that can be assigned with reasonable confidence to each of the five time periods we use here. Because the amount of land covered by survey has varied in each valley, extent of land area is displayed as a percent of area surveyed. Table II and Fig. 3 display considerable variation among the valleys in the ubiquity of landuse at different times.

Evidence of Paleolithic presence in the Penaguila valley is rarer than in any of the three other valleys discussed here. Less than 3% of the area surveyed displays the highest probability of Paleolithic occupation (TI $= 0.09$), less than 10% displays less convincing evidence (TI ≥ 0.7) of Paleolithic presence. On the other hand, evidence for Neolithic occupation is found across more of the area surveyed in the Penaguila than in the other valleys (TI ≥ 0.7 for 50% of the

Table II. Neolithic Vs. Paleolithic[a]: % of Area Surveyed for Temporal Index (TI) = 0.9 and 0.7

Valley	Phase	TI = 0.9	TI = 0.7	TI ≥ 0.7[b]
Penaguila	Neolithic	27.18%	23.22%	50.40%
	Paleolithic	2.59%	7.72%	9.84%
Polop Alto[c]	Neolithic	1.98%	27.74%	29.71%
	Paleolithic	3.64%	17.55%	17.55%
Alcalá[c]	Neolithic	8.06%	30.80%	38.86%
	Paleolithic	5.35%	9.16%	14.51%
Muro	Neolithic	5.46%	5.98%	11.45%
	Paleolithic	4.62%	9.89%	14.51%

[a]Includes Middle and Upper Paleolithic and excludes final Paleolithic/Mesolithic.
[b]May differ slightly from sum of other two columns because of way in which TI and SII are calculated independently for each survey patch.
[c]Random sample patches used for area calculations.

areas surveyed). The strongest evidence of Neolithic presence (TI = 0.9 for both Neolithic I and Neolithic II) is also widespread, occurring over 3–10 times more land area than in the other valleys. On the other hand, evidence for Paleolithic is more common in the Polop Alto than in the other valleys (TI ≥ 0.7 across nearly 18% of the area surveyed), whereas Neolithic landuse is less evident than in any other valley except the Muro survey area of the middle Serpis. Even though evidence for undifferentiated Neolithic landuse (TI = 0.7) is present over 27% of the land surveyed, clear signals for either Neolithic I or Neolithic II (TI = 0.9) are found on less than 2%. Furthermore, evidence for terminal Paleolithic use of the Polop Alto is rare, but is much more common in the Penaguila.

The Alcalá and middle Serpis valleys present yet different patterns. The Alcalá bears some similarities to both the Penaguila and Polop Alto patterns. As in the Polop, the Middle and Upper Paleolithic is fairly well represented while the final Paleolithic/Mesolithic is extremely rare. On the other hand, Neolithic artifacts—especially Neolithic II—are found over much of the valley (nearly 40% of the area surveyed). Nonetheless, the clearest signals of Neolithic landuse are still considerably less common than in the Penaguila. The Muro area of the middle Serpis shows a pattern of Paleolithic occupation very similar to that of the Alcalá valley, though with more coverage by final Paleolithic/Mesolithic materials. Clear evidence for both Neolithic I and II is present, like in the Penaguila and unlike the Alcalá and Polop Alto valleys, where Neolithic I evidence is less certain. However, evidence for Neolithic occupation overall appears to be much rarer than in any of the other three valleys.

Overall landuse ubiquity measures across these valleys indicate the most extensive Paleolithic presence (not including the final Paleolithic/Mesolithic) in the Polop Alto, and the least in the Penaguila. On the other hand, the Neolithic is present most extensively in the Penaguila and apparently rarest in the Muro

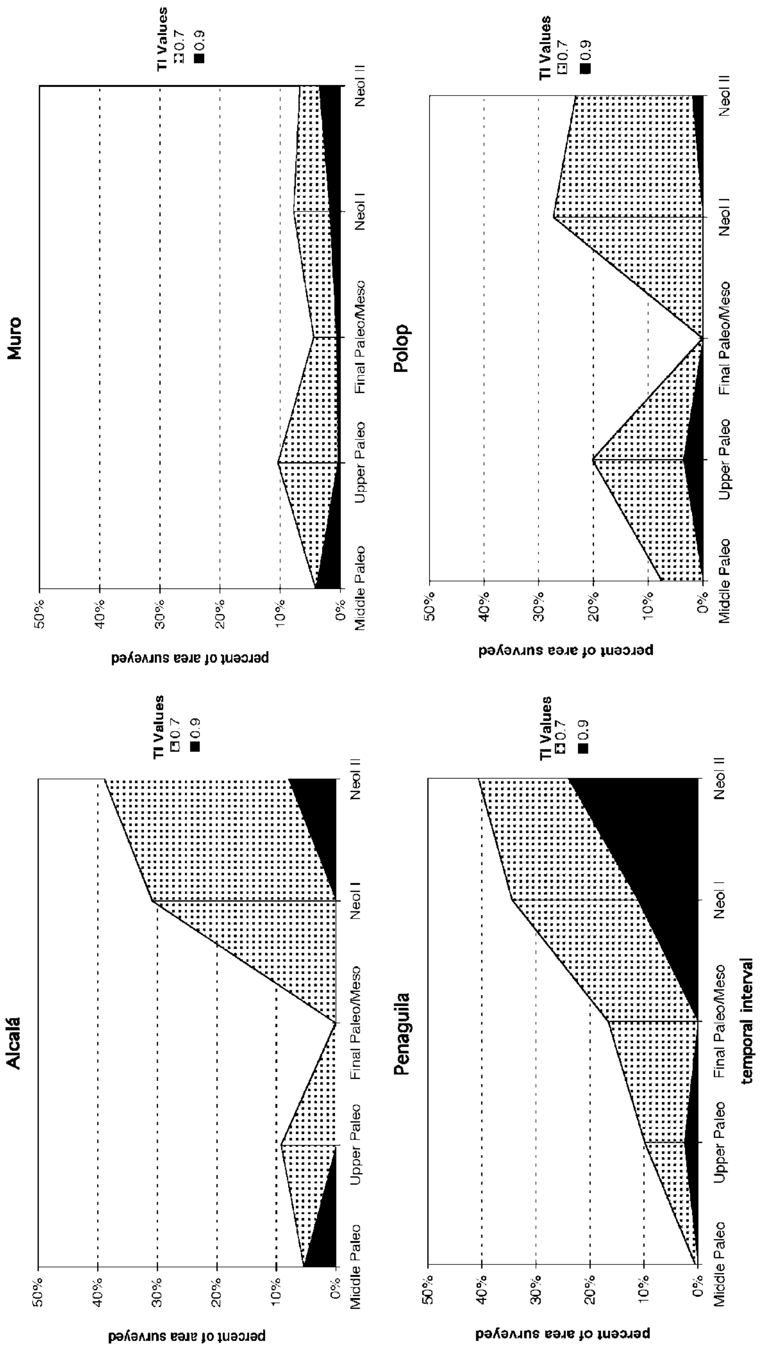

Fig. 3. Ubiquity of landuse for each chronological phase in each valley, measured as percent of land surveyed with Temporal Index (TI) values of 0.7 and 0.9.

area of the middle Serpis (but see below), although the Polop Alto shows the least coverage by patches with the clearest signals for Neolithic occupation.

Landuse Intensity

Although ubiquity measures spatial and temporal variation in the human *presence* in this region, human *activities* and the *intensity* of human use of the landscape also vary across space. In this respect, a measure that incorporates spatial variation in landuse intensity provides a different but complementary dimension for modeling prehistoric socioecosystems. By incorporating artifact accumulation density, SII serves as proxy for landuse intensity (Barton *et al.*, 1999). However, material culture accumulates over time, and long accumulation times can mirror intensive landuse in terms of artifact density on the modern landscape. For this reason, we scale SII measures by the length of each time period used in the analysis here (40 millennia for the Middle Paleolithic, 20 for the Upper Paleolithic, 7 for the final Paleolithic/Mesolithic, 1 for the Neolithic I and 1.4 for the Neolithic II). Figure 4 and Table III show the total spatial extent (standardized to percent of area surveyed) of patches with the highest of landuse intensity per millennium for each time period (i.e., those with SII values in the upper quartile).

Not surprisingly, Neolithic landuse appears more intensive than Paleolithic landuse. Given that total accumulation is scaled by time span, this also indicates that artifact accumulation rates are considerably more rapid during the Neolithic than in the Paleolithic. This is shown even more clearly in Fig. 5. Lithic accumulation rates vary by factors of 10–100 between the Paleolithic and Neolithic for patches with the highest SII values.

Patches with the highest intensity of landuse (SII in 90th percentile) for the Neolithic are most frequent in the Penaguila and Polop Alto valleys (at 3.49 and 4.63% of the areas surveyed respectively). On the other hand, the Alcalá shows the most extensive landuse of lower intensity (SII in the 75th–90th percentile) of the four valleys. Also, both the Penaguila and Polop Alto show a pattern of markedly greater areas occupied by intensive Neolithic I occupation than by Neolithic II occupation, while this trend is less notable (and even reversed for patches with SII in the 90th percentile) in the Alcalá and Muro areas. Although temporally weighted SII coverage is very low for the Paleolithic in all valleys (indicating low accumulation rates over long time periods), the Polop Alto shows the greatest extent of intensive Paleolithic landuse—mirroring the ubiquity evidence.

