♈ Chapter 9

Human Behavioral Ecology, Domestic Animals, and Land Use During the Transition to Agriculture in Valencia, Eastern Spain

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Abstract: Most applications of Human Behavioral Ecology (HBE) to questions of agricultural origins have focused on plant domestication in archaeological contexts in the New World, where domestic animals were generally less important in early agricultural societies . In contrast, domestic animals play an important part in subsistence strategies and land use in Old World early agricultural societies. In this chapter, we examine the role of domestic animals in changes of land use during the transition to, and consolidation of, food producing economies in Valencia, Spain. Using the behavioral ecological model of ideal free distribution as a heuristic concept, we show the tight linkage between agricultural subsistence strategies, herd management, and long-term dynamics of human land use. Two broadly different herd management strategies were stable for long periods of time and the shift from one to the other was tightly linked with socioecological changes during the Neolithic.

In recent years, ecological approaches to the origin of and transition to agriculture have been popular, especially in research conducted outside of Europe (e.g., Cowan and Watson 1992; Harris and Hillman 1989; Price and Gebauer 1995a; Smith 2002). These include studies founded in Human Behavioral Ecology (HBE), focusing on co-evolutionary processes, risk minimization strategies, resource selection or a combination of these as explanatory or exploratory models for understanding the adoption of domesticates into prehistoric subsistence practices (e.g., Barlow 2002, Blumler et al. 1991; Gremillion 1996a; Hawkes and O'Connell 1992; Layton et al. 1991; Piperno and Pearsall 1998; Rindos 1980, 1984; Winterhalder 1993; Winterhalder and Goland 1997).

Risk minimization is often called upon to explain the move from foraging to farming-based subsistence economies (see Winterhalder and Goland 1997; Redding 1981). In these models, domesticates, usually plants, are regarded as risk minimizers; initially adopted to diversify the existing resource base. Through co-evolutionary processes (Rindos 1980, 1984) or simple intensification, the efficiency of the resource as a food source rises. In this view, domesticates gradually became the dominant subsistence resources and risk minimization strategies shifted to a focus on

diversification through use of fall-back wild resources, plot dispersal, and perhaps other mechanisms (e.g., Blumler 1996; O'Shea 1989; Winterhalder 1990; Winterhalder and Goland 1993, 1997). These approaches have been effective in a variety of archaeological contexts, primarily when dealing with the origins of plant domestication and the gradual shift towards widespread food production. These studies are based on the concepts of foraging theory, in that they share the assumption that individuals will adjust their behavior to maximize the payoff or minimize the risks of various foraging and farming activities. For example, Gremillion (1996a) used diet breadth and opportunity cost models from optimal foraging theory to identify when an introduced crop would be adopted by agriculturalists. She argued that the adoption of a new resource is possible in times of abundance as well as in scarcity, but with different goals (e.g., efficiency maximization in the former and risk minimization in the latter). Using the models as a heuristic device, she then examines the introduction of the peach into the subsistence regime in the southeastern U. S. and the regional differences in the intensity of maize agriculture. She concluded that the adoption of new crops, especially ones with relatively low energetic contributions, can result from decisions to minimize subsistence risk (Gremillion 1996a: 199).

Applications of foraging theory to agricultural contexts with domestic animals are rare, and tend to focus on the initial stages of animal domestication (e.g., Redding 1981; Alvard and Kuznar 2001). Although foraging theory has been widely applied to hunting activities archaeologically and in the ethnographic present (see Winterhalder and Smith 2000), it seems ill-suited to the analysis of domestic animals, which appear to provide a stable, readily available source of meat without the costs associated with hunting wild animals (e.g., pursuit time and transportation costs; see Barlow 2002; Cannon 2003; Grayson and Cannon 1999). An exception is ethnographic research by Mace (1990, 1993a, 1993b), who has developed a model for explaining investment in herds and agriculture among agropastoralist societies in Sub-Saharan Africa. The dynamic optimality modeling she employs investigates the adaptiveness of pastoralist subsistence strategies for long-term household survival (Mace 1993a) and transitions between cultivation and pastoralism, based on the assumption that farming and herding households adopt strategies that maximize their chances of remaining viable over a

generation or longer (Mace 1993b). The modeling suggests that household wealth plays an important role in the subsistence decisions made (e.g., shift to more agriculture, management strategy of animals) and is a key factor in determining the optimal strategy of a household. In other words, there is no single optimal strategy for farming or pastoralism, or the combination thereof. Mace's research shows that an optimality-based model is effective for understanding the interplay between domesticated plants and animals in subsistence decisions, although the implications of this for archaeologists are limited by the extent to which we can generate the necessary data for evaluating the model from Neolithic contexts.

Foraging theory in general provides a multitude of approaches, some of which may be more useful than others for understanding the transition to agriculture and addressing contexts that include domestic animals. In this chapter we employ the ideal free distribution model, from behavioral ecology (Fretwell and Lucas 1970), to explore the dynamic relationship between domestic resource management and land use, and focus on the cultural and economic developments in Neolithic Spain (Valencia, eastern Spain). In the following, we briefly outline the cultural developments of the Neolithic in Valencia and describe the diachronic nature of agricultural production in the region. Secondly, we describe the ideal free distribution model. We then discuss the relationship between domestic animal management and land use in Neolithic Valencia. Finally, we suggest a model of Neolithic land use and how the ideal free distribution model may be a useful heuristic device for understanding the changes in the subsistence-settlement patterns that occurred in this region.

The Beginnings of Agriculture in Eastern Spain

In Europe, the origin of food production is usually explained by the introduction of farming techniques to a region via colonization by farmers or through indigenous adoption of farming practices, and subsequent processes of dispersion such as acculturation and/or migration (Bernabeu et al. 1993; Bernabeu et al. 2001; Price 2000b). The archaeological record in different parts of Europe suggests that this transition was highly varied. Agriculture became established quickly and apparently exclusively in some regions whereas others show long-term survival of distinct foraging and farming

populations in close proximity, with varying degrees of interaction (e.g., Barnett 1995, 2000; Binder 2000; Bogucki 2000; Clark 1990; Dennell 1985; Halstead 1996; Jochim 2000; Keeley 1996; Price 1996, 2000b; Thomas 1996; Tringham 2000; Whittle 1996; Zilhao 1993; Zvelebil 1986a, 1996; Zvelebil and Lillie 2000). For example, in central Europe the transition to agriculture is marked by the rapid appearance of agriculturalists known as the Linearbandkeramik (LBK) culture group. The archaeological record for LBK is dramatically different than for the Late Mesolithic hunter-gatherer groups in Germany. Late Mesolithic sites were generally ephemeral and contain the remains of wild foods collected. Contemporary LBK sites were larger and contain uniform house structures that suggest a high degree of residential stability. The settlements were strategically placed on productive loess soils and contain the charred remains of cultigens, domesticated animal bones, ceramics, and polished stone axes that were likely used to clear fields (Jochim 2000). This situation has long been considered a good example of agricultural migration and displacement of indigenous hunter-gatherers. Current research also suggests that dispersion of domesticates, farming techniques, and knowledge into non-farming areas and their adoption by local foragers may have played an important role in the transition to agriculture (Jochim 2000). A similar, but prolonged, transition from foraging to farming is evident in southern Scandinavia where indigenous hunter-gatherers traded with nearby farmers for nearly a millennium, followed by a rapid shift to an agricultural lifeway (Price and Gebauer 1995a; Price 2000c).

