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Abstract

Although difficult to estimate for prehistoric hunter-gatherer populations, demographic variables—population size, density, and the connectedness of demes—are critical for a better understanding of the processes of material culture change, especially in deep prehistory. Demography is the middle-range link between climatic changes and both biological and cultural evolutionary trajectories of human populations. Much of human material culture functions as a buffer against climatic changes, and the study of prehistoric population dynamics, estimated through changing frequencies of calibrated radiocarbon dates, therefore affords insights into how effectively such buffers operated and when they failed. In reviewing a number of case studies (Mesolithic Ireland, the origin of the Bromme culture, and the earliest late glacial human recolonization of southern Scandinavia), I suggest that a greater awareness of demographic processes, and in particular of demographic declines, provides many fresh insights into what structured the archaeological record. I argue that we cannot sideline climatic and environmental factors or extreme geophysical events in our reconstructions of prehistoric culture change. The implications of accepting demographic variability as a departure point for evaluating the archaeological record are discussed.

Keywords

14C dating, demography, prehistory, climatic stress, Mesolithic, Paleolithic, Ireland, Bromme culture, Scandinavia.

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FELIX RIEDE[1]

Abstract Although difficult to estimate for prehistoric hunter-gatherer populations, demographic variables—population size, density, and the connectedness of demes—are critical for a better understanding of the processes of material culture change, especially in deep prehistory. Demography is the middle-range link between climatic changes and both biological and cultural evolutionary trajectories of human populations. Much of human material culture functions as a buffer against climatic changes, and the study of prehistoric population dynamics, estimated through changing frequencies of calibrated radiocarbon dates, therefore affords insights into how effectively such buffers operated and when they failed. In reviewing a number of case studies (Mesolithic Ireland, the origin of the Bromme culture, and the earliest late glacial human recolonization of southern Scandinavia), I suggest that a greater awareness of demographic processes, and in particular of demographic declines, provides many fresh insights into what structured the archaeological record. I argue that we cannot sideline climatic and environmental factors or extreme geophysical events in our reconstructions of prehistoric culture change. The implications of accepting demographic variability as a departure point for evaluating the archaeological record are discussed.

Culture can usefully be conceptualized as a system of information transmission across generations that takes on Darwinian properties, because it displays features of variation between individuals, heritability of traits, and differential representation of these traits between generations (e.g., Boyd and Richerson 1985; Cavalli-Sforza and Feldman 1981; Eerkens and Lipo 2007; Richerson and Boyd 2005; Shennan 2002). If cultural change, then, is seen as evolutionary change, it is important to incorporate explicit notions of demography into explanations of what shapes these trajectories (Metcalf and Pavard 2007; Shennan 2000). The demographic dynamic of a given population is the sum of the life-history decisions made by individuals within this population and their effects on total patterns of

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fertility, survival, and migration. It forms the interface between the environment, which provides individuals with clues informing their life-history strategies, and society, which both shapes and is shaped by demographic processes: (Historical) demography effectively is (past) human ecology (Swedlund 1978; Voland 1998). Through censuses, parish records, and cemetery data, such values can be estimated—with great difficulty (Bocquet-Appel and Masset 1982, 1996)—for historic periods (see Chamberlain 2001, 2006; Imhof 1977), and in well-sampled regions at least this has resulted in useful syntheses of past demographic patterns (e.g., Bernardi and Hutter 2007).

However, a realistic estimation of demographic parameters for individuals and populations in early prehistory remains extremely challenging. The skeletal record for any population before the emergence of sedentary agricultural communities is so sparse and biased as to be virtually useless for demographic inferences. In addition, when dealing with premodern hominids, we cannot be certain how far present life-history patterns can be extrapolated into the past (e.g., Kennedy 2003; Key 2000). The steep increase in the availability of both modern and ancient genetic data has offered one way forward. Both data sets can be used to examine past demographic patterns [see, for instance, Wilson et al. (2001) and Forster (2004) for modern DNA and Haak et al. (2005) and Rudbeck et al. (2006) for ancient DNA], but they remain strictly inferential and are fraught with technical difficulties. In addition, patterns in the genetic record are at risk of being overinterpreted when they are equated with archaeological cultures or the like (e.g., King and Underhill 2002; Töpf et al. 2006; Zvelebil and Pettitt 2006).

In light of these methodological challenges, how can demography be assessed as an analytically useful variable in early prehistoric contexts? Beginning with the pioneer contribution of Clark (1965), investigators have used radiocarbon dates, coarsely, to examine large-scale trends in migration and, in relative levels, in population activity in space and time. Recent years have seen a great expansion in efforts to model past demography using ^{14}C dates, especially for the Neolithic (e.g., Bocquet-Appel et al. 2009; Gkiasta et al. 2003; Kuper and Kröpelin 2006; Shennan and Edinborough 2007) and late Paleolithic [e.g., Gamble et al. 2004, 2005, 2006; Housley et al. 1997; see also the review by Surovell and Brantingham (2007)]. The argument is that calibrated radiocarbon dates can serve "as proxies for population history at a regional scale" (Shennan and Edinborough 2007: 1344), especially when the data sets are sufficiently large to minimize potential sampling uncertainties. These studies examine broad trends in radiocarbon date frequencies on a continental level and point to a fairly high level of correlation between climatic trends and events with the modulations of these frequencies. This is interpreted as providing strong support for a general link between climate patterns and past human demography.

Although these suggestions are intriguing, the method itself has not gone unchallenged. In investigating the radiocarbon record of late prehistoric Ireland, Turney et al. (2006: 34), for instance, suggested that although "environmental change is a significantly more important factor in influencing human activity in the landscape than has hitherto been acknowledged," the curvilinear relationships, which are often interpreted as demographic fluctuations, are a product of targeted taphonomic bias. They argued that "stable, unstressed societies [are] archaeologically poorly visible in comparison with the increased visibility during periods of environmental downturn" because the economic mediation strategies adopted by societies under stress coincidently raise their archaeological profiles. It should be noted, however, that Turney et al.'s interpretation addresses specifically agricultural and in particular post-Neolithic societies in the temperate environs of Ireland. It is not clear, therefore, whether the correlation between environmental deterioration and archaeological visibility should be seen as a universal mechanism and what bearing this proposition has on early prehistoric contexts. In fact, as I attempt to show later, the ^{14}C record of early prehistoric Ireland yields a strong signal of population fluctuation, with periods of increased environmental stress linked to reductions in radiocarbon dates.

A broader criticism has been voiced by Surovell and Brantingham (2007) and Surovell et al. (2009), who claim that taphonomic biases distort the record of past human presence to such a degree that chance alone produces fluctuations in radiocarbon date frequencies and such that the record is invariably favored toward more recent sites. Their model is a general one, but these criticisms do flag the need for a better mechanistic link between climatic change and fluctuating human demography, a more thorough scrutinizing of any given radiocarbon date sequence under study, and, as Surovell and Brantingham suggest, the use of external data to aid in discriminating between demographic and alternative taphonomic interpretations of fluctuating probability frequency distributions.