Landuse Organization in Space and Time

Both ubiquity and intensity measures considered above compare total human landuse for each valley. However, not only can landuse intensity vary, but the

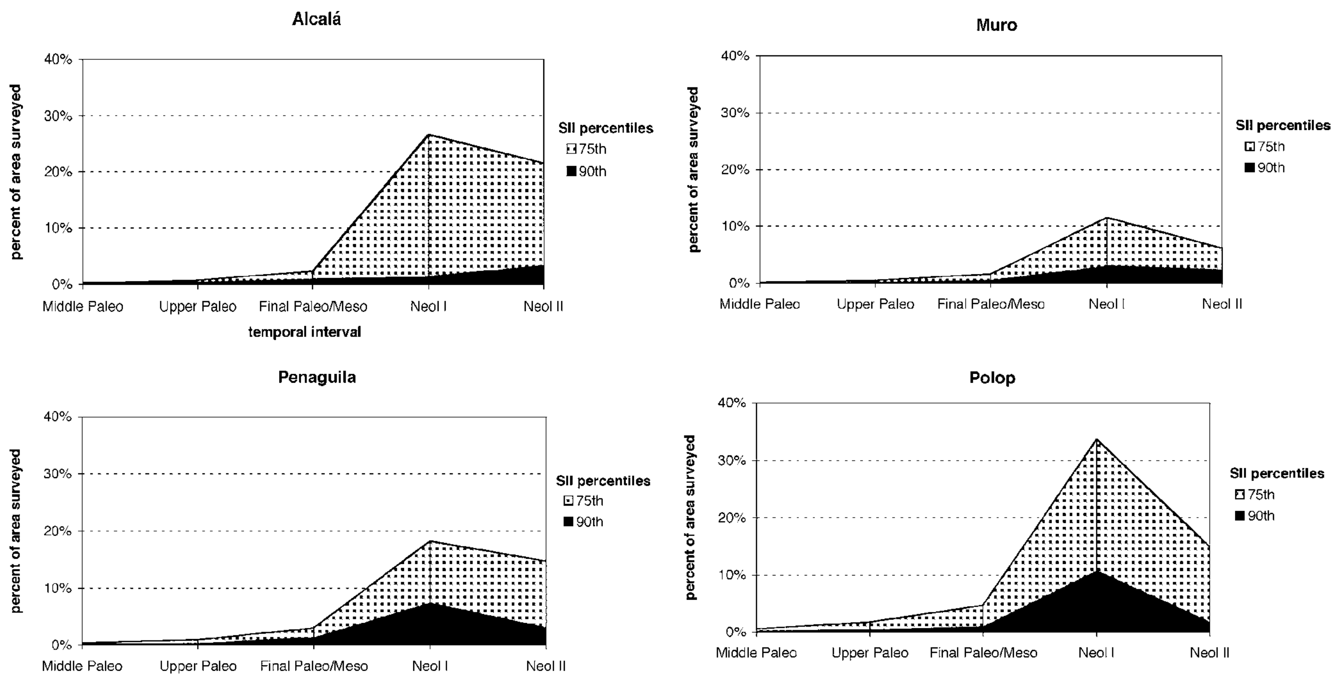

Fig. 4. Areal extent of different levels of landuse intensity, measured by Settlement Intensity Index (SII) values in the 50th–90th percentiles, for each temporal phase in each valley.

Table III. Neolithic Vs. Paleolithic[a]: % of Area Surveyed for Settlement Intensity Index (SII) in Square Kilometers Per Millennium

Valley	Phase	SII percentile		
		90th	75th–90th	Upper quartile[b]
Penaguila	Neolithic	3.49%	11.23%	13.21%
	Paleolithic	0.18%	0.21%	0.31%
Polop Alto[c]	Neolithic	4.63%	8.32%	8.82%
	Paleolithic	0.13%	0.37%	0.47%
Alcalá[c]	Neolithic	2.52%	12.54%	12.54%
	Paleolithic	0.20%	0.19%	0.32%
Muro	Neolithic	2.65%	2.94%	4.01%
	Paleolithic	0.11%	0.12%	0.19%

[a]Includes Middle and Upper Paleolithic and excludes final Paleolithic/ Mesolithic.
[b]May differ slightly from sum of other two columns because of way in which TI and SII are calculated independently for each survey patch.
[c]Random sample patches used for area calculations.

spatial configuration of landuse patterns varies as well. For example, even though evidence for Neolithic occupation in the Penaguila valley becomes increasingly common through time, the total area of most intensive landuse decreases from the Neolithic I to Neolithic II. Furthermore, it is clear that the ratio of more intensive (SII in the 90th percentile) to less intensive (SII in the 75th–90th percentile) landuse is much lower in the Alacalá than in any of the other valleys and especially in comparison with the Penaguila and Muro areas.

In addition to providing a means to quantify landuse characteristics in a systematic fashion, GIS also serves as a powerful tool for visualizing spatial patterning. We have used GIS in this way to construct models of prehistoric landuse in all the valleys studied. Figure 6 shows two of these models for the Upper Paleolithic and Neolithic II of the Polop valley. The maps model the spatial distribution of SII for each period,[4] illustrating two additional dimensions of spatial and temporal variability in prehistoric landuse observed throughout the region. First, landuse varies through time in its spatial *dispersion*. In Fig. 6, Upper Paleolithic landuse is more dispersed (many small "peaks") while Late Neolithic landuse is much less so (mostly clumped in a single large "peak"). Second, the degree of *persistence* in landuse at any give local may vary though time. In Fig. 6, the most intensive landuse is observed at different locales in the Upper Paleolithic and Late Neolithic. Such variability in dispersion and persistence characterizes

[4]These models are a more sophisticated presentation of the data used to create landuse models in previous work (Barton *et al.*, 1999). In Fig. 6, a set of 1000 randomly-selected points were distributed across the survey area. SII values were assigned to the points according to their location relative to study patches used to derive the SII values. Points near the edges of patches were assigned interpolated values based on SII values of surrounding patches. The point set was used to produce an interpolated landscape using a regularized spline tension algorithm (Neteler and Mitasova, 2002)

the long-term dynamics of landuse throughout this region and comprises a further set of key parameters for evaluating contingency in these landscapes.

Local density analysis (Johnson, 1984; Kintigh, 1990), based on this modeling, serves to summarize landuse dispersion across the valleys and time periods considered here (see also Barton *et al.*, 1999). As shown in Fig. 7, 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 from its peak across "neighborhoods" of increasingly large radii. Because the local density coefficient values (*y*-axis on the graphs) 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. Hence, we have scaled the graphs in Fig. 7 to the maximum coefficient value for each valley rather than keeping a constant scale.

The Alcalá valley represents one extreme with respect to dispersion measured in this way. LDA curves for all time periods peak at small neighborhood radii and rapidly falloff to their minimum value. This is typical of a dispersed scatter of tiny landuse clusters. The Middle Paleolithic shows the most dispersed pattern, with a slightly lower peak and slightly faster falloff than the other curves. Notably, the Paleolithic and Neolithic curves are nearly identical. At the other extreme are the Polop Alto LDA curves. Middle Paleolithic though Neolithic I show a low peak, followed by a falloff over slightly larger radii than the Alcalá valley, but still indicating a generally dispersed pattern extending into a more continuous background. However, the Neolithic II is markedly different in the Polop Alto. It shows a much higher peak that declines across larger neighborhood radii than other temporal phases, reflecting the highly clustered distribution—and large primary cluster (ca. 500 m)—that characterizes this phase and can be seen visually in the map of Fig. 6(b). The Penaguila valley is similar to the Polop except that the Neolithic I curve parallels the Neolithic II curve, rather than the Paleolithic ones, and the Neolithic curves are less peaked relative to the others. In other words, intensive landuse is dispersed in the Paleolithic through Mesolithic, but changes to clustered with the Neolithic I—though perhaps not as clustered as in the Neolithic II of the Polop Alto. Finally, in the Muro area of the middle Serpis, Paleolithic through Mesolithic shows a similarly dispersed distribution, with the Neolithic I showing more clustering and evidencing clusters that extend in size over larger neighborhood radii. However, the Neolithic II curve parallels the more dispersed Paleolithic ones, rather than the Neolithic I curve.

Long-term persistence in landuse can be measured in various ways. Excavated sites throughout the study region display variable occupational persistence. For example, in the Polop valley, Cova de Salt only has Middle Paleolithic materials, while Cova de la Falguera contains artifact accumulations that span the Mesolithic through the Neolithic. In the Middle Serpis, Cova Beneito accumulated artifacts from the Middle Paleolithic through the Upper Paleolithic; Cova de l'Or contains

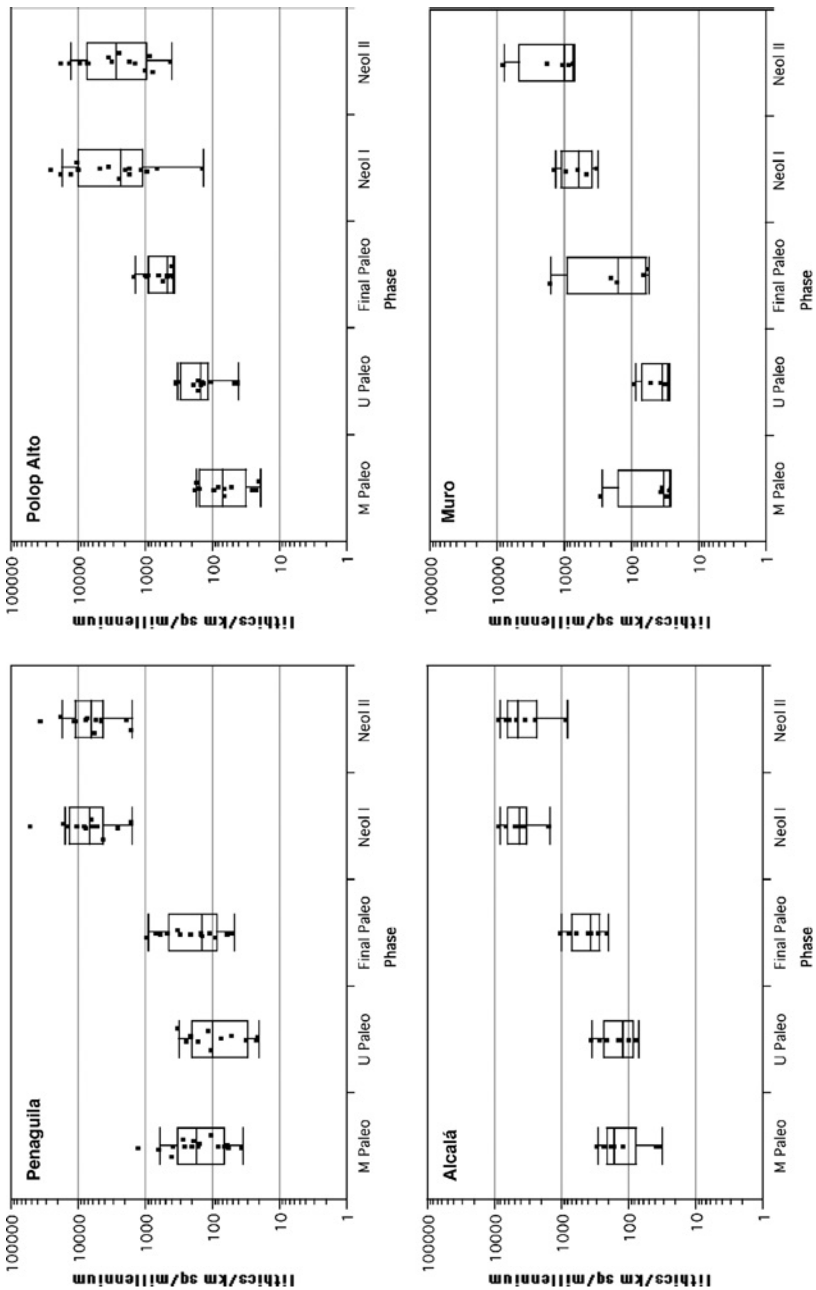

Fig. 5. Lithic accumulation rates, in pieces per kilometer squared per millennium, for each phase in each valley. Note log scale.