In eastern Spain (Figure 1), archaeological evidence indicates that the first domesticated plants (einkorn wheat, *Triticum monococcum*; barley, *Hordeum vulgare*; and legumes such as Haba beans, *Vicia faba*; lentils, *Lens culinaris*; and peas, *Pisum sativum*) and animals (sheep, *Ovis aries*; goat, *Capra hircus*; cow, *Bos taurus*; and pig, *Sus domesticus*) were introduced into the region by 5600 BC (Bernabeu et al. 1993; Bernabeu et al. 2001; Martí and Juan-Cabanilles 1997). The remains of these domesticated animals and plants are often found together with Cardial pottery, a distinctive type decorated with impressions of the Cardium shell. Cardial ceramics are considered to be part of the Impressed Ceramic Complex, the first pottery assemblages to be found widely distributed throughout the western Mediterranean (Martí 1998; Bernabeu 1995). The domesticated plants and animals are generally considered to be of Near

Eastern origin (Hopf 1991; Nguyen and Bunch 1980), despite potential wild progenitors of pigs and cows in the area (see Rowley-Conwy 1995).

In the western Mediterranean, researchers generally interpret Cardial assemblages in one of two ways; either as (i) a colonization of farmers or (ii) an indigenous adoption of domesticated animals and plants by foragers in the region (e.g., Barnett 1995, 2000; Bernabeu et al. 1993; Bernabeu et al. 2001; Bernabeu 1996; Donahue 1992; Martí and Juan-Cabanilles 1987; Martí 1998; Zilhao 1993,1998, 2000). Few data are currently available to address this question on a large scale. However, several studies focused on the Neolithic occupation of Portugal, Spain and southern France (Arnaud 1982; Barnett 1995, 2000; Barton et al. 1999; Barton et al. 2001; Bernabeu 1995, 1996; Binder 2000; Zilhao 1993, 1998, 2000), suggest that the introduction of agricultural practices to the Iberian Peninsula may have resulted from a combination of colonization and adoption by local hunter-gatherers (see Bernabeu 1996; Price 2000b, 2000c; Zilhao 2000).

The chronology of the Valencian Neolithic is reconstructed largely from archaeological sequences from two cave sites: Cova de l'Or and Cova de les Cendres (Martí and Juan-Cabanilles 1987, 1997; Martí 1998)(Figure 1), and primarily based on changes in pottery styles rather than the documentation of changing economic activities (Bernabeu 1989). The Neolithic is divided into two phases (Table 1), with subdivisions based on decorative shifts in ceramics (Bernabeu 1995). Neolithic I (5600-4500 BC) is defined by the predominance of decorated ceramics (primarily impressed and incised wares), including Cardial Ware, which appears in assemblages to varying degrees. Cardial impressed ceramics persist after 3800 BC in some parts of Valencia, but drop out of many assemblages across the Iberian Peninsula (Bernabeu 1989, 1995, 1996; Martí and Juan-Cabanilles 1997). Highly decorated wares decline during the subsequent Neolithic II (4500-2400 BC) phase in favor of undecorated ceramics. The final Neolithic II or Chalcolithic (HTC) (2400-1800 BC) is defined by the presence of "Bell Beaker" vessels, a characteristic form of pottery that marks the transition from the Neolithic to the Bronze Age in the region (Bernabeu 1995; Bernabeu and Pascual 1998).

In stark contrast to the early farming communities of the eastern Mediterranean (e.g., Nea Nikomedea in Greece or sites throughout the Levant; Bar-Yosef and Belfer-Cohen 1992; Byrd 1992; Whittle 1996), evidence in the Valencia Province for aggregated

settlement is not strong until the Neolithic II, several millennia after the introduction of domesticates and agricultural techniques to the region (Barton et al. 1999, 2001, 2002; Martí and Juan-Cabanilles 1987, 1997; Martí 1998; Whittle 1996). The settlement pattern appears to shift from dispersed, relatively ephemeral settlements in the Neolithic I to aggregated villages, such as Niuet and Arenal de la Costa (Fig. 1), later in the Neolithic II phase. These villages are characterized by labor investment in built facilities and internal organization (e.g., ditches, storage areas, wattle and daub constructed houses), and are located in similar ecological settings in larger valley bottoms and in upland valleys (Bernabeu 1993, 1995; Bernabeu et al. 1994; Pascual 1989). Although relatively little is known about early Neolithic open-air sites, current research at a number of open-air sites by Bernabeu (personal communication, 2002) and Barton, and others (e.g. Bosch et al. 2002) suggests that some degree of settlement aggregation may begin during the Neolithic I in some areas.

Settlement aggregation has been interpreted as a shift from agriculturalists to "campesinos", connoting an intensification of agricultural subsistence practices and corresponding changes in social organization and cultural behavior (Martí and Juan-Cabanilles 1987; Martí 1998), including the emergence of social stratification and intensified exchange relationships with more distant groups, such as in Andalucia in southern Spain several hundred kilometers away. As Barnett (2000) has recently suggested, the Neolithic in the Western Mediterranean presents an interpretive challenge as it represents the rapid and early appearance but slow assimilation of production-based economies among emergent agricultural societies (see also Zvelebil 1986). In other words, agriculture was the focus of subsistence activities well before characteristic features of agricultural societies, such as aggregated villages, are identifiable archaeologically. In Valencia, the available record suggests that domestic plants and animals were in use for over a millennium before aggregated farming villages became widely established in the region. Taking up this challenge, we suggest that the nature of domestic animal and plant management in the particular ecological landscape of Valencia affords insights to these developments. We now summarize what is known about early agricultural strategies in Valencia and then evaluate these data within the framework of the Ideal Free Distribution model.

The Nature of Early Agriculture in Valencia

        The reconstruction of early agricultural activity in any region is never an easy task. In Valencia, as is the case across most of the western Mediterranean, excavated Neolithic I data come almost exclusively from cave and rock shelter deposits. The only exception is ongoing research at the early Neolithic open-air site of Mas d'Is that so far has produced small floral and faunal samples that are still under study (Bernabeu 2001, personal communication). On the other hand, most Neolithic II subsistence data derive from open-air sites, with little from caves and rock shelters, making comparisons between time periods difficult. Results of archaeological survey in the region suggest that Neolithic I settlement was located on the valley floor (Bernabeu et al. 1999; Barton et al. 1999) , surrounded by fertile soils and close to water sources. In the Neolithic II, villages are found in similar locations to Neolithic I sites, but others are positioned in more marginal areas, such as along valley margins and in higher elevation valleys. In all cases, however, Neolithic II villages are close to water sources, often located at the convergence of streams and rivers. Neolithic II settlements are more readily identified on the surface than Neolithic I sites because of their greater density of archaeological material.