In this paper I attempt to address these reservations by first providing an ethnographically derived framework model for how forager populations respond demographically to climatic changes. I argue that population instability and demographic or cultural collapse are key factors in understanding hunter-gatherer population dynamics and their archaeological signatures, but I also note that "although ultimately environmentally driven, the operative factor resulting in cultural failure is social" (Mandryk 1993: 67). Such cultural failure can precipitate archaeologically as regional depopulation, site abandonment, or the change or disappearance of particular tool-making traditions, as suggested by Henrich (2004), but it can also lead to the collapse of reproductive networks and thus to biological change in the form of local extinction. Conversely, cultural elaboration and the success of particular manufacturing traditions or styles is often linked to positive demographic trends (Ghirlanda and Enquist 2007; Shennan 2000, 2001). In reviewing three case studies of successively greater antiquity—Mesolithic Ireland in the Holocene, the origin of the Bromme culture in the late Allerød, and the earliest late glacial human recolonization of southern Scandinavia during the Older Dryas/Bølling—I intend to illustrate the utility of calibrated radiocarbon dates as useful approximations of past demographic trends.

In the first case study, Mesolithic Ireland, I argue that even during the relatively mild and stable Holocene, forager populations were vulnerable to climatic changes, especially when they were geographically isolated (Riede et al. 2009; see also Gulløv 2000). In the second case study, the Bromme culture, I explore the demographic responses of hunter-gatherers to a particular geophysical event, the Laacher See volcanic eruption and its attendant climate changes (Riede 2007a, 2008). This case study is used to highlight the sensitivity of the approach to different scales of analysis. In the third case study I explore the pioneer colonization of southern Scandinavia by specialized hunter-gatherers of the so-called Hamburgian tradition. First colonizers operating at the margins of human habitat are particularly susceptible to stochastically induced demographic fluctuations and suffer more readily from social (i.e., informational and demographic) isolation (Whallon 2006; Wobst 1974, 1976), which in this case, I argue, had catastrophic social and biological consequences (Riede 2005, 2007b, 2009a).

Together these case studies form a gallery of recent uses of calibrated radiocarbon dates as proxies for human demographic dynamics in early prehistory. If the link between material culture change and demographic fluctuations is accepted, many other earlier periods of prehistory open themselves up to reinvestigation because we can begin to use changes in material culture as proxies for demographic trends. Models of premodern hominid population dynamics strongly suggest that regular local or regional extinction and repopulation dynamics were common (Eller 2002; Eller et al. 2004). These demographic punctuations may have been in response to steep climatic gradients that exerted considerable stress on hominids (e.g., Stringer et al. 2004); they may have been linked to extreme geophysical events, such as volcanic eruptions (e.g., de Lumley et al. 2008; Petraglia et al. 2007), which were much more common during the Quaternary than is often assumed by many archaeologists (see Bryson et al. 2006); or they may have occurred in the context of repeated colonization attempts into middle to high latitudes (Bar-Yosef and Belfer-Cohen 2001; Dennell 2003). In the final section of this paper I conclude with a number of suggestions outlining potential case studies for future consideration and methodological improvements that could further increase our confidence in demographic reconstructions of early prehistory beyond the use of calibrated radiocarbon dates.

Hunter-Gatherer Demography and Climate Change

Forager population densities are strongly linked to the biotic diversity of the niche in which they live (Kelly 1995). Computer simulations and ethnographic and ethnohistoric observations of hunter-gatherer demography are suggestive of its relative instability on many occasions (e.g., Belovsky 1988; Boone 2002; Diamond 2005; Keckler 1997; Laughlin and Brady 1978). Yet much of prehistoric archaeology appears to be underwritten by assumptions of stable or steadily growing human populations. Following an initial appearance, usually denoted by the oldest dated site, humans are thought to be present in an area even if archaeological data are absent (Davey and Innes 2002). In addition, stylistic changes in technology and shifts in settlement patterns are thought to relate to, for instance, economic intensification and population growth, which in turn is presumed to causally relate to slowly fluctuating climates. However, recent improvements in the resolution of our climatic records has shown that the gradual environmental changes documented, for instance, in many pollen cores are misleading and in fact mask a number of severe climatic fluctuations (e.g., Burroughs 2005). The realization that past climate was punctuated by rapid climatic fluctuations prompts a reconsideration of attendant demographic changes.

Can these climate oscillations be systematically linked to forager demography? The models discussed by Boone (2002) indicate that different kinds of environments, associated with varying kinds of primary productivity regimes, result in different kinds of demographic fluctuations. When the productivity of the environment changes over time, these dynamics become a great deal more complex still. As productivity decreases, carrying capacity K is depressed and will rapidly intersect with population density. In the absence of migration or innovations in subsistence technology that raise K, positive checks will lower population density.

A prima facie example of these processes at work comes from the Alaskan and Canadian Arctic. After J. G. E. Smith (1978) had noted the high degree to which Inuit and Chipewyan hunter-gatherers experienced economic uncertainty and adversity, Minc (1986) and Minc and Smith (1989) provided detailed data about how climatic changes affected the economy and hence the demography of these populations. These forager groups, which were economically specialized, lived in variable high-latitude high-risk environments. By matching detailed tree ring data of climatic change in the recent past against the known record of the key prey species, Minc and Smith were able to provide a rich account of how environmental changes affected the demographic trajectories of their groups under study. Although a lack of quantitative demographic data for these forager groups makes the link between prey herd size and human population densities ultimately dependent on oral and anecdotal histories, reasonable quantitative demographic data on other high-latitude hunter-gatherers are available (e.g., Constandse-Westermann 1993; Robert-Lamblin 2006). In general, hunter-gatherers are strongly dependent on key resources, and their demographic fate tracks that of their primary prey (Morin 2008; Stenton 1991) (Figure 1). Importantly, these fluctuations are not merely seasonal, nor are they caused by hunting pressure exerted by humans (Aanes et al. 2000; Helle and Kojola 2006, 2008). They are effectively unpredictable and become larger as climate deteriorates (Morin 2008). Times of economic or ecological adversity are associated with increased mortality and lowered population densities, even given the relatively moderate climatic changes of the recent past.

Importantly, many of the strategies adopted by these groups to mediate such unforeseen climatic changes were social in nature; that is, they relied on sufficiently high population densities not only of the deme directly affected but also of those immediately adjacent to it. This safety net created by social obligation and mutual aid among economically symbiotic populations (Halstead and O'Shea 1982) would have been much more difficult to maintain in early prehistory, given the markedly lower estimates of population densities (e.g., Bocquet-Appel et al. 2005; Zimmermann 1996). These low population densities would have required a greater degree of mobility in order to ensure the function of such social/mating