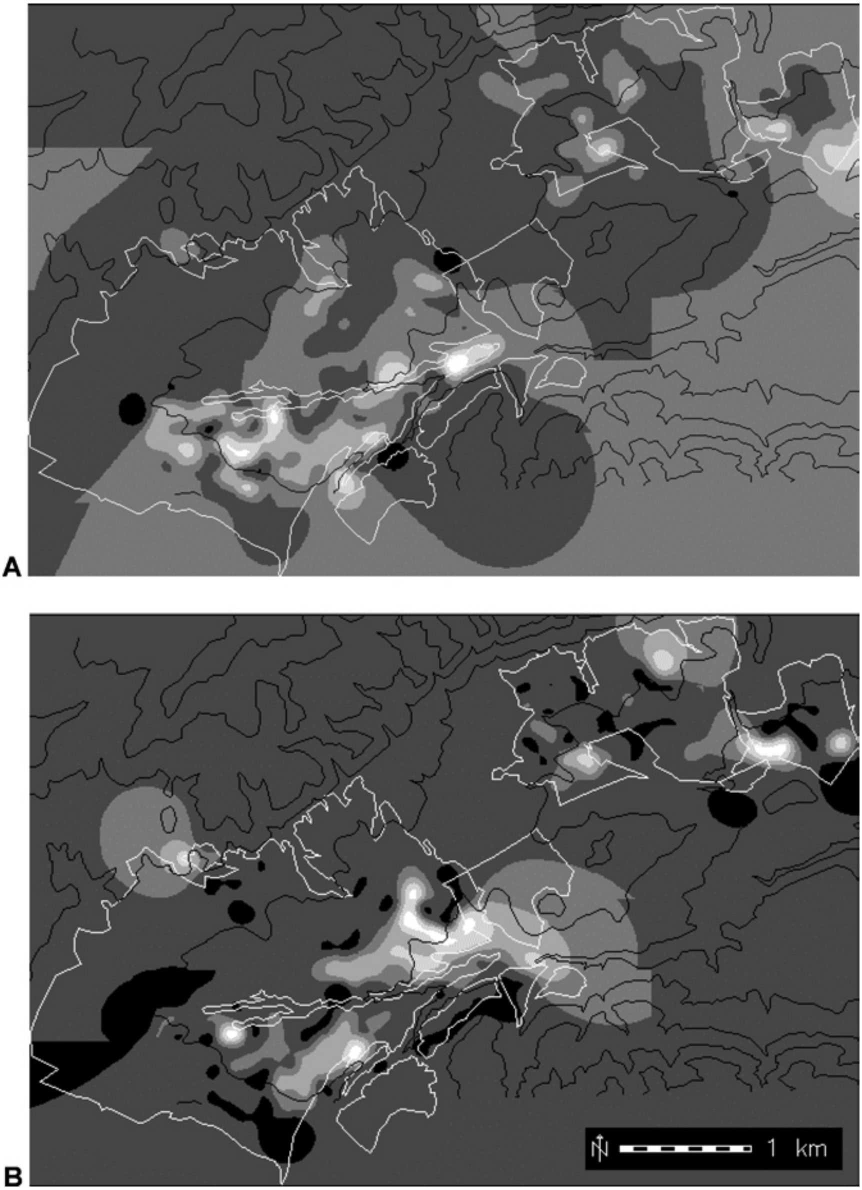

Fig. 6. Landuse dispersion for Upper Paleolithic (A) and Neolithic II (B) in the Polop Alto valley. Shading represents values of Settlement Intensity Index (SII) values for each temporal phase: higher values of SII are brighter and lower values are darker. 50 m contours of topography and outline of survey area shown.

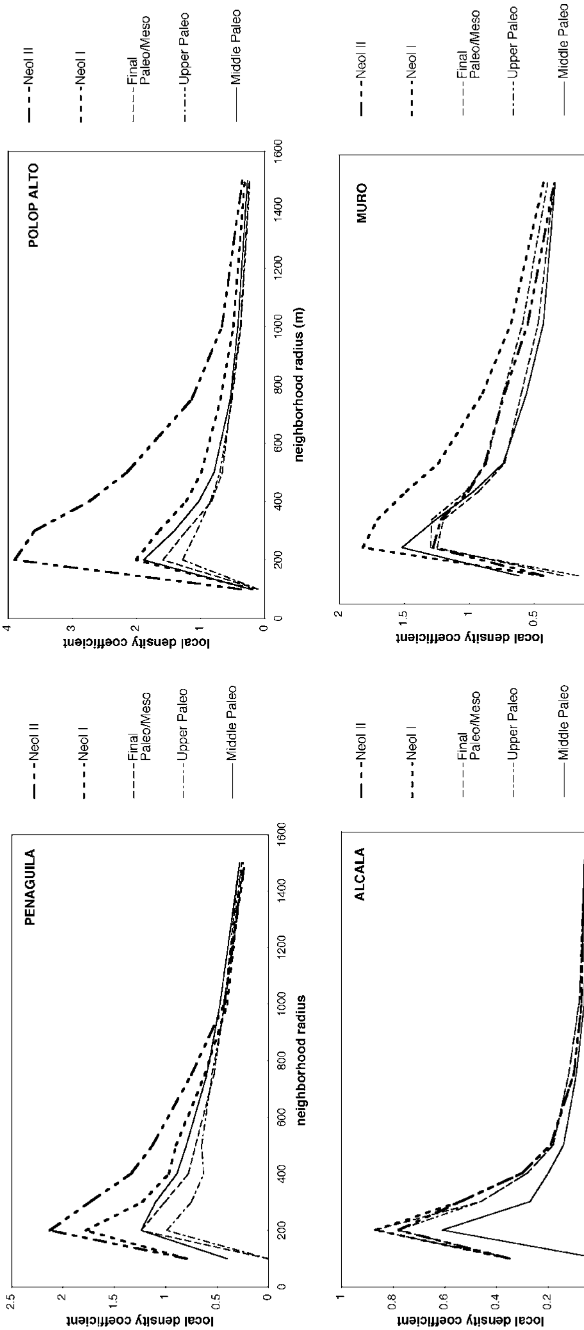

Fig. 7. Local density analysis for locales with Settlement Intensity Index (SII) in 90th percentile for each temporal phase.

Table IV. Persistence of Landuse for Patches in Upper Quartile for SII

Valley	M. Paleo	U. Paleo	Final Paleo/Meso	Neol I	Neol II
Alcalà					
Middle Paleolithic	*100%*	68%	68%	44%	44%
Upper Paleolithic	61%	*100%*	93%	44%	44%
Final Paleolithic/Mesolithic	59%	89%	*100%*	53%	53%
Neolithic I	31%	34%	43%	*100%*	100%
Neolithic II	28%	31%	39%	91%	*100%*
Muro					
Middle Paleolithic	*100%*	48%	82%	65%	61%
Upper Paleolithic	86%	*100%*	61%	33%	42%
Final Paleolithic/Mesolithic	72%	62%	*100%*	66%	53%
Neolithic I	52%	30%	59%	*100%*	49%
Neolithic II	78%	61%	77%	79%	*100%*
Penaguila					
Middle Paleolithic	*100%*	99%	99%	60%	79%
Upper Paleolithic	82%	*100%*	94%	49%	64%
Final Paleolithic/Mesolithic	72%	82%	*100%*	43%	56%
Neolithic I	50%	50%	50%	*100%*	39%
Neolithic II	58%	57%	57%	35%	*100%*
Polop					
Middle Paleolithic	*100%*	66%	65%	70%	70%
Upper Paleolithic	51%	*100%*	80%	45%	47%
Final Paleolithic/Mesolithic	52%	83%	*100%*	64%	66%
Neolithic I	59%	48%	66%	*100%*	93%
Neolithic II	62%	53%	72%	97%	*100%*

only Neolithic materials; open air locales of Niuet and Les Jovades are limited to Neolithic II occupations; Punxó has evidence of Epipaleolithic, Neolithic II, and Bronze Age use; and Encantada has accumulations of materials derived from the late Upper Paleolithic through Neolithic, with posible Middle Paleolithic materials a few 100 m away. However, it is difficult to assess landuse persistence in a systematic fashion across the study area from these individual locales.

At regional scales, persistence represents a form of spatial autocorrelation over time in GIS terms. Using GIS-derived landuse data described above, we present a simple measure of persistence across the four valleys in Table IV.[5] Each row indicates for the locales intensively occupied during each time period (row labels), the spatial extent of land also intensively occupied during other time periods. In the Penaguila valley, there is strong spatial persistence in landuse throughout the Paleolithic, with nearly all parts of the landscape with intensive Middle Paleolithic

[5]The values shown in Table IV closely parallel spatial covariance values that can be calculated in a GIS package such as GRASS or ArcView. However, we feel that simple percent overlap in the areal extent of study patches is easier to interpret for the nonspecialist in GIS. Note also that the values for the Polop Alto differ in a number of respects from those of a similar analysis presented earlier (Barton *et al.*, 1999) and based on somewhat different measurements of overlap. For a variety of reasons, we feel that the values presented here more accurately represent landuse persistence than those presented in the earlier work.

landuse also displaying similarly intensive landuse during the Upper Paleolithic and Epipaleolithic. Furthermore, only a small percentage of new locales were occupied during the Upper Paleolithic and Epipaleolithic (e.g., 82% of the land area with Upper Paleolithic landuse also shows evidence of Middle Paleolithic landuse). In the middle Serpis (i.e., Muro area), Upper Paleolithic landuse took place on a small subset of the locales occupied during the Middle Paleolithic (48% of the area occupied during the Middle Paleolithic continued to be occupied during the Upper Paleolithic, but 86% of area characterized by Upper Paleolithic landuse also shows evidence of equivalent Middle Paleolithic occupation). The Epipaleolithic displays a spatial shift in landuse, with a persistence of 61% from the Upper Paleolithic to the Epipaleolithic and 38% of the area with Epipaleolithic lacking occupation during the Upper Paleolithic. In both the Alcalá and Polop valleys, the Middle to Upper Paleolithic transition displays a corresponding shift in settlement, with 66–68% persistence but 39–49% of Upper Paleolithic landuse taking place in new locales. In both the Alcalá and Polop, there is much stronger persistence throughout the Late Pleistocene, from the Upper Paleolithic through the Epipaleolithic.

In all valleys, the Neolithic is accompanied by a spatial rearrangement of landuse. However, this shift is more marked in some valleys than in others. There is a considerable degree of persistence in landuse across the Epipaleolithic–Neolithic transition in the Polop and middle Serpis, but more striking spatial discontinuities in the Alcalá and Penaguila valleys. There are also notable differences in persistence among the valleys through the Neolithic. Both the Alcalá and Polop show extremely strong persistence from the Neolithic I to Neolithic II. In the middle Serpis, Neolithic II landuse appears to center on a limited subset of prior Neolithic I occupation (matching the pattern of the Middle–Upper Paleolithic transition in the same valley), while the Neolithic I and II occupations of the Penaguila valley show minimal overlap.