        Despite the lack of quantitative data from Neolithic faunal and floral assemblages, some patterns of domesticated plant and animal use are evident more generally in the archaeological record. Domestic legumes, wheat, and barley were grown from Neolithic I onwards (Badal et al. 1991) and it appears that additional cultigens were not added to this suite of cultivated plants later in the Neolithic (Bernabeu 1995). Wheat and barley are regularly found mixed together at Neolithic I sites in Valencia, a common pattern found throughout the western Mediterranean during the early Neolithic. This has been interpreted as evidence for inter-cropping of these two species (i.e. cultivation within the same plot; Bernabeu 1995; Bernabeu and Pascual 1998). However, in the Neolithic II, individual cultigens are found spatially segregated within archaeological deposits, with 95% of carbonized seeds encountered in an archaeological context (e.g. storage pit) from a single species, suggesting that the cultivation strategies were more focused. Alternatively, this pattern may be the result of differences in storage and consumption patterns between the Neolithic I and II.

Faunal assemblages at Neolithic sites indicate that goats, sheep, cows, and pigs were the primary domesticated animals tended in the region (Figure 2). In addition to these domesticated animals, a variety of wild taxa, such as deer (*Cervus elaphus*) and rabbits (*Oryctolagus cuniculus*) continued to be taken (Bernabeu 1995; Pérez 1999). Sheep and goats (ovicaprids) are numerically the most economically important domestic animal in all Neolithic sites studied, particularly during Neolithic I when the bones of these animals dominate faunal assemblages. The dietary importance of pigs and cows appears to change more dramatically within the suite of domestic animals over the course of the Neolithic (Bernabeu 1995; Pérez 1999). Figure 2 shows the relative percentage of identified domestic faunal remains from seven sites in eastern Spain. During the Neolithic I, 62-78% of the domestic animal assemblages consist of sheep and goats. Pigs are the second largest proportion of domestic animals, ranging from 14-36% of the assemblages. In contrast, only very few cows are documented (2-8%). In the Neolithic II sites of Niuet, Les Jovades and Ereta de Pedregal (Phase I-II), sheep and goats continue to dominate assemblages (~55%), and pigs remain in the 20-30% range. Notably, these sites show a significant increase in cow bone in comparison to the Neolithic I assemblages. During the Neolithic II, 20-30% of the domestic fauna found at archaeological sites are cow bones. Generally, the relative importance of pigs is greater than cattle in all of the sites published, but cows surpass pigs in some Chalcolithic assemblages such as Arenal de la Costa (see Figure 1 for location).

A possible exception to this pattern is found at the Neolithic I open-air site at Mas d'Is, where two of the three bones found at the site were cattle bones (Bernabeu 2002, personal communication). In comparison, the faunal analysis at the open-air Neolithic I lake settlement of La Draga in Catalunya revealed almost 30% cow bones with 25% pig and 30% sheep and goats of the total number of identifiable bone recovered (Bosch et al 2002: Figura 115). However, the analysis of minimum number of individuals evidences that only 10.9% of the identified animals at La Draga are cows, 12.3% pig, and 46.7% sheep and goats (Bosch et al. 2002: Figura 116), mirroring Neolithic I domestic animal assemblages elsewhere (see Pérez 1999). The predominance of cow bone at Mas d'Is (as well as the higher number of identified cow bones at La Draga) may well be due to taphonomic differences in survival rates of animal bones between species.

Diachronic changes are also found in herd composition and kill patterns of several species (see Bernabeu 1995). In the Neolithic II, more animals (especially cows, sheep, and goats) reached adulthood than in the Neolithic I, suggesting a shift from a primary use as a meat source to additional uses of secondary products such as milk, labor, and wool. This change in animal management has been noted throughout the Iberian Peninsula (Pérez 1999). Recently, Pérez (1999) summarized faunal data from several sites across the Iberian Peninsula and identified changes in herd management during the Neolithic II. Overall, cattle remains rise relative to other domestic taxa in the Neolithic II with a concurrent decline in ovicaprid bones. Pig bones generally remain constant through time. The relative dietary importance of wild animals, such as deer, wild boar, and rabbit, remained relatively constant throughout the Neolithic, but varied between sites (Pérez 1999). Charcoal studies of Niuet and Les Jovades (Badal 1993, 1994) show that in the second half of the Neolithic II, forested areas were limited to higher elevations. This is also evidenced by the low percentages of wild forest animals (such as deer) in archaeological assemblages at Niuet and Les Jovades (Pérez 1999: 97).

Farming Strategies in the Valencian Neolithic

The data from Neolithic sites in Valencia suggest two distinct forms of agriculture. The Neolithic I was a hoe-based farming strategy with relatively high yields that was conducted in well-watered regions and on the most fertile soils (Bernabeu 1995). By exploiting fertile land immediately around a settlement, it is thought to broadly resemble the traditional Mediterranean *el huerto* system of garden-plot cultivation. In this system, fields are located close to habitation sites and cultivation is more or less continuous, often without fallow or only short fallow periods. Rotation of cereals and legumes is frequent and other kinds of treatment, such as manuring, are possibly used. This planting strategy was complemented by ovicaprine husbandry, managed primarily for meat production and pastured in close proximity to habitation sites and agricultural fields. However, high productivity patches may have been limited and were dependant on the available soils and water. Therefore they may not have been amenable to significant intensification (Bernabeu 1995). Areas may have been too small to support large aggregations, or may have been too quickly depleted for long-term occupation by

larger groups. In general, however, this kind of locally focused, concentrated land use typified early Neolithic agropastoral systems elsewhere in the Mediterranean (Hill 2000; Rollefson and Kohler-Rollefson 1992).

During the Neolithic II a new farming strategy emerged. Much more extensive areas of less fertile upland soils were cleared and planted, facilitated by the possible introduction of the oxen-pulled plow. This is more similar to the traditional Mediterranean farming system known as *secano*, or dry land farming (Bernabeu 1995), in which larger plots are rotated between winter and spring cereals and fallow over a longer three year rotation. Due to the geographically extensive nature of this system, the distance between the villages and plots were larger (Bernabeu 1995). With more area in cultivation, herds had to be grazed in fallow fields or at greater distances from settlements. Herd management also shifted to a more diversified focus that emphasized secondary products, such as milk products, wool, and labor in addition to meat.

Ideal free distribution

The ideal free distribution (Fretwell and Lucas 1970) is widely used in non-human population ecology, making it one among a small set of fundamental behavioral ecology models (Sutherland 1996). It seeks to represent habitat selection choices of individuals based on the evolutionary framework that individuals will maximize fitness. Originally employed in studies on bird populations (Fretwell and Lucas 1970), the ideal free distribution model has since been applied to a variety of animal species. Anthropological applications include the spatial pattern of salmon fishing boats off the coast of Canada (Abrahams and Healey 1990) and sperm whalers in the Galapagos Islands and the North Pacific in the 19th century (Whitehead and Hope 1991).