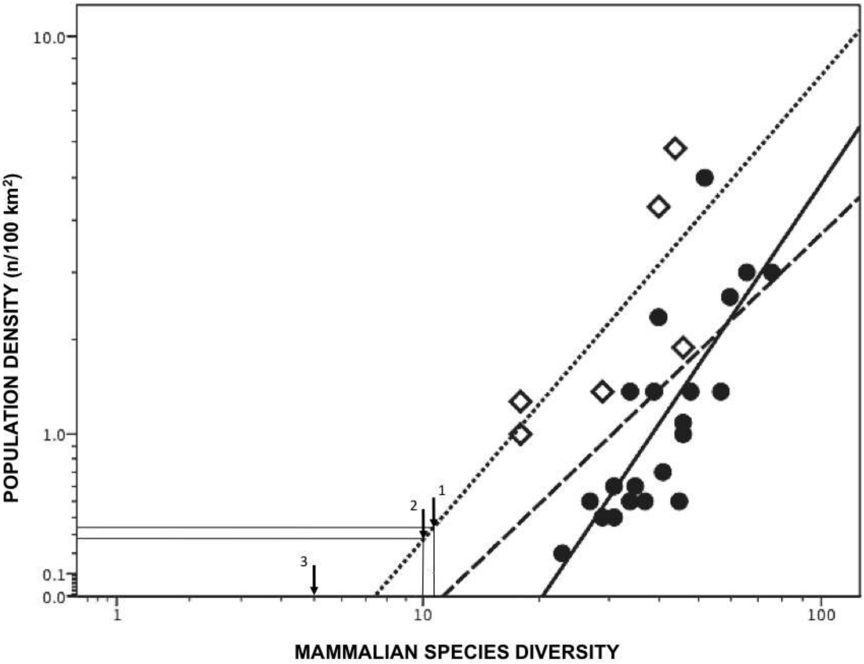

Figure 1. The relationship between ecosystem diversity (measured as large mammalian species diversity; mean $N_{\text{species}} = 33$) and population density among 27 hunter-gatherer populations in North America plotted on a log-log scale and the large mammal species diversity for the archaeological case studies discussed in this paper. Open diamonds denote those groups living in cold and open landscapes; filled circles denote forested northern to temperate groups. There is a strong (Spearman's rank) correlation between mammalian species diversity and forager population density in this data set: $r_s = 0.62$, $p < 0.002$, for the whole data set; $r_s = 0.82$, $p < 0.001$, for cold/open country groups; $r_s = 0.81$, $p < 0.07$, for temperate grassland groups. Data from Morin (2008). Linear fit lines have been added for the whole data set (dashed line), the cold/open country groups (dotted line), and the temperate/northern forested groups (solid line). Arrow 1 ($N_{\text{species}} = 11$) marks the Holocene species diversity in Ireland (Woodman et al. 1997) and intersects with the linear fit line for cold/open environment foragers at a corresponding population density of approximately 0.3–0.4 person/100 km^2. An intersection with the other linear fit lines is not achieved. Arrow 2 ($N_{\text{species}} = 10$) indicates the large mammal diversity during the Allerød/GI-1a–c period (Aaris-Sørensen 1999). An intersection with the cold/open linear fit line is achieved at a corresponding population density of 0.2–0.3 person/100 km^2. Traditionally, ethnographic analogies for both Mesolithic and Allerød period hunter-gatherers are not sought among groups living in such cold/open environments. Arrow 3 ($N_{\text{species}} = 5$) denotes the known species diversity during the Bølling/GI-1e period (Aaris-Sørensen 1999; see also Tromnau 2006), which witnessed the pioneer human colonization of southern Scandinavia. Note that arrow 3 does not intersect with any of the linear fit lines.

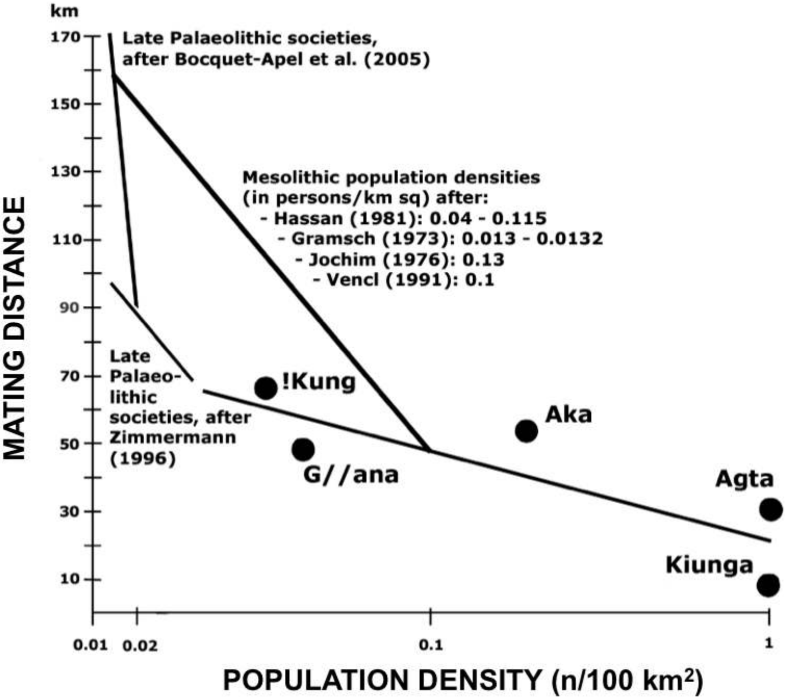

Figure 2. Known and reconstructed forager population densities plotted against mating distances. Redrawn from Cavalli-Sforza and Hewlett (1982) and Baales (2002).

networks (Figure 2). High mobility comes at a substantial social and reproductive cost, resulting in low population densities and high demographic instability (Burch 1972; Mandryk 1993; Odess 1998).

Until recently, the resolution of annually laid down tree rings was unrivaled with respect to charting humanly relevant changes in the environment. However, the advent of, in particular, high-resolution climatic information from the Arctic and Antarctic ice core projects has significantly added to and transformed our knowledge of past environs (Burroughs 2005). The magnitude and amplitude of climatic changes recorded in the ice cores contrast sharply with the smoothed signals produced by traditional pollen analyses. Although not problem-free, data from ice cores reach far back in time at virtually undiminished resolution and often without the gaps that plague tree ring data sets. At a 20-year resolution, the δ^{18}O measurements of the GISP2 ice core provide a proxy measurement of fluctuations in past temperatures that would have been noticeable to contemporaneous populations (Figure 3). Twenty years is less than one human (forager) generation (e.g., Matsumura and Forster 2008; Van de Velde et al. 1993), giving such changes particular relevance in the maintenance of ecological or landscape

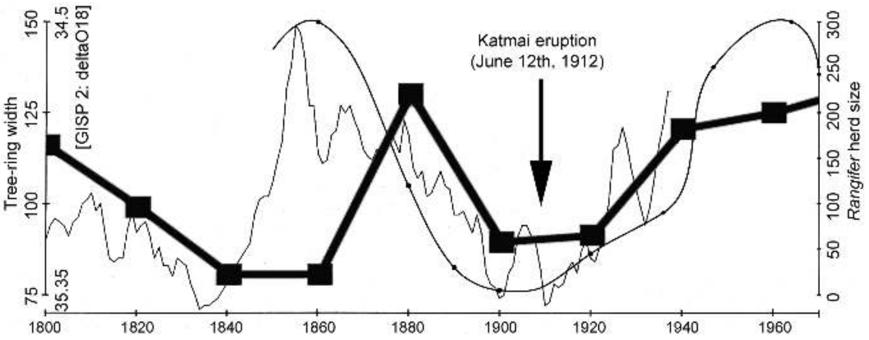

Figure 3. A plot of tree ring width, δ^{18}O temperature proxy measurements from the GISP2 ice core, and the fluctuating herd size of Alaskan reindeer. Note the good match between the tree ring and ice core signals. The human demography in this region strongly reflects these fluctuations (Minc and Smith 1989). Note also that the eruption of Katmai volcano in the summer of 1912 further affected the demography and land-use pattern of contemporaneous populations. The Katmai eruption was small (certainly compared with the Laacher See or Campanian Ignimbrite eruptions), but increasingly events such as this one are thought to have played a key role in shaping Arctic prehistory (Dumond 2004; VanderKoek and Nelson 2007). In addition, Northern Hemisphere mid- to high-latitude climate is also strongly affected by more distant eruptions, which contribute to the fluctuating climatic regimes and whose signal is preserved in both tree rings and ice cores (Briffa et al. 1998).

knowledge (Rockman and Steele 2003). In the sense, then, that human interaction with the environment is structured by their perception of it, rapid changes post a particular adaptive challenge (Richerson et al. 2001, 2005). Using ice core climatic proxy data therefore allows us to connect observed correlations between climatic changes and forager demography in the ethnographic present with those recorded in the archaeological record in prehistoric deep time.