We may well ask to what degree are these persistence measures affected by long-term landscape taphonomy. Where variability in persistence is primarily due to landscape change, we would expect to find that locales with evidence of older landuse would be more likely to display evidence of subsequent landuse, but locales with more recent landuse would be less likely to show evidence of prior landuse (with artifacts accumulating on “new” surfaces from which earlier artifact accumulations had been removed by erosion or buried). That is, the values following the 100% value in each row should be generally higher than those preceding it. This seems to be the case for the Paleolithic of the Penaguila valley, and possibly to a lesser degree for the Paleolithic of the Alcalá and Polop valleys. On the other hand, taphonomic factors alone do not seem to account for variation in persistence measures for the Paleolithic of the middle Serpis, or differences between the Paleolithic and Neolithic and between the Neolithic I and II in any of the valleys.

DISCUSSION: LONG-TERM SOCIOECOLOGY AND CONTINGENT LANDSCAPES

Pleistocene Socioecosystems

This suite of field and analytical protocols permit us to examine long-term dynamics in several different dimensions of prehistoric socioecosystems in eastern Spain. Measures of occupational ubiquity, landuse intensity, and the spatial dispersion and temporal persistence of landuse provide basis to develop models of changing socioecosystems within this region. In building these models, we also incorporate other forms of evidence from survey and excavation.

Paleolithic landuse throughout the region is characterized by a low intensity, spatially dispersed pattern—small loci of intensive landuse that are rather evenly distributed across the landscape, within a relatively continuous "background scatter" of behavioral residues. This distribution pattern probably also accounts for much of the comparatively high degree of landuse persistence that generally characterizes the Paleolithic across the valleys. Such an accumulation pattern is expected from sporadic use of the landscape by small bands of hunter–gatherers, whose use of the landscape can be described by "patch-choice" ecological models (Kelly, 1995) and dominated by residential mobility (sensu Binford, 1980). With comparatively low mobility costs, locales of human resource acquisition would have shifted regularly over time to avoid temporarily depleted patches and take advantage of changing configurations of the most productive resource suites. This, along with small human group size, mean that human impact on biota was limited both in spatial extent and reduction in plant or animal numbers, producing a patchwork of small locales in various states of recovery from human use. Probably only anthropogenic fire regimes could have altered the landscape at regional scales. However, while there is evidence of fire-related landscape changes by prehistoric hunter–gatherers elsewhere (Anderson and Smith, 1997; Barton *et al.*, 2004; Bush, 1988; Pyne, 1998; Webb, 1998), currently there is no direct evidence for such ecological manipulation in the study region during the Pleistocene. Since most plant or animal taxa could not differentially benefit from human interaction, due to fleeting, nonrecurrent use in any particular locale, human interaction with plants and animals could be better characterized as predatory rather than mutualistic (sensu Rindos, 1980, 1984).

Within this overall Paleolithic socioecological configuration, there is some limited, but potentially important variation among the four valleys. In the Alcalá valley, local density measures suggest that Paleolithic occupation was more sporadic than in any of the other valleys. In the Polop Alto, however, both ubiquity and landuse intensity measures indicate that this valley was more heavily and/or more regularly occupied by Paleolithic humans than any of the other three valleys.

Both the Alcalá and middle Serpis show drops in landuse ubiquity across the Middle–Upper Paleolithic transition. In the middle Serpis, this is also accompanied by a decline in artifact accumulation rates and marked restriction in occupation area (as indicated by landuse persistence values). It is unlikely that the larger, lower, and biophysically more diverse middle Serpis valley was abandoned during the Upper Paleolithic while the smaller and higher Polop and Penaguila valleys remained occupied. More likely, this represents a change to landuse focused in more spatially restricted areas. This is consistent with the persistence data and with LDA measures of dispersion. If this interpretation is correct, it marks the beginning of a more nucleated landuse pattern that has characterized the middle Serpis for most of its subsequent history. Dispersion measures and lithic accumulation rates suggest very low intensity, highly dispersed landuse for the Upper Paleolithic in the Polop and Penaguila valleys—more so than for the Middle Paleolithic—while the Upper Paleolithic in the Alcalá seems characterized by sporadic, tiny occupational loci. In human behavioral terms, whether this indicates a shift to overall greater residential mobility across the region, or whether it reflects some degree of central place foraging—centered in the larger middle Serpis with ephemeral special activity sites in the higher Polop and Penaguila—remains unclear. However, across Valencia, the late Pleistocene sees the beginning of a regional trend toward reduced residential mobility, with more intensive and efficient exploitation of local resources (Aura Tortosa *et al.*, 2002). In this context, lithic evidence from Cova Beneito in the middle Serpis suggests reduced residential mobility for the Upper Paleolithic in comparison with the Middle Paleolithic at this site (Villaverde *et al.*, 1998).

Evidence for human landuse across the Pleistocene/Holocene transition is difficult to evaluate in any of the valleys. Clear evidence of human presence at this time is only found in the Muro area, where patches with $TI = 0.9$ comprise only 0.7% of the area surveyed, and is lacking elsewhere. Part of the problem is that surface assemblages from this time period are difficult to differentiate from Upper Paleolithic or Neolithic I assemblages, with temporally diagnostic microliths difficult to recover during pedestrian survey in agricultural fields. Furthermore, these small, backed lithic components of compound tools range temporally from the late Upper Paleolithic through the Neolithic I (and in the case of use of the microburin technique, may extend into the Neolithic II). Nevertheless, landuse intensity measures suggest a human presence across the region during this time. This is corroborated by assemblages of this age recovered in recent excavations at the open air localities of Encantada (García Puchol and Barton, 2001), Albufera de Gaianes, and possibly Alt del Punxó (with a new radiocarbon date of 9348 ± 61 bp [AA57440]) in the valley. In other valleys, Cova de la Falguera, in the Polop Alto, and Tossal del la Roca, located at the outlet of the Alcalá, also contain assemblages of this age. However, no settlements clearly ascribed to this time have yet been identified in the Penaguila valley.

Previously, we suggested that a subtle, but significant change in the spatial configuration of landuse in the Polop Alto took place around the Pleistocene/Holocene transition that involved a shift toward fewer spatial clusters of recurrent or longer duration landuse (Barton *et al.*, 1999, 2002). We suggested that this might represent a more logistical resource acquisition and settlement strategy than seen in the Upper Paleolithic. This pattern also shows up in Fig. 5 as a marked jump in artifact accumulation rates (by a factor of 10) for the final Paleolithic. Such a final Paleolithic/Mesolithic jump in artifact accumulation rates is not apparent in the Penaguila. There is a slight increase in accumulation rates in the Alcalá valley and a more convincing one in the Muro area of the middle Serpis. The middle Serpis also sees a marked change in the locations of landuse at the end of the Pleistocene, as indicated by the persistence data.

Beyond the Polop Alto, analyses of excavated faunal collections suggest that the late Paleolithic sees an increase in intensive human use of fewer taxa, an increase in the use of small game, and the regular use of smaller geographic ranges by human groups (Aura Tortosa *et al.*, 2002; Bernabeu *et al.*, 2001; Villaverde *et al.*, 1998). Where seen most clearly, this final Paleolithic pattern suggests more intensive, recurrent or longer use of particular locales on the landscape. In these areas, the impacts of human activities would be more dramatic and longer-lived than seen in the Paleolithic configuration described above. Plant and animal resources would be at greater risk of depletion, while intensive plant and seed harvesting, and use of woody plants for fuel and construction materials could alter floral community structures locally. More regular and intensive use of parts of the landscape increase selective pressures on both plants and animals and the humans that used them. Some taxa would have opportunities (at the expense of other taxa) to develop increasingly mutualistic relationships—rather than predator/prey—with humans (sensu Rindos, 1980, 1984). Where such socioecological configurations are well established and successful, with predictable resources and a mix of predatory and mutualistic interactions with other taxa, humans could be expected to exercise increasingly proprietary control over geographic territory (Kelly, 1991; Smith, 1988). Nevertheless, this change in spatial configuration across the Pleistocene/Holocene boundary noted in the Polop Alto is variably expressed across the region.

In sum, evidence for both the Alcalá and Penaguila valleys indicate hunter–gatherer socioecosystems characterized by low-density, dispersed landuse, and probably associated with high residential mobility. A similar socioecological configuration characterizes the Polop for much of the Pleistocene. But at the end of the Pleistocene, the Polop system appears to reconfigure toward a less dispersed pattern that may signal a shift toward central-place foraging. Evidence from the middle Serpis suggests a similar shift in socioecosystem structure occurred earlier in late Pleistocene (i.e., Upper Paleolithic). The high potential for taphonomic alteration of the Pleistocene archaeological record, coupled with the generally low artifact accumulation rate of these hunter–gatherer systems makes interpretation difficult. However, these differences among the valleys remain important for understanding the subsequent socioecological dynamics of Neolithization in the region.

Holocene Socioecosystems

The appearance of Neolithic socioecosystems shows even greater variation across the study region than do earlier systems. In the Penaguila, the Neolithic I marks a dramatic change in spatial patterning of accumulations of human behavioral residues and, hence, probably a correspondingly significant change in the systems that produced them. Neolithic landuse is both much more extensive and more intensive than during the Paleolithic through the Mesolithic. Neolithic artifacts are found on five times more area than Paleolithic ones (Table II, Fig. 3) and artifact accumulation rates jump by a factor of 100 or more (Fig. 5). Neolithic landuse is also notably more clustered, and intensively occupied locales are larger than for the Paleolithic (Fig. 7). Corroborating the landuse changes indicated by the survey data is the nucleated Neolithic I settlement of Mas d'Is with monumental earthworks in the form of a series of very large ditches (>4 m deep, >10 m wide, and over 150 m long) that stands in marked contrast to the lack of known pre-Neolithic localities in the valley (Bernabeu Auban *et al.*, 2003). These structures (we have discovered another one at the Neolithic II site of Alt del Punxó) represent an enormous human labor investment in the modification of a very limited part of the landscape.

This combined evidence indicates that the Neolithic brought a significant change in human socioeconomic organization and most likely in the ways humans interacted with the environment in the Penaguila. Agriculture seems to have made this valley much more attractive for human occupation, to the extent that the agricultural socioecosystem seems to have filled a nearly empty niche here. After the initial spread of Neolithic socioecosystems into the Penaguila, there appears little subsequent change in nature of landuse through the Neolithic II. An increase in the extent of landuse, indicated by ubiquity in Fig. 3, accompanied by a slight decrease in the area occupied by the most intensive landuse (Fig. 4) suggests a trend toward increasing human use of the Penaguila landscape but with the focus of human activities taking place in slightly smaller areas. This would be consistent with a growing, but more sedentary population. Of interest are the persistence data indicating that the locations of landuse during the Neolithic II were distinct from those of the Neolithic I. In other words, while maintaining the new agricultural way of life across the Neolithic I and Neolithic II, it was necessary to shift the focus of human settlement to different locations within the valley.