With its focus on habitat selection, the model of ideal free distribution can be used to explore how individuals use and distribute themselves across a landscape under a variety of social and environmental conditions. A habitat is defined as the area where a species is able to colonize and live (Fretwell and Lucas 1970: 18). A landscape may be divided into different habitats, potentially of different sizes. Habitat selection is based on the suitability of the habitat, and both population-density dependent and independent factors may play a role in a habitat's suitability. The distribution of individuals among

habitats is therefore determined by the relative suitability of available habitats (Fretwell and Lucas 1970: 19). This point ties in with Brown's (1969) concept of the buffer effect: at low population densities, individuals tend to live predominantly in the better patches (or habitats). At higher population densities, a larger fraction will be found in poorer patches (see also Sutherland 1996:7). A habitat's *basic suitability* is defined when population density is close to zero. This is the first step in ordering habitats, and, by definition, no two habitats have equal basic suitabilities (Fretwell and Lucas 1970: 21).

Like any model, the ideal free distribution (IFD) has several assumptions. First, all individuals have the information to select and the ability to settle in the most suitable habitat available. There are no barriers (social or otherwise) that would prohibit this behavior. This optimization assumption is the "ideal" in the IFD. Secondly, all individuals are free to shift their habitat selection in response to local population density. As a result of this adjustment, all individuals within a local population will come to have identical expected success rates. In other words, there is equal access to resources within the habitat. This assumption provides the "free" in ideal free distribution. The model therefore assumes that individuals are able to enter any habitat on an equal basis with residents. Furthermore, the model assumes that all individuals are alike in their needs and therefore in their assessment of habitats.

It is key to the model that habitat suitability will change as a result of the density of individuals exploiting it. The value of a habitat may decline because of *interference* or *depletion*. Interference results in the short-term decline of intake rate that decreases a habitat's suitability due to the presence of others (Sutherland 1996: 7). Examples of interference include increases in fighting and stealing and under these conditions resources are simply less accessible. Depletion, on the other hand, works in the long-term and is defined by the actual removal or reduction of resources caused by immediate consumption or degradation of the environment through time.

Figure 3 graphically shows the expectations of the ideal free distribution model (after Fretwell and Lucas 1970: 24). In this figure, habitat 1 (H1) has a higher suitability than habitat 2 (H2), with basic suitability defined at zero population density. However, with increase in population, the suitability of the habitat declines. When density reaches point A, the suitability of H1 is equal to H2 with zero density. With increased

population, individuals will now settle in both H1 and H2. This pattern continues with habitat 3 (H3). When population density reaches point B, suitability is equal between H1, H2 and H3. With an increase in population, individuals will now settle in H1, H2, or H3. The general process is the following: If individuals are making the best habitat choice available to them, then they will distribute themselves first in the best resource location, and when the suitability there has dropped to the suitability level of the next ranked habitat, they will move so that their relative densities equalize the marginal suitabilities of the two habitats. This distribution is an equilibrium because no individual can gain by moving. As populations continue to increase, densities within each habitat will rise, and more habitats will be occupied.

Allee's Principle

Another type of change in suitability is found in Allee's principle. This states that habitat suitability measured by the survival and reproductive rates of individuals residing there may initially rise with increasing population size, up to some maximum (Allee et al. 1949). Only when population size increases beyond this threshold do survival and reproduction begin to decrease (Figure 4). In effect, at low densities there are increasing returns to scale. Among agricultural communities, an example of this might be investment in irrigation systems or field terraces. The terracing of hillsides requires a great amount of labor input, and a minimum number of individuals to tend the structures. However, terracing greatly increases the potential returns of farming by increasing the area available for farming.

Figure 4 shows two habitats that respond to population density and exploitation in a manner consistent with Allee's principle (after Sutherland 1996: 11 and Fretwell and Lucas 1970: 25). In this situation, individuals will settle in habitat 1 (H1) and enjoy an increase in suitability of their habitat (with growing density) until they reach a population density threshold. This increase in suitability may also be termed 'secondary suitability'. Further increases in population density will decrease the secondary suitability of H1 until population density A, when the suitability in H1 equals the suitability at zero density in H2. With a further increase in population size, individuals will now settle in H2 and H1. However, in accordance with Allee's principle, the suitability of H2 is *increasing* with a

growing population, while the suitability of H1 is decreasing. Secondary suitability is higher in H2 than at H1 at this point, so it becomes advantageous for individuals to move from H1 to H2. With the assumptions of the ideal free distribution, individuals will continue to move into H2 until the suitability in H2 reaches its threshold. At that point, individuals will fill both habitats so that the marginal suitability of the two is equal (see above). The model predicts that due to these changes in suitability, even a very small change in population density may result in a very large change in distribution (Fretwell and Lucas 1970).

As shown above, land use patterns in Valencia change from Neolithic I to Neolithic II. The ideal free distribution model provides a theoretically grounded framework for understanding the settlement shift visible in the Neolithic. It identifies a set of factors and processes that may be influencing habitat selection and population distribution, and makes predictions about how these should change with changes in population density, habitat suitability and related factors. Habitats will be settled in order of their basic suitability, and will be occupied in densities that equalize their marginal suitabilities. Livestock management involves use of the landscape to ensure that domestic animals are an economically viable resource. This spatial component of animal management is an important factor in estimating a habitat's suitability. Neolithic domestic animals of eastern Spain provide different meat yields. They also have differing potentials to provide secondary products and their lifespans and survival needs may be more or less suited to subsistence practices more generally practiced by farmers. Similarly, animal management strategies—and their attendant costs—also vary according to taxa and according to the ways in which animals are used. The management strategies employed for domestic animals influences the suitability of a habitat. Below, we examine the potential returns and costs of Neolithic animal husbandry in eastern Spain. Subsequently we examine the spatial components of animal management and their implications for habitat choices in light of the IFD.

Managing Domestic Animals in Spain

The diachronic patterns evident in faunal assemblages suggest changes in animal management during the course of the Neolithic, with pigs and cattle becoming a greater

percentage of domestic animal assemblages in the Neolithic II. In order to understand these changes, we summarize the temporal and spatial implications associated with the documented shifts in domestic animal assemblages at Neolithic sites. In the following, we look at some of the behavioral characteristics of each of the domestic animals found in Neolithic Spain to gauge the spatial and temporal needs that farmers had to reconcile to make animal management a worthwhile endeavor.

Cattle

Prior to their extinction in the 17th Century, aurochs (*Bos primigenius*), ancestors of domestic cattle (*Bos taurus*) were found extensively across Europe, including Spain. Prehistorically and historically, wild cattle are most commonly associated with wooded landscapes. Since cattle lack upper incisors, they primarily rely on plants that are easily torn, such as grasses, leaves, and the branch tips of woody plants.