Case Study 1: The Irish Early to Late Mesolithic Transition

Mesolithic Ireland is in many ways an interesting case study to examine from a demographic perspective. Located at the westernmost fringes of Europe, Ireland is characterized by an impoverished fauna and flora compared to the British mainland or continental Europe (Woodman et al. 1997). Equally, the cultural development in Holocene Ireland after its initial colonization departs significantly from what is known from the rest of the British Isles (Wickham-Jones and Woodman 1998; Woodman 1978, 2004). Of particular interest is the "remarkable" (Costa et al. 2005: 19) transition from a fully microlithic tool kit with strong stylistic affinities to mainland technocomplexes to a regionally restricted and much cruder macrolithic set with few formal tool types. Although it has long been noted that "the size of human population in most parts of Europe during the Mesolithic was low" and that "human population numbers oscillated substantially in the past in response to

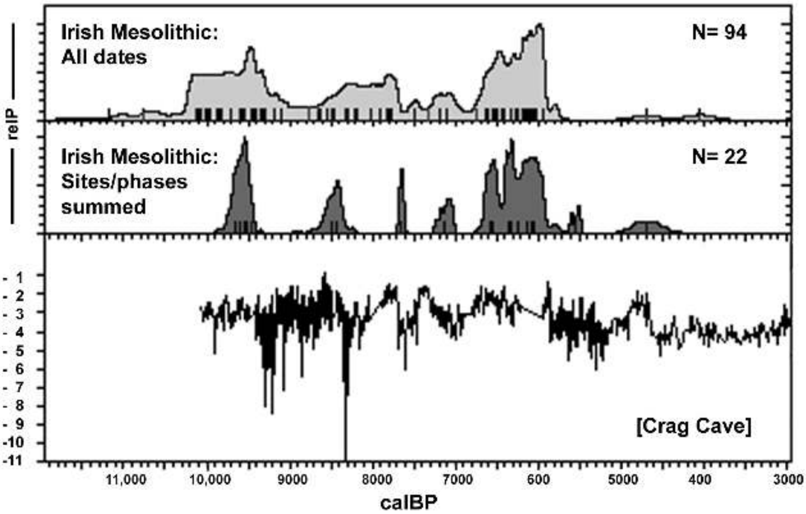

Figure 4. The Irish Mesolithic radiocarbon record, calibrated against the climatic proxy ($\delta^{18}O$) record from Crag Cave (see McDermott et al. 2001). See text and Riede et al. (2009) for more information.

major climatic events" (Price 1999: 185), recent interpretations of the Irish Mesolithic sideline such considerations in favor of changes in mobility or taphonomic biases (Costa et al. 2005; Woodman 2000; Woodman and Andersen 1990).

Prompted by the demographic model for the loss of cultural capital by Henrich (2004), we have reexamined the available radiocarbon record for the Irish Mesolithic transition (Riede et al. 2009). Despite the skepticism expressed by some investigators regarding the value of the Irish Mesolithic radiocarbon record (Woodman 2000), there are pronounced fluctuations in the summed frequency distribution of the calibrated dates, and probability troughs coincide with major early Holocene climatic upheavals, such as the preboreal oscillation, the 8,200 event (Rohling and Pälike 2005), and the regionally specific 7,000 event (Diefendorf et al. 2006).

To begin, I have calibrated and summed all currently available ^{14}C results for the Irish Mesolithic using CALPAL (http://www.calpal.de) into a single probability distribution frequency graph (Figure 4, top). To minimize the bias introduced into such an analysis by heavily investigated single phases or date-rich sites, I show in the bottom plot the sum of the pooled mean of the total ^{14}C for each distinct archaeological occupation phase. The uncalibrated pooled mean probability distribution frequency for each phase was calculated using the R_Combine function in OxCal (http://c14.arch.ox.ac.uk) and then calibrated and summed using CALPAL, following the method of Shennan and Edinborough (2007). This reduced data set retains a largely identical peak and trough structure (Figure 4, bottom). Elsewhere, Riede et al. (2009) report further procedures that can increase our confidence in interpreting these curves as demographic proxies rather than taphonomic or calibration artifacts.

Interestingly, the use of summed radiocarbon date frequencies as proxies of population densities was strongly inspired by a study of such fluctuations in Tasmania (Holdaway and Porch 1995). Tasmania in turn has served as an ethnographic canvas on which Henrich (2004) developed his model linking cultural changes (in particular, maladaptive changes and the loss of cultural capital) to demographic parameters and the mechanics of social learning. Mesolithic Ireland, being only somewhat larger than Tasmania and having been isolated by a treacherous stretch of water that would "not have provided an effective or friendly route for . . . faunal and floral migrations from Britain (and Europe) to Ireland" (Lambeck and Purcell 2001: 505), may present an important empirical backing for Henrich's model. With important stepping-stones such as the Isle of Man depopulated for long periods of time (Davey and Innes 2002) and with the population densities during the Mesolithic similarly low or lower than those recorded in (contact period) Tasmania [0.08–0.145 person/km^2 (Kelly 1995); compare with Figure 2], even moderate reductions in population size both in Ireland and on the mainland [as a result of, for instance, the knock-on effect of the Storegga tsunami (D. E. Smith et al. 2004; Weninger et al. 2008)] would have strongly moved the remaining parameter values of Henrich's model—population density and connectedness—toward the conditions that lead to the loss of complex cultural skills. Although Henrich's model has not gone without criticism [see Read (2006) and Henrich's (2006) response] and is, as Henrich himself points out, in need of experimental verification using replication studies, the Irish material culture sequence (Wickham-Jones and Woodman 1998) conforms well to the specific predictions laid out by the model: a targeted loss of more complex technologies (composite tools, organic technology, etc.) but a maintenance of or even improvement in simple technologies.