This is in marked contrast to the agricultural transition in the Polop. In many respects, as we have discussed in detail elsewhere, Neolithic I landuse patterns bear more resemblance to those of the final Paleolithic/Mesolithic than to the subsequent Neolithic II (Barton *et al.*, 1999, 2002). Landuse ubiquity is roughly equivalent between the Paleolithic and Neolithic (Fig. 3). Although there is evidence for more intensive landuse in the Neolithic I (Fig. 4), the spatial organization of landuse changes little (Fig. 7). Moreover, Neolithic I artifact accumulation rates overlap both the final Paleolithic/Mesolithic and Neolithic ranges, although they are more variable than either (Fig. 5). Combined, these data indicate that the initial Neolithic continued many aspects of the socioecology of the terminal Pleistocene and early Holocene.

In human terms, two models for these patterns suggest themselves. The first involves logistically organized foragers who incorporated selected domesticates into a subsistence economy already characterized by a mix of predation and mutualism in human relationships with plants and animals. This also would involve a limited degree of landscape manipulation (either unintentionally though more intensive use of particular plants and animals in restricted geographical areas, or intentionally by activities such as planned burning or culling) that enhanced the productivity of selected subsistence resources. In this respect, it is noteworthy that Cova de la Falguera, in the Polo Alto, was used by both Mesolithic and Neolithic people, (although there is currently a gap of over 500 years between radiocarbon dates for the latest Mesolithic and earliest Neolithic occupations of the rock shelter).

The second model is that the Polop became a frontier zone between agriculturalists—perhaps settled primarily in the Serpis or Penaguila valleys—and populations maintaining a foraging economy—possibly centered in the neighboring Vinolopó valley to the northwest (where several Mesolithic locales are reported around the former Laguna de Villena). If the valley represented a contested (or at least ambiguously controlled) landscape, Neolithic farmers could have been limited to periodic pastoral forays into the Polop producing an archaeological record similar to that of logistic foragers.

Unlike the situation in the Penaguila, a significant change in landuse is seen across the Neolithic I/II transition in the Polop Alto, where it is reflected mainly in a spatial reorganization of settlement into a tightly clustered or nucleated configuration (see Figs. 5(b) and 6). We interpret this as indicating a shift away from a pattern of landuse that began in the terminal Pleistocene as central-place foraging and extended into the early Neolithic in spite of the appearance of domesticates, toward the more sedentary farming hamlets that also characterize settlement in the Penaguila from the Neolithic I onwards. While the end result of agricultural socioecosystems replacing both dispersed and logistically organized forager systems was the same for the Penaguila and Polop, the human inhabitants of these valleys followed different paths to reach these ends. Interestingly, this organizational shift in the Polop is *not* accompanied by a corresponding shift in the locations of landuse. That is, as opposed to the Penaguila, the way of life changed in important ways for the Neolithic inhabitants of the Polop, but the spatial focus of their activities did not. These differences, discussed more below, are the reciprocal results and causes of long-term variation in the human use of these valleys.

In the Alcalá valley, we see yet another pattern; there seems very little change in the way the valley was used from the Paleolithic all the way through the Neolithic II. Areas with artifactual indications of human presence become much more common with the Neolithic (Fig. 3), but still are characterized by extensive, low intensity landuse (Fig. 4). Similarly, artifact accumulation rates increase on patches representing the most intensive Neolithic landuse (Fig. 5), but the spatial patterning of landuse remains as dispersed in the Neolithic as it is in the Paleolithic (Fig. 7). However, while there is strong spatial persistence in landuse within the Paleolithic and Neolithic, there is a dramatic break in the locations of most intensive landuse with the beginning of food production in this valley. In terms of human subsistence activities, this may simply indicate a shift from mobile hunting to mobile herding, utilizing different locales within the valley, but with little permanent settlement in either case.

Finally, the Muro area of the middle Serpis portrays a dynamic that is again different from the other three valleys. Landuse ubiquity changes little from the Paleolithic through the Neolithic (Table II, Fig. 3) and only the Alcalá has a lower total area of most intensive landuse across the Paleolithic/Neolithic transition (Table III, Fig. 4). Persistence data indicate a modest shift in settlement locales from the end of the Pleistocene to the beginning of the Neolithic, on par with the values seen in the Polop. Also like the Polop, artifact accumulation rates show the biggest jump with the final Paleolithic/Mesolithic, where they also show the greatest variation of all time periods (Fig. 5). However, unlike any of the other valleys, artifact accumulation rates also show a marked increase from the Neolithic I to the Neolithic II.

On the other hand, there is better evidence for Neolithic I occupation in the middle Serpis than in either the Polo Alto or Alcalá valleys, and it shows a notably more clustered spatial pattern than the preceding temporal phases (Fig. 7). Furthermore, the well known Neolithic I cave site of Cova de l'Or is located here, with evidence of domestic cereals and ovicaprids. In sum, this suggests that this area falls somewhere between the processes of Neolithization described for the Penaguila and the Polop Alto—perhaps indicating a socioecosystem that incorporated a wider diversity of human–environment interaction than either of the other two valleys.

Surprising is the lack of strong evidence for Neolithic II landuse within the Muro survey area proper. All measures considered here, except artifact accumulation rates and persistence, indicate a return to a socioecological pattern more typical of the Paleolithic than the Neolithic. This apparent reversal may be more an artifact of recent than Neolithic landuse, however. Unlike the other four valleys, much of the central part of the middle Serpis valley is heavily urbanized, precluding systematic survey in the very areas most likely to be attractive to Neolithic farmers. In fact, three Neolithic II sites—at least one very large—have been excavated near the Muro survey area. These are the previously mentioned settlements of Niuet, Punxó, and Les Jovades. The excavated part of Nieut suggests that it was a substantial domestic settlement, with houses, storage pits, and a surrounding dike (Bernabeu *et al.*, 1994); Punxó also has an enormous ditch that appears at least as large as those of Mas d'Is (Barton, personal communication, 2003); and the surviving part of Jovades is primarily a field of over 100 very large bell-shaped storage pits that would have supported a large sedentary settlement (Bernabeu, 1993; Pascual Benito, 1989). If this area could have been surveyed systematically, it would likely show dramatic increases in landuse intensity, artifact accumulation rates, and landuse clustering for the Muro area during the Neolithic II.

Contingent Landscapes

The dynamics of late Quaternary socioecosystems—especially the replacement of forager systems with agricultural ones—varied considerably across the four valleys considered here, even though all fall within a 20-km radius and are generally similar in biophysical character. However, there are some differences—primarily in valley size and elevation. For example, the middle Serpis is the largest, the Penaguila and Polop Alto intermediate in size, and the Alcalá valley is the smallest. Similarly, the middle Serpis is the lowest and the Polop Alto the highest of the valleys. The largest and most intensive Neolithic II settlement of the four valleys seems to be in the middle Serpis; the least intensive in the Alcalá. It is possible that while there was sufficient arable land to support substantial populations of sedentary agriculturalists in the middle Serpis, the Alcalá valley was simply too small to sustain more than short-term occupation. However, the Alcalá also was the least intensively occupied of the valleys during the Paleolithic—even when valley size is taken into account—suggesting that extent of arable land is not the only explanation for the differences between this valley and the middle Serpis. Whatever factors limited human use of the Alcalá valley in the Neolithic, they also extend back into the Pleistocene. Similarly, valley size does little to explain the early and sudden appearance of an agricultural socioecosystem in the Penaguila and its lack in the larger Polop Alto valley, nor does elevation, as these two valleys differ only by 200 m at the most. While the Polop may experience a slightly shorter growing season, cereals are cultivated successfully in both valleys today. Hence, these biophysical differences do not appear sufficient of themselves to account for the range socioecological variation noted in the four valleys.

Because landscapes are the cumulative products of the operation of socioecosystems in the physical world, humans must always contend with (and frame their decisions in the context of) the outcomes of their predecessors' behaviors. In this sense, the intertwined social and natural landscapes that are the context of human societies are contingent on socioecological history as well as the physical conditions under which this history took place. For example, the Penaguila seems to have lacked a substantial population of pre-Neolithic foragers, meaning that Neolithic agricultural systems faced little competition from forager systems. Moreover, agriculture seems to have been a considerably more productive strategy in human terms than foraging, further favoring managed agricultural ecosystems over extractive foraging ones. Landscape alteration by farming communities—including forest clearance, ovicaprid grazing, and fuelwood collection—would have made the valley even less attractive to foragers, further increasing the selective advantage of farming. Such alteration may have also made the locales in which farming was most successful initially less attractive for subsequent Neolithic farmers. Persistence data indicate a marked spatial shift in the locations of most intensive landuse between the Neolithic I and II. Today, the valley is highly eroded, with the archaeological record of Neolithic and prior landuse confined to uneroded remnant surfaces that comprise a fraction of the valley's total area. In other words, the unattractiveness of the valley for Pleistocene and Holocene foragers enhanced its attractiveness for agriculturalists early on. However, the early success of agriculture here may have forced later farmers to shift their settlements to new locales as productivity declined in what was originally prime land.

This settlement shift may also signal an even more significant change in Neolithic socioecosystems than is apparent here in the landuse data alone. The Neolithic I in Valencia is characterized by intensive, hoe horticulture and ovicaprid husbandry in restricted areas of valley bottoms (Bernabeu Auban, 1995; McClure *et al.*, n.d.). The productivity of mixed agriculture in this setting encouraged increased dependence on a limited suite of agricultural products over wild plants and animals. However the nature and location of Neolithic I subsistence farming also posed significant risks of erosion for the fertile soils alongside drainages (McClure *et al.*, n.d.). The cycle of land clearance, tillage, conversion of fields with declining productivity to ovicaprid grazing, and new land clearance exposed increasing areas of Holocene alluvium to the erosional effects of winter rains following the summer drought of the Mediterranean climate. The cumulative effects of such landscape transformation would favor the continued clearance of new valley-bottom locales over a system of fallowing, amplifying landscape degradation due to Neolithic I agriculture. This eventually forced farmers into utilizing upland landscapes, away from the eroded valley bottoms.

Upland zones on Pleistocene terraces and alluvial fans were less immediately subject to valley-bottom erosion and entrenchment. However, the clay-rich *terra rossa* soils would have been harder to till with hoes and digging sticks, and less fertile than recent valley-bottom alluvium. Hence, upland farming was more costly in terms of labor needed to prepare larger tracts of land and the need for domestic animals for plowing, and required more extensive land use with fallowing to be sufficiently productive to support extant agricultural populations (McClure *et al.*, n.d.). As upland farming spread to increasingly steeper slopes, it also required the construction of terraces and other measures to control severe sheet erosion (van Andel *et al.*, 1990; van Andel and Zanagger, 1990). These higher costs favored population aggregation to pool resources to make the greater investments (e.g., shared draught animals and labor for terrace construction and maintenance), and new social organizations to manage the more complex labor needs and the more extensive and diverse agricultural lands. Monumental earthworks at Mas d'Is attest to the presence of such coordinated labor pools in the Penaguila (Bernabeu Auban *et al.*, 2003). Supporting these more extensive, complex socioecosystems required even greater agricultural production and favored new social mechanisms to distribute agricultural products in time and space. However, these new socioecosystems also put ever larger areas of land at risk of degradation, requiring increasingly intensive landscape management to maintain productivity (Butzer, 1996).