The domestic cattle found in Neolithic contexts are thought to have been introduced from the eastern Mediterranean (Bernabeu 1995; Martí 1998; Pérez 2002) and not domesticated locally despite the presence of wild cows in the region prior to the Neolithic. Cattle are present in low frequency in Valencian Neolithic I, but their importance increases notably during the Neolithic II. Furthermore, kill patterns document a change in herd management in the Neolithic II, when more animals reached adulthood, indicating a shift from use primarily as a meat source to also include milk production and labor (Bernabeu 1995; Pérez 1999). The latter is clearly supported by bone pathologies on the articulations of extremities found only in Neolithic II assemblages that seem to indicate use as draught animals for plows and/or carts (Pérez 1999).

Modern cattle do not have a specific breeding season and calving can occur at any time (Gregg 1988: 103). Farmers, however, can control the breeding season by restricting a bull's access to heifers. This provides farmers the opportunity to dictate when calves and associated lactation take place. On the other hand, it also means that a farmer must spatially separate the bulls and heifers to create a breeding season. This means a greater investment in pens to keep the animals separate.

Cattle provide farmers with a wide array of products, such as meat, milk, blood, leather, bone, and labor. Gregg (1988) has tabulated the amount of meat and milk production a herd of cattle would provide, as well as its required grazing area. Our estimates are taken from Gregg (1988) and based on modern, unimproved cattle (Dyson-Hudson and Dyson-Hudson 1970) and estimates of Neolithic cattle sizes. On average, a single mature cow can provide 1.78 liters of milk surplus daily and a meat offtake of ca. 225 kg, while requiring an average of 1.5 ha (3.7 acres) of pasture (Bakels 1982) or 1 ha (2.47 acres) of forested land per month for grazing (Bogucki 1982) (Table 2). Steers or castrated bulls are difficult to identify archaeologically (Grigson 1982), but they provide a range of advantages to farmers. Castration speeds weight gain in cattle and makes the animal easier to handle. An older steer, also called an ox, provides the strongest and most reliable source of labor.

Sheep and Goat

Although mountain goats (*Capra pyrenaica*) were present in Valencia during the early Neolithic, domestic goats (*Capra hircus*) were introduced to the region from the Near East (Nguyen and Bunch 1980; Pérez 2002) and not domesticated locally. Domestic sheep and goats (ovicaprids) combined dominate all of the Neolithic I and II faunal assemblages in the Province of Valencia, comprising 48-78% of domestic animal assemblages (Figure 2), and show an increase in the ratio of sheep to goats through time (Bernabeu 1995; Bernabeu and Pascual 1998; Pérez 1999).

After bearing young (1-2 per year), sheep lactate for an average of 135 days, whereas goats lactate for 210 days. In terms of milk for human consumption, Redding (1981) estimates that the daily average of milk from sheep is 0.33 l and goats is 0.38 l. The meat offtake is approximately 50% of the live weight, resulting in ca. 12 kg for adult females and 5 kg for lambs and kids (see Gregg 1988) (Table 2).

Changes in slaughter patterns of both sheep and goat suggest a corresponding change in herd use between the Neolithic I and II. In the Neolithic I site of Cova de l'Or (ca. 5500-4900 BC) the vast majority of ovicaprids killed were under 3 years of age (Bernabeu 1995). This pattern is found at other Neolithic I cave sites throughout the Mediterranean, and contrasts with Neolithic II villages, where the majority of animals

were harvested after reaching adulthood (Bernabeu 1995). As with cattle, this pattern suggests the increased use of secondary products (milk products, wool) in addition to meat.

Pigs

Wild boar (*Sus scrofa*), the ancestor of the domestic pig (*Sus domesticus*) is found throughout the European continent and remains a popular game animal in Valencia. It is very difficult to separate the two species in archaeological assemblages, which has led some researchers to argue for an indigenous domestication or very late introduction of domestic pigs in parts of the western Mediterranean (e.g. Rowley-Conwy 1995). However, the introduction of pigs to Mediterranean islands as part of an initial agricultural package is well documented (Pérez 2002), and substantiates the possibility that pigs were introduced in other parts of the western Mediterranean as well. In Valencia, it is generally assumed that domestic pigs were introduced along with the suite of domestic animals, and the separation of wild and domestic animals in archaeological sites is based on osteological metric analyses. Throughout the Valencian Neolithic, pigs comprise the next largest percentage of domestic faunal remains at archaeological sites after combined ovicaprids, although cattle come to nearly equal pig remains in some Neolithic II contexts (Bernabeu 1995).

Meat production is the primary advantage of pig farming. Pigs are the most prolific breeders of all domesticates in the western Mediterranean (up to 15 piglets a year). Pigs can live up to 20 years, maturing rapidly, and provide the highest caloric meat yield of any of the available domesticates. Prehistoric pigs were much smaller than modern pigs, and their meat offtake per adult animal is estimated at ca. 15-25 kg (Glass 1991; Gregg 1988; Jacomet and Schibler 1985; Müller 1985) (Table 2). Furthermore, pigs are omnivorous, preferring nuts and fruits, and can convert refuse and spoilage into a nutrient rich food source.

However, keeping pigs has its challenges. As Zeder (1996, 1998) points out, pigs have higher water requirements, a lower heat tolerance, and cannot convert cellulose-rich grasses into proteins. Hence in arid environments they are usually kept close to home with access to shade and wallow (Zeder 1998). Pigs congregate in smaller groups and

follow a dominant individual, often an older sow. This tracking behavior is easily transferred to a human swine herder (Zeder 1996). Pigs are not easily moved over great distances unlike other domesticates being discussed here. It is likely that during the Neolithic, movement was limited to short seasonal trips between river bottoms and oak forested hillsides (Zeder 1996).

The role of secondary products

One of the most long-standing discussions in studies on Old World domestic animals is the question of secondary products. To what extent were milk and wool important products of early domesticates? Did these influence decisions to domesticate or adopt certain species, and if so, how? Sherratt (1981) systematically called the use of secondary products in early Neolithic times into question. His study compiles the evidence for the use of the plow and cart and the production of milk and wool in the Old World, with emphasis placed on the Near East and Europe, and concludes that secondary products only came into use several millennia after the spread of agriculture, well into the Valencian Neolithic II. Pictorial documentation from archaic Sumerian Uruk in southern Mesopotamia and pictograms on Akkadian period cylinder-seals from Mesopotamia and Assyria show that the plow and cart were in use by the third millennium BC. Archaeological evidence in central Europe dating to the third millennium BC and later, in the form of grave goods, ceramic vessel design, and rock art, show cattle yoked to carts or plows. In regard to domestic animal products, Sherratt suggests that milking and wool manufacture were a late development in animal domestication. Early domesticates were not genetically modified enough to provide good and stable sources of milk and wool. Wooly sheep are a late phenomenon, appearing after several millennia of human selection. In terms of milk, Sherratt points to lactose intolerance among humans and low yields among animals as the main deterrents of early production practices. He argues that these characteristics emerged through time by active human selection of animal populations. A decrease in lactose intolerance and concurrent manufacture of milk products, in turn, is the result of millennia of human-animal interrelationships.