Case Study 2: The Laacher See Eruption and Material Culture Change in Late Glacial Europe

Beginning with the landmark contribution by Housley et al. (1997), the late glacial period of Northern Europe has been heavily investigated using summed probability frequencies of calibrated radiocarbon dates. Although there is certainly some debate about the method of choice (e.g., Blackwell and Buck 2003; Blockley et al. 2000, 2004), Gamble et al. (2006) [and also Gamble et al. (2004, 2005)] sketched out the basic continental-scale framework for the discussion of late glacial demography. They identify five phases covering the time period from 25,000 years ago (BP) to 11,500 years BP, each characterized by different demographic trends. The last two of these phases, dating to 14,500–12,900 years BP and 12,900–11,500 years BP, are the focus of the present discussion. They reflect, according to Gamble et al. (2005), population stasis followed by contraction during the last and fitful glacial re-advances during the Younger Dryas/GS-1. Although Gamble and colleagues do show that there is a correlation between summed probability frequencies and climatic proxies, they ignore the potential contribution of unique and extreme geophysical events, such as volcanic eruptions, and their ecological consequences on late glacial forager demography at a regional level. A much greater number of volcanic eruptions than commonly assumed occurred during the late Pleistocene in areas occupied by hunter-gatherers (see Bryson et al. 2006; Nowell et al. 2006), and archaeologists are increasingly aware that such events, by means of demography, may have acted as important stimuli for cultural changes (de Boer and Sanders 2002; Grattan 2006; Grattan and Torrence 2007).

The Laacher See eruption was one of the largest late Pleistocene eruptions in the Northern Hemisphere and is dated to late spring/early summer some 13,000 years ago (Baales et al. 2002). This eruption has been studied intensively from a volcanological perspective (Schmincke 1988, 2004; Schmincke et al. 1999) and has favored the often remarkable preservation of many important late glacial archaeological sites (Baales and Street 1999; Street et al. 2006). Although some attention has been paid to the impact of its fallout on the ecology in regions far removed from the eruptive center (de Klerk et al. 2008), an investigation into its potential role as a stimulant for demographic or culture historical changes at this distance has only recently begun (Riede 2007a, 2008; Riede and Bazely 2009; Riede and Wheeler 2009) (Figure 5).

Using the summed probability distribution frequencies of the calibrated ^{14}C dates for the Northern European late glacial period and dividing these up by region and cultural affiliation, we can see that the Laacher See eruption marks the important transition from northwestern Federmesser to Bromme culture in southern Scandinavia and from northeastern Federmesser to Perstunian culture in the sub-Baltic region (Figure 6). These two post–Laacher See eruption so-called large-tanged-point technocomplexes are noteworthy for two reasons. First, both are characterized by a much greater degree of regional specificity, yet their “territories” are not contiguous, despite many years of focused research in the area (Terberger 2006). Second, they are characterized by a “simplified” (Barton 1992: 192), typologically poor tool kit consisting of only large-tanged points, scrapers, and burins and a generally “straightforward” (Madsen 1992: 128) technology. In fact, the emergence of these technocomplexes with their characteristic large-tanged points marks the loss of bow and arrow technology and a return to the exclusive use of the spear thrower (Riede 2009b).

As already noted, such a loss of cultural capital is not unknown from the ethnographic record (Rivers 1926 [1912]), and given that spatially extensive social networks created and maintained through high mobility and used as safety nets in case of resource shortage have often been cited as a key component of late glacial adaptations (Gamble 1997; Jochim 1999; Whallon 2006; Wobst 1974, 1976), it is possible that a disruption of these traditional exchange and communication routes may have led to the social and demographic isolation of peripheral groups. The material culture consequences of this sudden drop in demic connectedness, if not size and density, again conform rather precisely to the predictions of Henrich (2004). More complex skills—manifested archaeologically in stone

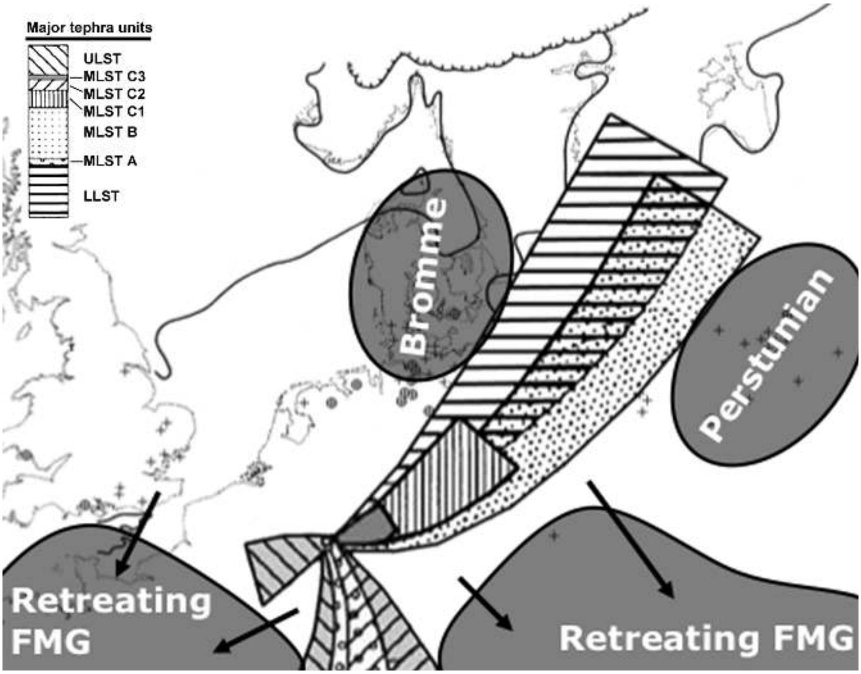

Figure 5. Schematic map of Northern Europe showing the approximate extent of the Laacher See eruption tephra fallout phases (from Schmincke et al. 1999) in relation to the occurrence of posteruption technocomplexes. These are superimposed on a map (from Barton 1992) of preeruption sites with assemblages that may have been ancestral to the later Bromme and Perstunian cultures (Riede 2007a, 2008). FMG, Federmesser-Gruppen (i.e., the Federmesser culture).

tool production methods, organic tools such as harpoons and antler axes, and bow and arrow technology—preferentially disappear from the archaeological record. A number of mechanistic links between the tephra fall and the effective depopulation of large parts of central Europe have been suggested (Riede 2007a), and preliminary results (Riede and Bazely 2009; Riede and Wheeler 2009) lend support to the notion that the multicausal consequences of the eruption made the affected landscapes unattractive for forager settlement at least until the onset of the Younger Dryas/GS-1 cooling episode some 200–300 years later, which substantially reshuffled the forager populations in Northern Europe once again.

Case Study 3: Demography, Social Relations, and Biosocial Collapse in the Pioneer Colonizers of Southern Scandinavia

The final case study considered here returns to a forager population specialized in reindeer hunting, the so-called Hamburgian of the North European