The middle Serpis presents a similar picture, though one made more complex by urbanization as mentioned above. There are many more Neolithic II settlements than Neolithic I settlements (especially open-air localities) known from the middle Serpis valley (Bernabeu *et al.*, 1989). As mentioned above, Les Jovades has large-scale storage and Punxó has monumental earthworks. Persistence data for the Muro survey area shows a modest shift and more marked contraction (or aggregation) of settlement from the Neolithic I to Neolithic II. However, none of the excavated Neolithic II sites have yet produced evidence of prior Neolithic I occupation. Finally, like the Penaguila, the middle Serpis and its tributaries are deeply entrenched, with little remains of late Pleistocene/early Holocene alluvium (Bernabeu *et al.*, 1994). There is paleobotanical and sedimentary evidence for devegetation of valley slopes and increased runoff in the middle Serpis by the end of the late Neolithic (Dupré Ollivier, 1988; Fumanal Garcia, 1995), and the deep incision of the Serpis and Penaguila floodplains postdates the Neolithic II site of Niuet, but possibly not by much (Barton and Clark, 1993). This severe erosion, up to 50 m deep in places, has cut through several known Neolithic II sites (including Punxó, Niuet, and Les Jovades) and may be partly responsible for the apparent rarity Neolithic I sites in the valley.

Settlement remained nucleated in both the Penaguila and middle Serpis valleys from the Neolithic onwards. Evidence of Bronze Age settlement is found throughout the region, but clearly concentrated in the middle Serpis (Rubio Gomis, 1987). Generally, these settlements are located on piedmont slopes, even farther from valley centers, continuing the trend toward upland agriculture that began in the Neolithic. In addition to Bronze Age settlements, the middle Serpis has a large Iron-Age Iberic center, La Serret (Llobregat Conesa *et al.*, 1992), and evidence of Roman occupation in Cocentaina (Domenech, personal communication, 2000). Following the reconquista in the mid-13th century, the city of Alcoi was built on Serpis floodplain remnants, incorporating the steeply incised banks into its defensive walls. There are currently several small towns in the Penaguila which date to at least the Moorish occupation prior to A.D. 1250. The middle Serpis is urbanized with a clear settlement hierarchy including the city of Alcoi, large towns of Muro and Cocentaina, and numerous smaller towns and villages.

Most modern agriculture (primarily arboriculture) takes place on terraced remnant high Pleistocene alluvial terraces, alluvial fans, and montane slopes of these valleys. More limited areas of cereal cultivation are found in the Penaguila on some of the remnants of the same surfaces that supported Neolithic populations. Cereals are extremely rare in the middle Serpis today, although small, irrigated, intensively cultivated gardens are interspersed among the olive groves and orchards. Most of the remnant level terrace surfaces that supported Neolithic agriculture in the middle Serpis are urbanized today.

The Polop Alto, on the other hand, has evidence of well-established forager populations from the Paleolithic onwards. Landuse data implies that Late Pleistocene and Early Holocene foragers especially may have evolved a mixed predatory/mutualistic relationships with subsistence animals and plants that permitted them to regularly reoccupy or occupy for longer times the same places on the landscape. This highly successful strategy would have offered considerable competition to the initial spread of agricultural settlements during the early Neolithic. Notably, landuse change from the final Paleolithic through the Neolithic I appear minimal, whether because the valley continued to be occupied by foragers who incorporated domestic plants and animals into a successful socioecosystem or because the valley became a frontier between agricultural and foraging systems. In either case, this mixed economic strategy was eventually replaced by a fully agricultural one by the Neolithic II—possibly because the use of domesticates encouraged cumulative landscape alteration (especially forest clearance) that increased the overall productivity of the system but at the expense of competing wild subsistence resources.

Because of its long-term history, the Polop entered into the regional Neolithic II socioecosystem as a place of lower population density and limited use. While it is plausible that logistical foraging systems similar to those of the Polop evolved in the middle Serpis, they do not appear to have inhibited the early adoption of agricultural socioecosystems in the Serpis by at least some of the inhabitants. By the time of the Neolithic II, even though landuse in the Polop assumed a fully Neolithic character, 2500 years of cumulative human investments in the landscapes of other nearby valleys such as the middle Serpis (with large-scale storage, monumental earthworks, and presumably extensive field clearance) made them the preferred centers of social and economic power, population, and the focus of subsequent large-scale landscape alteration.

With respect to the long-term effects on the landscape, the Polop has experienced much less erosion than either the Penaguila or Middle Serpis valleys, though it is intermediate between them in size and equivalent to the Penaguila in elevation. The most significant erosional entrenchment in the Polop is the result of headward erosion of the Baranc Troncal, extending upwards into the valley from the middle Serpis, into which it drains (Barton *et al.*, 2002). In this respect, the most prominent erosion in the Polop is a result of events in the middle Serpis.

Settlement largely remained dispersed in the Polop. As indicated above, the Neolithic II occupation in the valley seems to center around a single hamlet. There is a Bronze Age hamlet, El Corral, in the Polop (Trelis, 1992), along with a few other small settlements (Rubio Gomis, 1987), all located on the mountain slopes surrounding the valley. We encountered one, and possibly a second, Iberic farmstead in the Polop, and a Roman villa is known from the upper end of the valley. A small Moorish guard tower and dispersed *masias*—or villa-like estates—dot the valley today. Annuals, primarily cereals and sunflowers, are cultivated throughout the valley bottom today, while arboriculture occupies some terraced mountain slopes—although not to the extent seen in the middle Serpis. Interestingly, a nature preserve, the Font Roja, occupies much of the uplands along the south side of the valley. This area has been a forest preserve (originally a royal hunting demesne) since at least the 13th century, preserving one of the few stands of Mediterranean forest in Valencia.

Human settlement in the Alcalá valley, too, has remained light since the Neolithic. Two small Bronze Age settlements are known from the valley margins (Rubio Gomis, 1987). An Iberic fortress is located near the crest of the Sierra de la Forada, north of the valley. But it is probably situated more to guard the Val de Gallinera that runs north of the mountain crest and forms a natural passage from the Mediterranean to the Serpis valley. Today, there is a tiny hamlet, Alcalá de Jovades, in the valley that served as a Moorish refuge site during uprisings of the 13th and 14th centuries. Like the Polop, the Alcalá has experienced minimal incision. Most landscape transformation in both the Polo and Alcalá valleys is extensive sheet erosion resulting from changing agricultural practices over the past several centuries (Barton *et al.*, 1999, 2002). Agriculture in the Alcalá is primarily arboriculture, mirroring its inability to provide a long-term base for Neolithic subsistence farmers.

CONCLUDING THOUGHTS

An important goal of this paper has been to outline a systematic framework in which archaeologists can undertake long-term studies of human socioecosystems at regional scales. This has been an important objective of the discipline for a long time. However, it has largely been realized in an anecdotal or, at best, qualitative manner. New methods and technology offer the potential of putting such research on a more systematic, quantitative basis. And in so doing, making it possible to better evaluate and build on the results of such long-term, regional studies. In the case of the research presented here, there are several observations of particular note about socioecological processes and how we study them.

Making effective use of new technologies to understand long-term socioecological processes requires us to conceptualize the archaeological record somewhat differently than we normally do. Although archaeologists often talk of systems and dynamics, they often operationalize inferences of the human past in terms of a series of "snapshots" of activities at tiny samples of particular locales on landscapes (i.e., sites). This has been the primary research protocol of archaeology for over 150 years. Half a century ago, the concepts of systematic survey and settlement systems were introduced. This expanded archaeological horizons to a group of point locales across a region, but still remained conceptually far from realizing the linkages between social *systems* and the archaeological record, and even more strongly emphasized a "snapshot" perception of the record. Over the past 50 years, there has been a growing recognition that this is both methodologically and conceptually inadequate for understanding human systems and explaining their operations. We have tried to build on this recognition and describe an integrated suite of concepts, field methods, and analytical protocols aimed at modeling the dynamics of prehistoric socioecosystems. Along these lines, it is important to understand how humans behave, but it is equally important to understand how the physical outcomes of that behavior creates the archaeological record that we study. This point was made by Michael Schiffer nearly three decades ago (Schiffer, 1976, 1980, 1983, 1987), but archaeologists still seem to have difficulty in grasping its implications. We have built on these concepts by extending them to landscape scales, but it has required new ways of thinking about the archaeological record and how we study it.

With respect to long-term socioecological processes in the western Mediterranean, general evolutionary principles are useful for developing models for the transformation of societies of foragers into Neolithic farmers. But the outcomes of such evolutionary algorithms (sensu Dennett, 1995) were highly contingent on particular local histories—encompassing both the natural and social contexts and their dynamics (Bintliff, 1999). Although there is an overall convergence in the replacement of forager systems with farming ones, there was considerable variation in the paths taken in different regions to reach this end. These differences cannot be explained by nonhuman biophysical properties of each valley alone, but need models that include human social dynamics as well. In this respect, while we focus here on the ecological dynamics of human subsistence systems, this does not mean that social relationships are simply a consequence of those dynamics. Interactions among people are as much a critical aspect of socioecosystems as are interactions between people and the natural world. But evidence for such intersocial dynamics remains much more equivocal currently. More effort is needed to include social relationships more systematically in our analytical protocols and interpretative frameworks, in order to better understand the interplay between the social and ecological dimensions.

Not simply human society, but the earth's landscapes also are the cumulative product of long-term socioecosystem dynamics. Furthermore, they too are as contingent on the human past as they are on the natural one. In fact, these two pasts are difficult to disentangle and endeavoring to do so risks an incomplete understanding of either. Human actors do not encounter a landscape as a sort of *tabula rasa* that can be shaped according their perceptions and actions. Both human actions and perceptions are contingent in many ways on both the social and natural historical contexts in which they are reproduced. The landscapes of the central País Valenciano today and how they are used by their modern inhabitants is related to the long-term socioecology of this region as well as to modern social, political, and economic parameters. Developing policy for modern societies in this or any other region of the world without taking into account the socioecological past on which it is contingent forgoes vital information needed for effective planning. Archaeologists know well that the past is littered with the unforeseen and often deleterious (for humans) consequences of similar decisions.