However, many of his arguments have been questioned, especially by archaeologists working in Europe (e.g. Gregg 1988; Rowly-Conwy 1995). Historic

documents exist only from the third millennium BC onwards, and therefore serve as a *terminus antes quem*, rather than a dating of the use of secondary products. Furthermore, there is disagreement over the influence of lactose intolerance on the generation of milk products. Fermented milk products, such as cheese and yogurt, have a lower lactose content than milk (McCraken 1971; Sherratt 1981). Indeed, despite high levels of lactose intolerance, modern populations continue to consume fermented milk products. In addition, Sherratt himself argues for milk product consumption after the third millennium BC. Despite presumed evolutionary changes in cattle during the Neolithic (Sherratt 1981:276), it still remains unclear why milk manufacture could only have taken place after several millennia of agriculture.

In addition to meat, cattle may provide milk and labor. The identification of milk production in archaeological contexts is difficult, and is mostly based on herd composition through the identification of kill patterns. The use of cattle (especially steers or oxen) for labor can be deduced from kill patterns as well as bone pathologies caused by physical stress. Sheep and goats also may be kept for milk and wool. Wool production is very difficult to identify directly archaeologically, and is usually indicated by textile production artifacts, such as spindle whorls or loom weights. Finally, while pigs provide a very stable and secure source of meat, they do not offer any other services or products other than refuse management.

Table 3 shows a ranking of domestic animals found in the Valencian Neolithic. In terms of caloric returns from meat alone, cattle rank the highest, followed by pigs, and then ovicaprids. The ranking changes when secondary products are added to the mix of energy return potential. When ranked by milk yield, cows again rank highest, followed by goat and sheep. However, when ranked by the energetic rate of milk (kcal/kg), sheep rank highest, followed by cow and goat. In terms of reproductive capacity, pigs rank the highest of all of the domestic animals available. The finite rate of increase (Table 2; Russell 1988) shows the average rate at which a herd might grow. These data are not available for pigs, but differences in rate of increase are visible between goat (the highest), sheep and cows. The risk of herd loss was likely another element playing into agropastoralists' decisions at the time. Species react differently to climatic fluctuations, and management strategies may be influenced by pastoralists' desire to maximize herd

stability (Redding 1981, 1982; Mace and Houston 1989; Mace 1990, 1993a, 1993b). The relative importance of domestic animals based solely on meat offtake is very different than if milk and reproductive capacity are considered.

Animal management costs

      As previously mentioned, managing domestic animals must take into account total extraction costs as well as returns. Time and labor for butchery and meat preparation should be generally equivalent to the extraction costs incurred for wild animals. However, herd management and its attendant costs can vary between domestic taxa, including the extraction and processing of some secondary products - especially milk, wool, and animal labor. In terms of management strategies, the domestic animals of Neolithic Valencia have different life histories and behavior, which, to a large extent, define a set of temporal and spatial needs that must be maintained and organized by a farmer.

      Although pigs are comfortable foraging in woodland areas, they are difficult to supervise in such contexts - entailing search costs if humans are to harvest their meat. Therefore, domestic pigs are generally kept close to houses for use in refuse management, and, due to their need for shade and wallow, pig often require some architectural investment (e.g., a sty). Furthermore, pigs are not very mobile and require at least a part of the household to remain in proximity to the habitation.

      Sheep and goats are much more mobile than pigs, and can be taken to a wide range of areas for long or short stays. However, these animals consume relatively large amounts of cellulose-rich plant materials (one hectare grazing area can supply 150kg cattle vs. 133 kg sheep or goat meat offtake; Gregg 1988) and must be brought into fresh pasture regularly. Due to their agility, goats can reach leaves of trees and shrubs inaccessible to sheep, which allows them to forage more diverse resources. On the other hand, sheep move and feed in fairly tight groups and can graze in open vegetation more efficiently than goats (Halstead 1981:324; Williamson and Payne 1965:284-5). Sheep and goat ratios therefore inform us not only of the herd management goal (herd stability or protein maximization, see Redding 1981, 1982), but also of a farmers' spatial organization.

In a meat production strategy, herds of sheep and goats are kept small and many young animals are slaughtered at an early age. Only a few animals are allowed to mature to adulthood, providing greater meat packages and ensuring the reproductive survival of the herd. In a milk producing strategy, more lactating females are kept and herds are generally larger. Kill patterns show a preference for adult animals. Bucks and rams are lone animals, so in both strategies a spatial segregation between them and the does/ewes and young is expected. This separation can occur with relatively little investment by the farmer. However, the animals must be kept out of fields. Depending on the size of the herd, this may mean tethering the animals individually, or constructing a corral. Alternatively, people may erect fences around their fields to keep out all free-ranging herbivores (wild or domestic). In either case, some sort of supervision while grazing near fields is necessary, and these options are potentially visible archaeologically.

Of all the domestic animals available in the Valencian Neolithic, cattle have the highest time and space requirements. As stated earlier, calving can occur at any time of the season, so if a farmer wants to control herd size and calving season, bulls and heifers must be kept apart from one another. Although they need less fodder per unit of body weight than sheep and goats (Clutton-Brock and Harvey 1978; Halstead 1981), cows require large amounts of grazing area and/or leafy fodder. Also, they cannot thrive in a range of diverse vegetation communities as ovicaprids.

In a meat management strategy, cattle herds are small and consist of a bull and several heifers, with calves slaughtered at a higher rate. In a milk production strategy, more heifers must be kept to produce sufficient milk, increasing the grazing area needed. If oxen are kept for labor, these too need space for grazing away from plots, although the grazing area may be supplemented by bringing fodder to the animals. All of this requires an infrastructure and labor investment much greater than for the other animals.

Management costs seem notably lower for ovicaprids than for other Neolithic domestic animals in Mediterranean environments. They can be supported on small patches of landscape and on more diverse forage than cattle. Their smaller size and more regular breeding schedule also make them more manageable. While cattle better survive the cool humid climates and dense forests of northern and central Europe, they lose this advantage in the mesic and seasonally arid Mediterranean. Ovicaprids are not as prolific

as pigs, but they require fewer built and maintained facilities and can thrive in a wider variety of habitats. Although ovicaprids do not consume refuse like pigs do, neither do they potentially compete with humans for food as do the omnivorous pigs.

We hypothesize that these overall lower management costs gave ovicaprids a net higher return across the Mediterranean in the early phases of the Neolithic, in spite of lower package size than cattle and lower reproduction rate than pigs. The potential for milk and wool secondary products helped maintain this high ranking over time in the Mediterranean. In the Neolithic II of Valencia, however, socioeconomic changes in the form of population aggregation and associated shifts in settlement in conjunction with different agricultural practices increased the net return rate of both cattle and pigs relative to ovicaprids. In a positive feedback relationship, these latter domestic taxa also helped to make these changes possible. Below, we discuss how the ideal free distribution concept provides a heuristic structure to address the interrelationships between cultivation, animal management, and long-term dynamics of human land use in the Neolithic of the western Mediterranean using this consideration of the relative costs and benefits of each of the domesticated resources (Table 3).