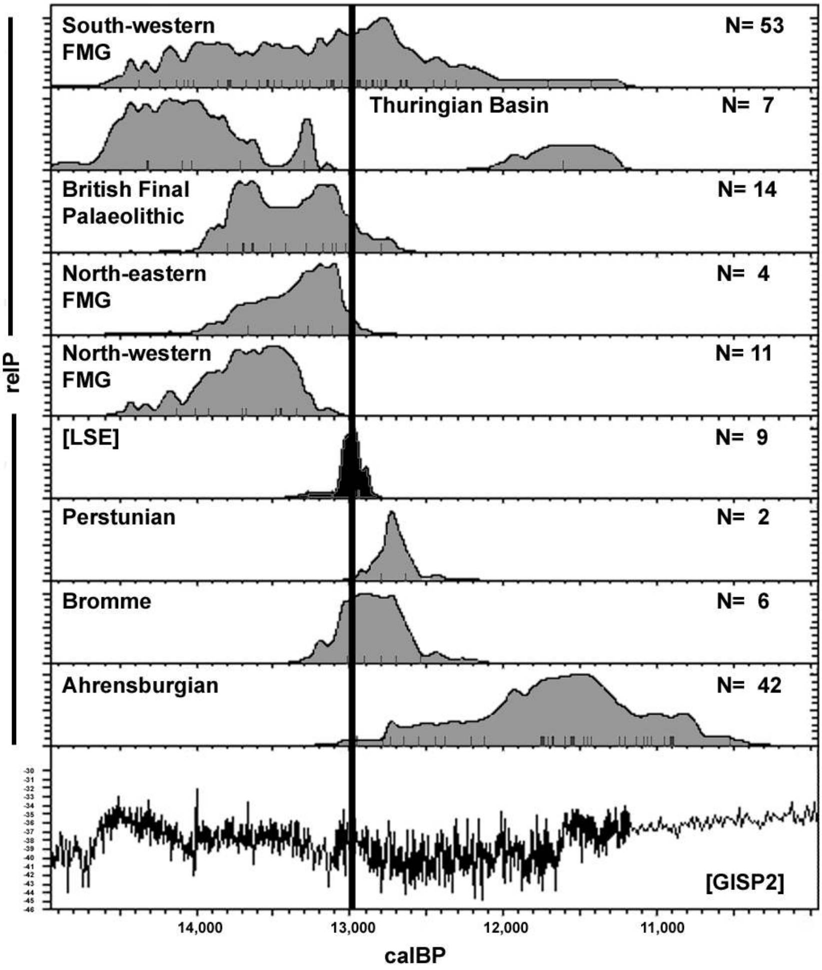

Figure 6. The summed probability frequency distributions for the calibrated radiocarbon dates of the late glacial period in Northern Europe set against, at the bottom, the δ^{18}O temperature proxy data from the GISP2 ice core. As has been argued by Eriksen (1996), the Thuringian basin (an important communication route between northern and central Europe) had become depopulated perhaps even before the Laacher See eruption. On the British Isles, which were never directly affected by fallout from the Laacher See eruption, demographic knock-on effects may also have led to a reduction in population activity, although the effects of the Laacher See eruption are difficult to disentangle from those of the Younger Dryas/GS-1 event. It is only in the southwest (i.e., the Low Countries and France) that date frequencies rose after the Laacher See eruption. It is here that unbroken stratified sequences of cultural development from the late Magdalenian to the Federmesser to the Mesolithic exist (Bodu 1998).

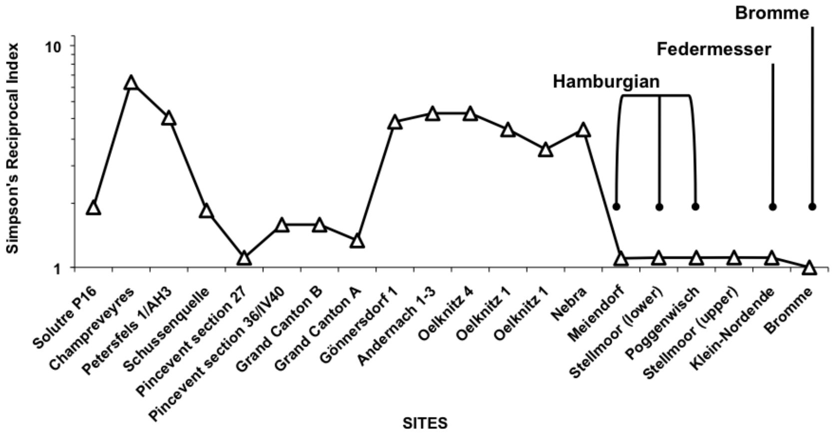

Figure 7. Faunal diversity measures calculated as Simpson's reciprocal index (logarithmic scale) for the large mammal faunas at a series of North European late glacial sites, arranged in latitudinal order and with the relevant cultural associations given. Although these values may not be directly comparable to those plotted in Figure 1, faunal diversity is shown to significantly decline with latitude ($r_s = -0.56$, $p < 0.01$), despite the large climatic fluctuations spanned by these sites. The extremely low diversity values in the northernmost sites are noteworthy. Faunal data from Gaudzinski and Street (2003) and Eriksen (1996). See Morin (2008) for a similar analysis.

Plain (Eriksen 2002). These foragers, operating "at the border of human habitat" (Fischer 1996: 157) conform well to the model of pioneer colonizers in unfamiliar landscapes (Riede 2005, 2007b), and they brought a sophisticated flint technology and a linear settlement pattern to the area, reminiscent of their ancestral lifestyles (Madsen 1996; Petersen and Johansen 1996). However, the sizes of their settlements are consistently small, and faunal remains attest to "resource scarcity" (Grønnow 1985: 155) among populations that likely lived under low population densities (Figure 7). In addition, no physical storage of resources is documented for this technocomplex, nor is there evidence for the use of dogs or watercraft to aid in covering long distances. Although the debate about reindeer herd following as a viable hunter-gatherer adaptation is fierce (Burch 1972, 1991; Gordon 1990a, 1990b), a case can be made for the Hamburgian technocomplex to represent an attempt at practicing just that, an unaided pedestrian herd-following economy (Riede 2007b, 2009a).

The radiocarbon record for the Hamburgian (Grimm and Weber 2008) is short, and the cultural successors in the region differ markedly in virtually all archaeologically accessible characteristics (e.g., Hartz 1987). In addition, the summed probability distribution frequencies of the calibrated radiocarbon dates decline steeply simultaneously with a similar decline in the reindeer population in the region at the Older Dryas/GI-1d transition (Aaris-Sørensen et al. 2007) (Figure 8). Morin (2008) has recently shown that *Rangifer* herd sizes in historical times fluctuated in largely unpredictable cycles and that the fluctuations were

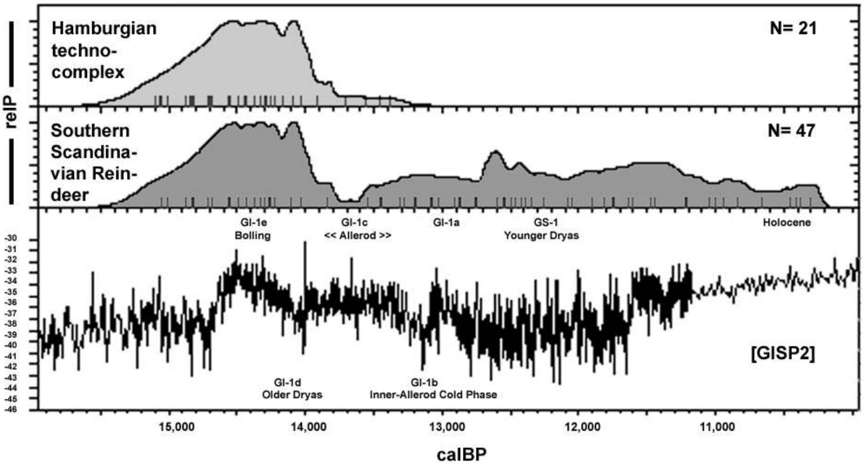

Figure 8. The summed probability frequency distributions for the Hamburgian technocomplex juxtaposed with the GISP2 δ^{18}O temperature proxy and the radiocarbon dates for the reindeer population of southern Scandinavia (from Aaris-Sørensen et al. 2007). The climatic phase notation follows Björck et al. (1998).

aggravated by poor climatic conditions. Given that even in historic times "drastic reductions in availability [of *Rangifer*] brought about considerable hardship, including cases of death through starvation" (Stenton 1991: 19) and that the late glacial climate witnessed oscillations of greater amplitude and magnitude than in the Holocene, the Hamburgian population may have suffered an extreme demographic decline brought on by climatically induced stress (Brothwell 1998; Stringer et al. 2004).