Several years ago, Karl Butzer published a seminal paper on the anthropogenic nature of Mediterranean landscapes (Butzer, 1996). Among the points made in that article, Butzer noted that the stability of Mediterranean landscapes today requires human presence and active intervention. In this sense, humans are a keystone species of Mediterranean ecosystems. This tightly and complexly intertwined character of the social and natural is the reason for our use of the term "socioecosystem." Butzer (1996) and van der Leeuw (2000) have also raised questions about the meaning of "degraded" landscapes, and the relationships between such degradation, human impacts on the environment, and long-term sustainability. Certainly, the Mediterranean landscape is transformed from what it was 8000 years ago. In many senses we could call it degraded. However, this landscape has supported agriculture and complex civilization for longer than any other place in the world. Furthermore, it remains a highly popular tourist destination because of its widely perceived aesthetic "beauty."

It is tempting to characterize the socioecological history of the Mediterranean as one in which human replaced a "natural" landscape with a new anthropomorphic one. However, the situation—as usual—is more complex than this. For anyone who studys Mediterranean ecosystems, it is clearly apparent that most of the same plants and animals that inhabited the region at the beginning of the Holocene still do today. What has happened is perhaps better characterized as a reorganization of the components of Holocene ecosystems. For example, much of the region was covered by a oak-pine-pistachio woodland 8 millennia ago, with scattered fruit trees like olive and almond, and interspersed with occasional clearings in which grew stands of annual plants such as cereal grasses and legumes. Today, our study area is dominated by an anthropogenic "woodland" of olive and almond, with scattered stands of pine and oak. There are also large expanses of cereal grasses in some valleys (primarily wheat), with copses of trees around the margins and along terrace walls. Legumes are dispersed throughout this woodland in the form of small gardens. Ovicaprids and cattle still roam these woods, but their "domestic" variants predominate. Given the enthusiastic fall hunting season, it is difficult to tell whether wild or domestic pigs are more common. Perhaps the most notable "new" aspects of modern Mediterranean socioecosystem are the many new taxa—both plant and animal—that humans have introduced. This has been deleterious for some preexisting species, but it has also tremendously increased the total biodiversity of this region.

Humans long ago passed the point where their absence had little or no effect on terrestrial ecology. Like it or not, we are today a keystone species—perhaps the most significant keystone species in many cases—of terrestrial ecosystems. Our decisions will play an important role in shaping terrestrial ecosystems for the foreseeable future—whether by constructing urban skyscrapers, setting aside an area as a "wilderness" preserve (by stopping human hunting, plant harvesting, and anthropogenic fire that may have taken place for millennia previously), managing fire and timber harvesting in a national forest, or tilling a field for monocropping. And the socioecosystems that our decisions will create are the ones we and our descendents must live with. An understanding of the past that shaped the present, and the role humans played in that past can give a better chance to create a world that we want to live in.

ACKNOWLEDGMENTS

This research has been supported by the National Science Foundation (Grant Nos. BCS-0075292 and BNS-9115209), the Council for the International Exchange of Scholars (Fulbright Senior Research Fellowship), Arizona State University, the Universitat de València, and the Diputación de Valencia. We acknowledge the contributions of Margaret MacMinn-Barton, Sara McClure, Ernestina Badal, Neus La Roca, and Teresa Orozco to this research.

REFERENCES CITED

Anderson, R. S., and Smith, S. J. (1997). The sedimentary record of fire in montane meadows, Sierra Nevada, California, USA: A preliminary assessment. In Clark, J. S., Cachier, H., Goldammer, J. G., and Stocks, B (eds.), *Sediment Records of Biomass Burning and Global Change*, Springer-Verlag, Berlin, pp. 313–327.

Aura, J. E., and Pérez-Ripoll, M. (1995). El Holoceno inicial en el Mediterráneo español (11.000–7.000 BP). Características culturales y económicas. In Villaverde, V. (ed.), *Los últimos cazadores. Transformaciones culturales y económicas durante el Tardiglaciar y el inicio del Holoceno en el ámbito mediterráneo*, Instituto de Cultura Juan Gil-Albert, Diputación Prov. de Alicante, Alicante, pp. 119–146.

Aura Tortosa, J. E., Villaverde Bonilla, V., Pérez Ripoll, M., Martínez Valle, R., and Guillem Calatayud, P. M. (2002). Big game and small prey: Paleolithic and epipaleolithic economy from Valencia (Spain). *Journal of Archaeological Method and Theory* **9:** 215–268.

Balée, W. (ed.) (1998). *Advances in Historical Ecology*, Columbia University Press, New York.

Barton, C. M. (1988). *Lithic variability and Middle Paleolithic Behavior: New Evidence from the Iberian Penninsula*, British Archaeological Reports, Oxford.

Barton, C. M., Bernabeu Auban, J., Aura Tortosa, J. E., Garcia, O., and La Roca, N. (2002). Dynamic landscapes, artifact taphonomy, and landuse modeling in the western Mediterranean. *Geoarchaeology* **17:** 155–190.

Barton, C. M., Bernabeu Auban, J., Aura Tortosa, J. E., and Garcia Puchol, O. (1999). Landscape dynamics and socioeconomic change: An example from the Polop Alto valley. *American Antiquity* **64:** 609–634.

Barton, C. M., Bernabeu Auban, J., Aura Tortosa, J. E., and Molina Balaguer, L. (2001). Historical contingency, nonlinearity, and the neolithization of the western Mediterranean. In *66th Annual Meeting of the Society for American Archaeology*, New Orleans.

Barton, C. M., Bernabeu Auban, J., Aura Tortosa, J. E., and Molina Balaguer, L. (2004). Historical contingency, nonlinearity, and the neolithization of the western Mediterranean. In Wandsnider, L. and Athanassopoulos, E. (eds.), *Current Issues in Mediterranean Landscape Archaeology*, Philadelphia, University of Pennsylvania Press, pp. 99–124.

Barton, C. M., and Clark, G. A. (1993). Cultural and natural formation processes in late Quaternary cave and rockshelter sites of western Europe and the Near East. In Goldberg, P., Nash, D. T., and Petraglia, M. D. (eds.), *Formation Processes in Archaeological Context*, Prehistory Press, Madison, WI, pp. 33–52.

Barton, C. M., Schmich, S., and James, S. R. (2004). The ecology of human colonization in pristine landscapes. In Barton, C. M., Clark, G. A., Yesner, D. R., and Pearson, G. (eds.), *The Settlement of the American Continents: A Multidisciplinary Approach to Human Biogeography*, Tucson, University of Arizona Press, pp. 138–161.

Bender, B. (1993). Stonehenge—Contested landscapes (Medieval to present-day). In Bender, B. (ed.), *Landscapes—Politics and Perspectives*, Berg, Providence, RI, pp. 245–279.

Bernabeu Auban, J. (1995). Origen y consolidación de las sociedades agrícolas. El País Valenciano entre el Neolítico y la Edad del Bronce. *Actes de les Segones Jornades d'Arqueologia* 37–60.

Bernabeu Auban, J. (1999). Pots, symbols, and territories: The archaeological context of neolithisation in Mediterranean Spain. *Documenta Praehistorica* **26:** 101–119.

Bernabeu Auban, J., Barton, C. M., Garcia, O., and La Roca, N. (1999). Prospecciones sistemáticas en el valle del Alcoi (Alicante): primeros resultados. *Arqueología Espacial* **21:** 29–64.

Bernabeu Auban, J., Orozco Köhler, T., Diez Castillo, A., and Gomez Puche, M. (2003). Mas d'Is (Penàguila, Alicante): aldeas y recintos monumentales del Neolítico Antiguo en el Valle del Serpis. *Trabajos de Prehistoria* **60**: 39–60.

Bernabeu, J. (1993). El IIIr. Milenio a.C. en el País Valenciano. Los poblados de Jovades (Cocentaina. Alacant) y Arenal de la Costa (Ontinyent, Valencia). *Saguntum* **26:** 11–179.

Bernabeu, J., Barton, C. M., Garcia, O., and La Roca, N. (1999). Prospecciones sistemáticas en el valle del Alcoi (Alicante): primeros resultados. *Arqueología Espacial* **21:** 29–64.

Bernabeu, J., Barton, C. M., Garcia, O., and La Roca, N. (2000). Systematic survey in Alicante, Spain: First results. *Türkyie Bilimer Akademisi Arkeoloji Dergisi* **3:** 57–86.

Bernabeu, J., Barton, C. M., and Perez Ripoll, M. (2001). A taphonomic perspective on Neolithic beginnings: Theory, interpretation, and empirical data in the western Mediterranean. *Journal of Archaeological Science* **28:** 597–612.

Bernabeu, J., Guitart, I., and Pascual, L. (1989). Reflexiones en torno al patrón de asentamiento en el País Valenciano entre el Neolítico y la Edad del Bronce. *Saguntum* **22:** 99–123.

Bernabeu, J., and Juan-Cabanilles, J. (1994). Le Neolithique au Pays Valencien. XXIVeme Congres Prehistorique de France.

Bernabeu, J., Pascual, J. L., Orozco, T., Badal, E., Fumanal, M. P., and García Puchol, O. (1994). Niuet (L'Alquería d'Asnar). Poblado del IIIr milenio a.C. *Recerques del Museu d'Alcoi* **3:** 9–74.

Bettinger, R. L. (1991). *Hunter–gatherers: Archaeological and evolutionary theory*, Plenum Press, New York.

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

Binford, L. R. (1981). Behavioral archaeology and the "Pompeii Premise." *Journal of Anthropological Research* **37:** 195–208.

Bintliff, J. (ed.) (1999). *Structure and Contingency: Evolutionary Processes in Life and Human Society*, Leicester University Press, London.

Birkeland, P. W. (1999). *Soils and Geomorphology*, Oxford University Press, New York.

Bottema, S., Entjes-Nieborg, G., and van Zeist, W. (eds.) (1990). *Man's Role in the Shaping of the Eastern Mediterranean Landscape*, A.A. Balkema, Rotterdam.

Bradley, R. (1991). Rock art and the perception of landscape. *Cambridge Archaeological Journal* **1:** 77–101.

Braudel, F. (1980). *On History*, University of Chicago Press, Chicago.

Bush, M. B. (1988). Early Mesolithic disturbance: A force on the landscape. *Journal of Archaeological Science* **15:** 453–462.

Butzer, K. W. (1982). *Archaeology as Human Ecology*, Cambridge University Press, Cambridge, UK.

Butzer, K. W. (1996). Ecology in the long view: Settlement histories, agrosystemic strategies, and ecological performance. *Journal of Field Archaeology* **23:** 141–150.

Cacho, C., Fumanal, M. P., López, P., López, J. A., Pérez, R. M., Martínez Valle, R., Uzquiano, P., Arnanz, A., Sanchez Marco, A., Sevilla, P., Morales, A., Roselló, E., Garralda, M. D., and García Carrillo, M. (1996). El Tossal de la Roca (Vall d'Alcalà, Alicante). Reconstrucción paleoambiental y cultural del Tardiglaciar al Holoceno inicial. *Recerques del Museu d'Alcoi* **4:** 11–102.