Domestic Animals, Land Use and Ideal Free Distribution during the Valencian Neolithic: A Model of Change

As described above, the Neolithic I agricultural strategy may be characterized as a dispersed settlement focusing on the most productive landscape patches for hoe-agriculture, complemented by relatively small numbers of domestic animals. Of the domestic species available, sheep and goats were favored because of their low management costs. Neolithic I farmers utilized few high-ranking patches per household in an intensive fashion, farming a patch until a fertility decline made it more productive to shift to another equally high-ranking patch. In terms of the ideal free distribution, we see these patches as being part of one habitat (Figure 5, H1). We have argued that domestic animals were kept for meat production. Sheep and goats complimented the plant management strategy by allowing humans to harvest resources in patches that would rank low for hoe-agriculture, such as abandoned fields and upland areas beyond the easily cultivated valley bottoms. In this context, sheep and goat would have been

more favorable than higher-ranking cows and pigs by minimizing the area needed for pasture and fodder. Sheep and goats also are easily moved from one area to another. Farmers could thus convert inedible vegetation into meat and access wild resources not available in the valley bottoms by letting their livestock graze in these upland areas.

However, this strategy had some long-term and unforeseen consequences. Sheep grazing closely crop ground foliage, preventing the regeneration of seedlings, while goats preferentially browse leaves and twigs, especially new foliage, preventing seed generation. By farming more productive alluvial soils in the valley bottoms and then shifting these fields to intensive pasture for sheep and goat, where the latter are particularly efficient foragers, the lands were at a higher risk of major erosion during the winter rainy season when vegetation cover is at a minimum. Deforestation and increased sediment transport is evidenced by palaeobotanical and palynological data by the end of the Neolithic I (e.g., Badal 1990; Badal et al. 1994; Bernabeu and Badal 1990; Dupré 1988; Fumanal 1986; Fumanal and Dupré 1986). Changes in human population density would further have complicated this situation. Figure 5 shows the decline in the suitability of H1 with increased population density. Over time, high-ranking patches for hoe agriculture became scarcer, while sheep and goat grazing impacted areas farther afield. In essence, this farming strategy likely was an unintentional, expansive process with irreversible ecological consequences that resulted in the decline of suitability for this habitat. Notably, this was not simply a population-dependent decline in suitability, as indicated for classic ideal free distribution modeling described above, but a reduction of basic suitability that permanently lowered the ability of this habitat to support agropastoralists independent of subsequent shifts in population density.

The long-term response to the growing shortage of patches suitable for the Neolithic I agricultural pattern was to begin exploiting another habitat (Figure 5, H2) for agriculture during the Neolithic II. This was accompanied by more extensive clearance of woodland and use of ox-drawn plows. In some respects, this also represents a different socioecological niche. Originally unoccupied, at some point in the late Neolithic I, the suitability of the valley margins (H2) began to match that of the heavily exploited and depleted riverine floodplains (H1). Due to the permanent drop in the suitability curve for H1 habitats favored by Neolithic I agropastoralists, the new H2

habitats occupied by Neolithic II populations - and their new socioecological niche - remained favored over alternative habitats even with subsequent density-related declines in suitability. The Allee effect (Figure 5) for H2 is based on the necessary investments made in agricultural architecture, such as terracing. As is often the case in a shift to another habitat, occupation of this habitat entailed greater labor input per return with more extensive land-use, now a tactic comparable in returns to the best yields available in the more localized but depleted bottom lands. Numerous large storage pits at Les Jovades testify to sustaining a sizable sedentary population (Bernabeu 1993, 1995; Bernabeu and Pascual 1998; Pascual 1989). Archaeological evidence from a number of cave sites shows a shift in use of caves as corrals for sheep and goats during the Neolithic II (Badal 1999). The labor investment in constructing corrals suggests that larger herds of livestock were kept in the cave for longer periods of time. Farmers were thus using areas farther from villages for prolonged periods of time. These corrals would house ovicaprids while farmers could hunt and gather in upland areas.

This shift also had other, associated repercussions to human subsistence economy. These changes conform to predictions of other behavioral ecology models, especially the diet breadth model of Optimal Foraging Theory. In Neolithic I contexts, the success of *el huerto* agropastoralism made a few domesticates a high ranking set of resources - i.e., a high caloric return for labor invested in cultivation and processing - with a corresponding reduction in diet breadth over prior Mesolithic foragers. The subsequent decline in the productivity and availability of *el huerto* habitats of highest suitability (H1) may have meant a corresponding change in the use of domesticates as labor investment costs increased relative to caloric return with the shift to extensive Neolithic II agropastoralism.

The diet breadth model predicts that people will diversify their diet in response to the loss of high-ranking resources. In fact, some evidence suggests that one of the behavioral responses of farmers to these challenges during the Neolithic II may have been a notable increase in the use of wild plants and animals while tending domestic animals away from villages (Martí and Juan-Cabanilles 1987: 119-124). This is a counter-intuitive pattern for an expanding agricultural economy, but in line with predictions of foraging theory. As the overall return of the subsistence system declined,

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resources formerly neglected because of low value relative to pursuit and handling costs should now become attractive. A more geographical consideration may also be important here: relocation to valley margins may have put people into closer proximity to species newly attractive to collectors.

Consistent with the Allee effect, we propose that the suitability of this new habitat for farming activity (Figure 5, H2) began to rise thanks to labor investment, improved technology, and changes in domestic animal management. Domestic animal management shifted from a focus on meat-production to meat and milk production strategies, with a greater use of cows and pigs. In conjunction, a more fundamental reorganization of scheduling and labor may have accompanied the economic changes. With a greater number of animals more to the settlement or household than in the Neolithic I, different members of a family (e.g., the young or old) may have been charged with activities such as feeding and milking, while others may have invested more time and labor into the construction of corrals and pens. Scheduling of activities would have been dictated in part by the animals' needs and in part by the demands of more extensive plant agriculture.

Mace (1993a, b) and Mace and Houston (1989) offer additional explanations for this kind of shift in strategies related to long-term viability of households. Reasons for such a shift could include changes in risk management strategies based on household wealth and a greater investment in farming as the subsistence focus. For instance, Mace and Houston (1989) demonstrate that in their study area in sub-Saharan Africa the optimal ratio of camels to goats for long-term household viability depends on total household wealth. The probability of a household remaining viable is dependent on the number and type of stock held. Their model predicts the herd species composition that a household should keep to maximize its long-term viability and how this is influenced by changes in household wealth (Mace and Houston 1989: 187-188). Goat herds grow at faster rates than camel herds, but they are more liable to heavy losses in droughts. In addition, camels have higher food yields (1:8 ratio) and can be traded for a greater amount of other food sources than goats (Mace and Houston 1989: 189-191; tab. 1). Based on these parameters, the optimal species mixtures vary depending on general household wealth. Poorer households should not invest in camels until total livestock

wealth is well above the minimum wealth at which a household could theoretically exchange goats for a camel (Mace and Houston 1989:192). After this point, the majority of the household's wealth should be invested in camels. In times of household wealth decline, camels can then be exchanged for goats, investing in camels again only when the herd size has increased. Mace and Houston's (1989) study is particularly interesting in light of herd management changes during the Neolithic in Valencia. The increase in high yield, but higher risk cattle relative to sheep and goats in the Neolithic II may be an indication of greater household wealth than in the Neolithic I. A complementary idea focuses on the role of farming relative to domestic animal management (Mace 1993a,b). Shifts in farming practices in the Neolithic II, such as use of the plough, may have increased agricultural yields and provided the basis for increased household wealth, allowing the animal management strategy to shift towards high yield, high risk cattle. If Neolithic II households were indeed wealthier than in the Neolithic I, new light would be shed on other socioeconomic changes documented during the Neolithic II, such as the emergence of social hierarchies and the development of long-distance exchange. At present archaeological data are lacking to test this hypothesis, but it remains an intriguing idea.