Following Halstead and O'Shea (1989), Minc and Smith (1989) identified four responses against climatically induced stress: diversification, storage, exchange, and increased mobility. The admittedly scarce faunal record of the Hamburgian technocomplex does not reveal evidence of economic diversification, nor is storage attested. Exchange (i.e., the social storage of ecologically complementary resources among nearby groups) was not an option readily available to these foragers. Living a "life without close neighbours" (Åkerlund 2002: 43), the Hamburgians suffered from practicing a linear economy and settlement pattern and from being marginal with regard to the social networks of late glacial Europe (sensu Wobst 1976). Increased mobility in marginal landscapes entails social and reproductive costs (Pennington 2001; Surovell 2000), especially under the conditions of lower than ethnographic population density in the Paleolithic. As argued by Mandryk (1993: 67), such mobility pressures can lead to the breakdown of social and reproductive networks, and "without mating networks, mates cannot be ensured, and biological (reproductive) failure follows. Collapsed networks also would result in a lack of the information necessary for dealing with the variable and unpredictable environment and the breakdown of alliance systems that acted as insurance—all leading to eventual subsistence failure." Odess (1998: 421) further remarked that once individual demes disappear, the strain on the larger population becomes compounded: "Loss of population from an area would likely have required an increase in reproductive effort on part of people who formerly relied on those in that area for spouses. This increased effort would in theory eventually result in an expansion of the geographical area included within that pool, or *a reduction in the viability of the remaining members of the marriage pool*" (emphasis added). This sentiment was echoed more recently by Whallon (2006: 261), who concluded that a "false move to an area without adequate resources uses up energy to no avail, increasing subsistence stress and risking starvation and, ultimately, death—the ultimate maladaptation."

Although there are perhaps alternative explanations for the extensive changes in the archaeological record of late glacial Scandinavia, such a more punctuated view of repeated, short-lived population pulses mirrors similar suggestions for other Northern European regions (Pettitt 2008) and is line with inferences drawn from population genetic data on Scandinavian populations (Achili et al. 2004; Karlsson et al. 2006; Pereira et al. 2005) that link the successful and demographically viable colonization of Scandinavia with Ahrensburgian (i.e., postglacial) populations. In a broader comparative perspective, a model of episodic regional extinction and recolonization is in harmony with similar data on the fate of specialized terrestrial foragers in the Arctic (Fitzhugh 1997).

As suggested by Henrich (2004), demographic depression in small and isolated groups can lead to the maladaptive loss of cultural capital. In addition, however, demographic depression in small and isolated groups can lead to their disappearance. During the late glacial pioneer colonization of southern Scandinavia, there is no evidence for a reduction of cultural competences, but perhaps the population decline was so rapid and involved such high levels of mortality—especially in the old and skilled (see Gurven et al. 2006; Richter 2001; Walker et al. 2002)—that populations disappeared without much of an archaeological trace. Soltis et al. (1995) suggested that a mortality rate upward of 30% can prompt extremely rapid cultural change as survivors abandon their ways of doing and making things in order to blend in with surrounding groups: "Alternatives to increasing production and attaining higher levels of social organization, *including cultural extinction*, are always available" (Newell and Constandse-Westermann 1984: 13, emphasis added). Although archaeological data alone cannot, ultimately, distinguish between the competing hypotheses of biological continuity versus discontinuity, future genetic work may be able to evaluate them independently of the archaeological database.

Discussion

Archaeologists can access information about prehistoric demography in a number of different ways [see Bocquet-Appel (2008) and Chamberlain (2006) for recent reviews]. In this paper I have focused on only one such method: dates as data, that is, the use of summed probability distribution frequencies of calibrated radiocarbon dates. More specifically, I have been concerned with viewing prehistoric human demography in relation to the environment, and it is recognized explicitly here that past human adaptations can and did fail because "even the most adaptable of creatures will experience limits to its tolerance space, outside of which it is unable to behave adaptively" (Laland and Brown 2006: 98). However, this is not advocacy for a return to crude environmental determinism. Many selectively relevant features of "the environment" have increasingly come under our control or indeed are fully of our own making, and many of these serve the purpose of buffering against larger scale environmental changes (Laland et al. 2000; Odling-Smee et al. 2003). The degree to which particular adaptations were or were not successful can be explored using archaeological data sets, within the context of an explicitly evolutionary approach (Riede 2009c).

One component of such an approach is the inclusion of demographic considerations into models of culture change. The three case studies offered here suggest some of the ways in which detailed auxiliary archaeological, climatological, and other information can be used in substantiating demographic interpretations. Both cultural elaboration (Collard and Shennan 2000; Shennan 2001) and decline (Henrich 2004; Soltis et al. 1995) can be linked to demographic conditions. The focus here has been on demographic declines and their consequences, in part because these are an understudied area of research. The case studies reviewed in this paper illustrate that, first, an overwhelming taphonomic bias against older sites cannot be clearly demonstrated. In addition, the utility of ^{14}C dates as demographic proxies may, to some degree, depend on the chosen scale of analysis. Although many previous studies have considered continental-scale patterns, those presented here argue for a regional dissection of such broad trends. Finally, the utility of ^{14}C dates as demographic proxies may also depend on their linkage to appropriate archaeological units. Some discussion of the difficulties in identifying such units has taken place (Foley 1987; Gamble et al. 2005), but further evaluation is necessary if we want to confidently link changes in material culture to demographic dynamics.

So, where might this research go in the future? Working with radiocarbon dates relies, most fundamentally, on these being available, and researchers are strongly urged to both publish any new ^{14}C determinations and submit them to, or collate them in, publicly available radiocarbon databases (e.g., Gkiasta et al. 2003; Niekus 2005/2006; http://geo.kuleuven.be/geography/projects/14c-palaeolithic; http://www.jungsteinsite.de/radon/radon.htm). In addition, it would be desirable to develop more rigorous means of statistically evaluating the properties of the summed probability distribution frequencies, with respect to both their departure from randomness and their correlation with climatic proxies [see M. A. Smith et al. (2008) for an attempt]. However, many climatic proxies may not be perfectly suitable when the goal is to investigate the relationship of human demography to the environment. As Stringer et al. (2004) have pointed out, both the magnitude and the amplitude of environmental change are important when calculating the "stress" (see Brothwell 1998) exerted by the environment. Efforts should be

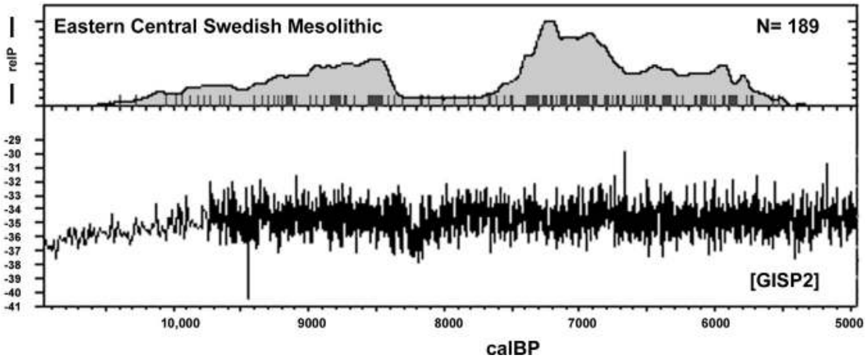

Figure 9. The early Holocene settlement history in east-central Sweden reaches its peak just before the 8,200 event, which coincides with a shift in technology and settlement pattern [see references in Gruber (2005)]. This figure is based on a coherent and recently obtained suite of high-resolution AMS radiocarbon dates (Carlsson et al. 2005; M. Guinard, personal communication, 2009; Knutsson et al. 1999).

made, therefore, to devise more sophisticated methods of calculating indexes of environmental stress relevant to past human populations.