Collins, J. P., Kinzig, A., Grimm, N. B., Fagan, W. F., Hope, D., Wu, J., and Borer, E. T. (2000). A new urban ecology. *American Scientist* **88:** 416–425.

Crumley, C. L. (ed.) (1994). *Historical Ecology: Cultural Knowledge and Changing Landscapes*, School of American Research Press, Santa Fe, NM.

Dennett, D. C. (1995). *Darwin's Dangerous Idea*, Simon & Schuster, New York.

Doménech, E. M. (1990). Aportaciones al Epipaleolítico del norte de la Provincia de Alicante. *Alberri* **3:** 15–166.

Doménech Faus, E. M. (1999). Els últims Neandertals i els primers Homo sapiens al Mediterrani Espanyol. Una qüestió de convivència en Cova Beneito?: Muro de l'Alcoi. Festes de Moros i Cristians en Honor a la Mare de Déu dels Desemparats.

Dunnell, R. C. (1992). The notion of site. In Rossignol, J., and Wandsnider, L. (eds.), *Space, Time, and Archaeological Landscapes*, Plenum, New York, pp. 21–41.

Dupré Ollivier, M. (1988). *Palinología y Paleoambiente: Nuevos Datos Españoles*, Servicio de Investigación Prehistórica, Valencia.

Ebert, J. I., Camilli, E. L., and Berman, M. J. (1996). GIS in the analysis of distributional archaeological data. In Maschner, H. D. G. (ed.), *New Methods, Old Problems: Geographic Information Systems in Modern Archaeological Research*. Southern Illinois University, Carbondale, pp. 25–37.

Fernández Peris, J. (1993). El paleolítico inferior en el País Valenciano: una aproximación a su estudio. *Recerques del Museu d'Alcoi* **2:** 7–22.

Fernández Peris, J., Guillem Calatayud, P. M., and Martínez Valle, R. (1997). *Cova del Bolomor: els Primers Habitants de les Terres Valencianes*, Museo de Prehistoria and Sercivio de Investigacion Prehistorica, Valencia.

Fisher, C. T., and Thurston, T. L. (1999). Special section. Dynamic landscapes and socio-political process: The topography of anthropogenic environments in global perspective. *Antiquity* **73:** 630–688.

Flannery, K. (1986). *Guilá Naquitz: Archaic Foraging & Early Agriculture in Oaxaca*, Academic Press, New York.

Foley, R. (1981). *Off-Site Archaeology and Human Adaptation in Eastern Africa*, British Archaeological Reports, Oxford.

Fumanal Garcia, M. P. (1995). Los depósitos cuaternarios en cuevas y abrigos. Implicaciones sedimentoclimáticas. In Roselló, V. M. (ed.), *El Cuaternario del País Valenciano*, Universitat de València., Valencia, pp. 115–124.

Galvan, B. (1992). El Salt (Alcoi, Alicante): estado actual de las investigaciones. *Recerques del Museu d'Alcoi* **1:** 73–80.

García Puchol, O. (2002). *Tecnología y Tipología de la Piedra Tallada Durante el Proceso de Neolitización*, PhD, Universitat de València., Valencia.
García Puchol, O., and Barton, C. M. (2001). Las ocupaciones prehistóricas del Barranc de l'Encantada (Beniarrés, Alacant): un primer balance de la intervención auqueológica en el Área. *Recerques del Museu d'Alcoi* **10:** 25–42.
Gould, S. J. (1989). *Wonderful life: The Burgess Shale and Nature of History*, W.W. Norton, New York.
Holling, C. S. (2001). Understanding the complexity of economic, ecological, and social systems. *Ecosystems* **4:** 390–405.
Iturbe, G., Fumanal, M. P., Carrión, J. S., Cortell, E., Martinez, R., Guillem, P. M., Garralda, M. D., and Vandermeersch, B. (1993). Cova Beneito (Muro, Alicante): una perspectiva interdisciplinar. *Recerques del Museu d'Alcoi* **2:** 23–88.
Johnson, I. (1984). Cell frequency recording and analysis of artifact distributions. In Hietala, H. J. (ed.), *Intrasite Spatial Analysis in Archaeology*, Cambridge University Press, Cambridge, UK, pp. 75–96.
Kelly, R. L. (1991). Sedentism, sociopolitical inequality, and resource fluctuations. In Gregg, S. (ed.), *Between Bands and States*, Center for Archaeological Investigations, Southern Illinois University, Carbondale, pp. 135–158.
Kelly, R. L. (1995). *The Foraging Spectrum: Diversity in Hunter–Gatherer Lifeways*, Smithsonian Institution Press, Washington, DC.
Kintigh, K. W. (1990). Intrasite spatial analysis: A commentary on major methods. In Voorrips, A. (ed.), *Mathematics and Information Science in Archaeology: A Flexible Framework*, Holos, Bonn, pp. 165–200.
Llobera, M. (2001). Building past landscape perception with GIS: Understanding topographic prominence. *Journal of Archaeological Science* **28:** 1005–1014.
Llobregat Conesa, E. A., Cortell Pérez, E., Juan Moltó, J., and Segura Martí, J. M. (1992). El urbanismo Ibérico en la Serreta. *Recerques del Museu d'Alcoi* **1:** 37–70.
Martí, B., Pascual, V., Gallard, M. D., López, P., Pérez Ripoll, M., Acuña, J. D., and Robles, F. (1980). *Cova de l'Or (Beniarrés, Alicante), Vols. 1–2*, Servicio de Investigación Prehistórica de Valencia, València.
McClure, S., Jochim, M. A., and Barton, C. M. (n.d.). Behavioral ecology, domestic animals, and land use during the transition to agriculture in Valencia, eastern Spain. In Kennett, D., and Winterhalder, B. (eds.), *Foraging, Theory and the Transition to Agriculture*, Smithsonian Institution Press, Washingtion, DC.
McGlade, J. (1995). Archaeology and the ecodynamics of human-modified landscapes. *Antiquity* **69:** 113–132.
McGlade, J. (1999). Archaeology and the evolution of cultural landscapes: Towards an interdisciplinary research agenda. In Ucko, P. J., and Layton, R. (eds.), *The Archaeology and Anthropology of Landscape*, London, Routledge, pp. 459–482.
Neteler, M., and Mitasova, H. (2002). *Open Source GIS: A GRASS GIS Approach*. Boston: Kluwer Academic Publishers.
Pascual Benito, J. L. (1989). Les Jovades (Concentaina, Alacant), habitat del Neolitic final amb estructures excavades: Sitges i fosses. *Alberri* **2:** 9–54.
Pyne, S. (1997). *Vestal Fire: An Environmental History*, University of Washington Press, Seattle.
Pyne, S. J. (1998). Forged in fire: History, land, and anthropogenic fire. In Balée, W. (ed.), *Advances in Historical Ecology*, Columbia University Press, New York, pp. 64–103.
Redman, C. L., and Kinzig, A. P. (2003). Resilience of past landscapes: Resilience theory, society, and the longue durée [online]. *Conservation Ecology* **7:** 14.
Rindos, D. (1980). Symbiosis, instability, and the origins and spread of agriculture: A new model. *Current Anthropology* **21:** 751–772.
Rindos, D. (1984). *The Origins of Agriculture: An Evolutionary Perspective*, Academic Press, New York.
Rossignol, J., and Wandsnider, L. (1992). *Space Time and Archaeological Landscapes*, Plenum, New York.
Rubio Gomis, F. (1987). *Catálogo de Materiales y Yacimientos de la Cultura del Bronce Valenciano*, Ayuntamiento de Alcoy, Alcoi.

Schiffer, M. B. (1976). *Behavioral Archaeology*, Academic Press, New York.
Schiffer, M. B. (1980). *Formation Processes of the Archaeological Record*, University of Utah Press, Salt Lake City.
Schiffer, M. B. (1983). Towards the identification of formation processes. *American Antiquity* **48:** 675–706.
Schiffer, M. B. (1987). *Formation Processes of the Archaeological Record*, University of New Mexico Press, Albuquerque.
Sheridan, T. E. (1995). Arizona: The political ecology of a desert state. *Journal of Political Ecology* **2:** 41–57.
Smith, E. A. (1988). Risk and uncertainty in the "original affluent society": Evolutionary ecology of resource-sharing and land tenure. In Ingold, T., and Riches, D. (eds.), *Hunters and Gatherers I: History, Evolution and Social Change*, James Woodburn, Oxford, pp. 222–251.
Trelis, J. (1992). Excavaciones en el yacimiento de la Edad del Bronce de Mas del Corral (Alcoy-Alicante). *Recerques del Museu d'Alcoi* **1:** 85–90.
Ucko, P. J., and Layton, R. (1999). *The Archaeology and Anthropology of Landscape*, Routledge, London.
van Andel, T. H., and Zanagger, E. (1990). Landscape stability and destabilization in the prehistory of Greece. In Bottema, S., Entjes-Nieborg, G., and Zeist, W. (eds.), *Man's Role in the Shaping of the Eastern Mediterranean Landscape*, A. A. Balkema, Rotterdam, the Netherlands, pp. 139–157.
van Andel, T. H., Zangger, E., and Demitrack, A. (1990). Land use and soil erosion in prehistoric and historical Greece. *Journal of Field Archaeology* **17:** 379.
van der Leeuw, S. (2000). Land degradation as a socionatural process. In McIntosh, J. A., Tainter, J. A., and McIntosh, S. K. (eds.), *The Way the Wind Blows: Climate, History, and Human Action*, Columbia University Press, New York, pp. 357–384.
Villaverde, V. (1984). *La Cova Negra de Xàtiva y el musteriense de la región central del mediterráneo español*, Servicio de Investigación Prehistórica, Valencia.
Villaverde, V., Aura Tortosa, J. E., and Barton, C. M. (1998). The Upper Paleolithic in Mediterranean Spain: A review of current evidence. *Journal of World Prehistory* **12:** 121–198.
Waters, M. R., and Kuehn, D. D. (1996). The geoarchaeology of place: The effect of geological processes on the preservation and interpretation of the archaeological record. *American Antiquity* **61:** 483–497.
Webb, R. E. (1998). Megamarsupial extinction: The carrying capacity argument. *Antiquity* **72:** 46–55.
Zimmerer, K. S. (1994). Human geography and the "new ecology": The prospect and promise of integration. *Annals of the Association of American Geographers* **84:** 108–125.
Zvelebil, M., Green, S. W., and Macklin, M. B. (1992). Archaeological landscapes, lithic scatters, and human behavior. In Rossignol, J., and Wandsnider, L. (eds.), *Space, Time, and Archaeological Landscapes*, Plenum, New York, pp. 193–226.