Furthermore, during the Neolithic II, land-use broadened to include upland areas with marginal soils in plant agriculture as well as grazing areas for animals in an extensive manner. This strategy is analogous to a shift to central place foraging (e.g., Barlow 2002; Cannon 2003; Grayson and Cannon 1999). People appear to have aggregated in locales best able to exploit remnant valley bottoms, extensive upland fields, and a new environmental mosaic, created largely by human activity, for a differently balanced suite of domestic animals (Figure 6). The IDF model also shows that changes in population density, although a factor in settlement shifts, did not have to be large in order to produce a great shift in land use. A marginal increase in population density in the Neolithic I habitat (valley floors) may have prompted initial settlement of valley margins, where a growing population began using the oxen-drawn plough and may have constructed terraces, enhancing the secondary suitability of the habitat. This process would appear as a qualitative shift and may have rapidly drawn population and settlement away from the riverine margins.

Conclusions

In this chapter we have attempted to illustrate how ideas from behavioral ecology, specifically the ideal free distribution, can be used heuristically to address fundamental issues in the transition to agriculture in eastern Spain. The Neolithic in Valencia is characterized by the quick and early emergence of production-based economies in the Neolithic I (by 5600 BC) and the slow development of aggregated village communities and associated shifts in habitat in the Neolithic II. By looking to habitat selection models, behavioral ecology has given us a theoretically grounded framework to analyze changes in settlement and subsistence practices as phenomena that are inextricably linked. Our study has shown that when the valley floors used intensively by Neolithic I farmers declined in suitability, they were faced with the challenge that their farming strategy, which was stable for more than a millennium, was no longer viable. In response, people in the Neolithic II shifted to a second habitat (valley margins) that increased in its secondary suitability through the adoption of a new technology, the plough, and possible investment in agricultural architecture. Farmers changed their habitats, intensified their domestic resources in innovative ways by shifting domestic animal management strategies and expanded their use of the landscape. Changes of household wealth during the Neolithic II may help explain the shifts in animal management strategies, but hypotheses remain to be tested. Despite the stability of Neolithic I farming strategies, it is this Neolithic II pattern that remained a stable strategy for many millennia afterwards with irreversible ecological consequences, and has created much of the modern Mediterranean landscape. Behavioral ecology has given us a set of tools to examine a fundamental shift in human prehistory from a different perspective, and provided new questions to be examined with the archaeological record.

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Figures

Figure 9.1. Archaeological sites in Valencia mentioned in text.

Figure 9.2. Relative percentage of identified domestic faunal remains from seven sites in Valencia. Parentheses indicate chronological placement of site (after Bernabeu 1995; Bernabeu and Pascual 1998; Pérez 1999).

Figure 9.3. Ideal free distribution model (after Fretwell and Lucas 1970: 24; Sutherland 1996: 5).

Figure 9.4. Allee's principle (after Fretwell and Lucas 1970: 25; Sutherland 1996: 11).

Figure 9.5. Adapted ideal free distribution and Allee's principle models for the Neolithic in Valencia, Spain. Habitat 1 (H1) represents settlement during Neolithic I, habitat 2 (H2) represents the Neolithic II settlement pattern.

Figure 9.6. Idealized Neolithic subsistence systems in Valencia, Spain

Tables

Table 9.1. Chronology of the Neolithic in Valencia, Spain.

Table 9.2. Domestic animal products, area requirements, and birthing rates. Unless otherwise noted, data from Bogucki (1982) as summarized in Gregg (1988). Note values for pig (*Sus domesticus*) are estimates for smaller, prehistoric pigs as opposed to modern breeds (Bogucki 1982).

Table 9.3. Domestic animals in descending rank order according to different characteristics (compiled from Gregg 1988; Glass 1991; Redding 1981; Russell 1988).
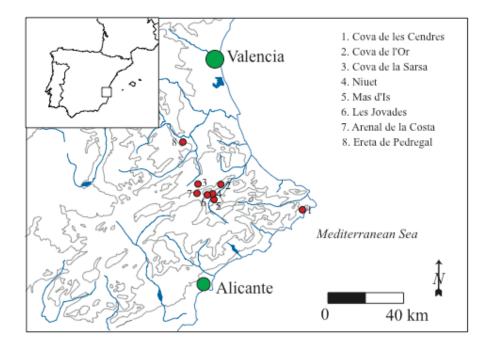
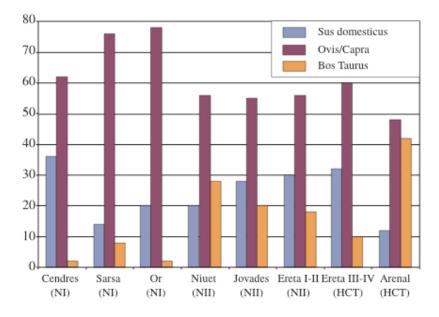Figure 1. Location of sites mentioned in text.

Figure 2. Relative percentage of identified domestic faunal remains from seven sites in Valencia.
Parentheses indicate chronological placement of site (after Perez 1999).
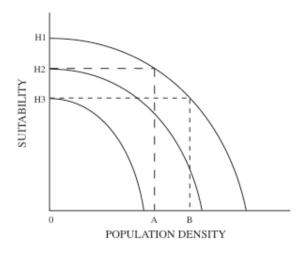
9-37

Figure 3. Ideal free distribution (after Fretwell and Lucas 1970: 24; Sutherland 1996: 5)
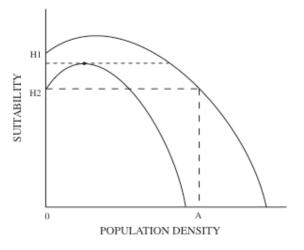

Figure 4. Allee's principle (after Fretwell and Lucas 1970: 25; Sutherland 1996: 11)
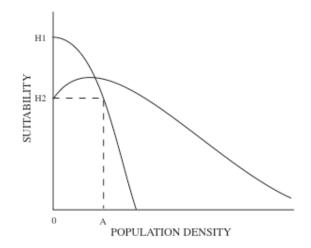
Figure 5. Adapted Ideal free distribution and Allee's principle models for the Neolithic in Valencia, Spain. Habitat 1 (H1) represents settlement during Neolithic I, habitat 2 (H2) represents the Neolithic II settlement pattern.