An explicitly demographic perspective could profitably be applied to a number of empirical arenas. Beginning with the Mesolithic, many regions show evidence of unusual shifts in technology and settlement pattern. In east-central Sweden, for instance, isolated coastal communities abandoned the characteristic and sophisticated Mesolithic microblade technology (Olofsson 2002) around 8,000 years ago. Instead they shifted the bulk of their production to quartz, which is far more difficult to fashion into similarly efficient tool components (see Åkerlund 2002; Gustafsson 1998). Calibrating the available radiocarbon dates indicates that this shift coincides with the 8,200 event (Figure 9). Given this event's impact on Mesolithic demography in Ireland and farther to the south in Scandinavia (Edinborough 2009), one may speculate that the disruption of contact and exchange with more southerly groups (the source of the flint for microblade production) may have led to an important reconfiguring of social structures. Whether stochastic effects in the sense of Henrich (2004) were responsible for the disappearance of microblades or whether the shift from ancestral and imported modes to new and indigenous modes of manufacture were politically motivated (e.g., Collard and Shennan 2000) or whether this dating lacuna is partly or wholly the result of a marine transgression [dated broadly to 7,500–8,000 BP and in evidence at two sites (Knutsson et al. 1999)] remains to be investigated in detail. It may indeed be possible that the combined pressures of the 8,200 event and the marine transgression resulted in demographic fluctuations.

On the far side of the Holocene-Pleistocene boundary, David (1973) argued that some of the technological changes seen in Upper Paleolithic assemblages in Europe may relate to processes of demographic growth and collapse. In particular, David highlighted collapse in relation to the emergence of highly specialized hunting economies. The merits and risks of specialization (in particular in reindeer hunting) have been much discussed in the literature (e.g., Mellars 2004), and it has long been accepted that, although it represents a highly viable short-term strategy, "specialization, in light of human history, is a dangerous phenomenon" (Colson 1979: 22). Perhaps it is time to systematically reexamine the European Upper Paleolithic with its repeated evolution of specialized hunter-gatherers for evidence of demographic slumps.

Moving deeper into prehistory and to the outer frontier of radiocarbon dating, Fedele et al. (2002) have suggested that the massive Campanian Ignimbrite (Y-5) eruption, dated to c. 38,000 years ago, may have played an important role in the transition between Neanderthals and anatomically modern humans in Europe. Subsequent publications by this group have taken an explicitly ecological stance and are concerned with working out the timing and stratigraphic correlations of the various tephra layers at numerous sites in southern and central Europe (Fedele et al. 2003, 2007, 2008; Giaccio et al. 2006). Although summed probability distribution frequencies of calibrated radiocarbon dates are used as a research tool, these are not discussed in demographic terms and the potential knock-on effects of population displacement are not considered in any detail [but see Fedele et al. (2008)].

Beyond the limits of radiocarbon dating, the exploration of prehistoric demography becomes rather more speculative. Did the supereruption of Mount Toba (Oppenheimer 2002) really have no observable impact on the Middle Paleolithic occupants of the Indian subcontinent (Petraglia et al. 2007) while constituting the crucible for genetic modernity in Africa (Ambrose 1998; Rampino and Ambrose 2000)? Perhaps the sporadic appearance and disappearance of elaborate and regionally specific cultural traits across the African continent suggests that fluctuating demography over at least the last 300,000 years (Clark 1988; McBrearty and Brooks 2000) played an important role in the cultural and perhaps biological evolution of *Homo sapiens*, as tentatively proposed by Bird and O'Connell (2006). A clearer discussion of this issue, however, is hampered by the assumption that once a given trait arose (harpoons, personal ornaments, etc.), it then became a fixed feature of all *Homo* populations from then on (see McBrearty and Brooks 2000, Figure 13), with the exception perhaps of geometric microliths (Wurz 1999) and the associated projectile technology (Bretzke et al. 2006; Villa et al. 2005). By the same token, could low and fluctuating population numbers have acted to create the periodic emergence and disappearance of blade or leaf-point technologies in the Middle Paleolithic (e.g., Bar-Yosef and Kuhn 1999; Bolus and Conard 2001; Bosinski 1967) or of microlithic technologies in many parts of the world during the Pleistocene (Burdukiewicz 2005)?

The results of modeling efforts point to the importance of repeated local and regional extinction and recolonization events in premodern hominids (Eller 2002; Eller et al. 2004; Hawks 2008), and these may have occurred in relation to environmental changes (Foley 1994). "There is no reason to suppose that our demographic history suddenly simplified" (Goldstein and Chikhi 2002: 132), even following the emergence of anatomically and genetically modern humans (Foley and Lahr 2003; Lahr and Foley 1998), but the rapidly increasing body of genetic evidence for past demography remains difficult to integrate systematically with the archaeological database. Is the demographic decline identified in Mesolithic Ireland, for instance, still reflected in the unique features of the contemporary Irish population's genetic makeup (Hill et al. 2000)? How could we increase our confidence in evaluating unsuccessful dispersals with respect to the chronologies now available for different genetic markers (Forster 2004)? Can geneticists derive specific hypotheses or predictions from their data alone that can then be tested using archaeological information, or vice versa? Up to now, the grain of the archaeological record has been much finer than that of the genetic database. Although genetic data are rapidly catching up in this respect, archaeologists are falling behind in making their data available for public scrutiny and use. Bringing these two domains in line is a major challenge for future research. Shennan (2000: 821) has long argued that "the single most important factor in understanding culture change is population dynamics," and clearly the study of ancient demography should draw on all available data sets: osteological, ecological, radiometric, archaeological, and genetic. Here I argue that, when available, calibrated ^{14}C dates can be used to crudely but usefully estimate fluctuating levels of population activity or density at a regional level and that these can be linked to processes of biosocial change as reflected in the archaeological record. Taphonomic and sampling concerns have to be, and can be, addressed case by case (e.g., M. A. Smith et al. 2008), and care has to be taken when interpreting summed radiocarbon dates (e.g., Buchanan et al. 2008). Although the method as a whole remains "explicitly exploratory" (M. A. Smith et al. 2008: 390) at this stage, previous and ongoing research, such as that reviewed here, is rapidly accumulating a body of comparative material strongly suggesting that significant and archaeologically accessible population fluctuations in relation to climatic and environmental changes cannot be sidelined in our reconstructions of early prehistory.

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