

Testing the Hypothesis of a Worldwide Neolithic Demographic Transition

Corroboration from American Cemeteries

by Jean-Pierre Bocquet-Appel and Stephan Naji

The signal of a major demographic change characterized by a relatively abrupt increase in the proportion of immature skeletons has been detected in a paleoanthropological database of 38 Mesolithic-Neolithic cemeteries from Europe and North Africa. From the Mesolithic to the Neolithic, the proportion of immature skeletons increases by 20–30% over a period of 500–700 years, indicating a notable increase in the crude birth rate. This shift has been called the Neolithic demographic transition. A similar signal has been detected in an independent set of archaeological data, namely, enclosures. This paper presents results from a sample of 62 cemeteries in North America (7,755 BP–350 BP) that point to the same transition over a period of 600–800 years.

The signal of a Neolithic demographic transition has been detected in a paleoanthropological database of Mesolithic-Neolithic cemeteries in Europe and North Africa (Bocquet-Appel 2002; Bocquet-Appel and Paz de Miguel Ibáñez 2002). The database represents a time-space sample of a nonconventional marker, the proportion of immature skeletons (aged 5–19 years) in cemeteries. In a growing population the proportion of immature individuals (dead or alive) is high, while in a declining population it is low (McCaa 2000; Johansson and Horowitz 1986; Sattenspiel and Harpending 1983). The signal of the transition is characterized by a relatively abrupt increase in the proportion of immature skeletons; from the Mesolithic to the Neolithic, the proportion increases by 20–30%. An independent archaeological marker of demographic growth the chronological variation in the frequency of some 700 enclosures and enclosure systems, has revealed a similar signal (Bocquet-Appel and Dubouloz 2004). The link between demographic growth and enclosure frequency is based on the hypothesis that the number of collective buildings increases as the population grows. The detection of the signal in Europe has provided grounds for a prediction regarding its worldwide impact: if a Neolithic demographic transition occurred in Europe, it must also have happened in all the independent centers of agricultural invention in the

world. The signal of this transition should therefore be observable in cemetery data from those centers (Bocquet-Appel and Dubouloz 2004).

In the first part of this paper, the prediction of a worldwide transition observable in skeletal data is tested for the first time outside Europe and North Africa with data from 62 North American cemeteries. Can the signal of the transition that we have identified in Europe and North Africa be detected in the North American data, even though the invention of agriculture there occurred 7,000–8,000 years later? In the second part, we combine the two sets of data to describe the pattern of a demographic transition as a response to the economic shift from forager to horticulturalist-farmer—the strength and the rate of the response, whether it occurred before or after the introduction of the farming system, and whether the tempo of demographic change was identical everywhere. Finally, we consider various hypotheses (nutritional and/or social) as proxy parameters for the impact of economic change on fertility. Comparing demographic trends between continents allows us to point to hypotheses that go beyond regional ecology. To identify this transition, which coincides with the economic shift from forager to farmer, the name “Neolithic demographic transition” will be used here even though “Neolithic” strictly refers to an Old World archaeological period.

Material and Methods

The data are represented, after an in-depth search of the literature, by a nonconventional demographic indicator, the proportion P of immature skeletons (5–19 years of age) relative to the overall skeletal population of the cemetery, excluding children under 5 years of age, $d(5+)$, who are known

Jean-Pierre Bocquet-Appel is research director at the National Center for Scientific Research (UPR 2147, 44 rue de l'Amiral Mouchez, 75014 Paris, France [bocquet-appel@ivry.cnrs.fr]). **Stephan Naji** is a Ph.D. candidate in anthropology at the Ecole des Hautes Etudes en Sciences Sociales in Paris. This paper was submitted 17 IX 04 and accepted 31 V 05.

to be underrepresented. In other words, ${}_{15}P_5 = d(5-i)/d(5+)$ (Bocquet-Appel and Paz de Miguel Ibáñez 2002) (${}_{15}P_5$ being the skeleton proportion at age 5 and age 5 plus 15 years, that is, 5 to 19 years). The criteria used for selecting the cemeteries were as follows: (1) the possibility, with a reasonable amount of manipulation, of redistributing the skeletons from non-standardized age-groups into demographic age-classes, (2) cultural homogeneity (cemeteries in which several periods were mixed were rejected or split into homogeneous periods), (3) the existence of absolute or relative dates, (4) the apparently "natural death" of the individuals (cemeteries suspected to be the result of mass violent death were excluded), (5) the inclusion of postcontact cemeteries only when the detected demographic transition took place prior to 1492, and (6) excavation of at least 50% of the evaluated cemetery size. This yielded a sample of 62 cemeteries (24 forager, 38 horticulturist-farmer) (see fig. 1 and table 1). Whenever possible, the (calibrated) dates assigned to the cemeteries were those of the original publications (table 1). When site chronologies did not exist, the average dates of the cultures (or horizons) of these cemeteries or regional syntheses were used instead (Buikstra and Konigsberg 1986; Cassidy 1984; Cohen 1989; Cowan and Watson 1992; Crawford, Smith, and Bowyer 1997; Diehl 1996; Goodman et al. 1984; Hart 1990; Hutchinson et al. 1998; Larsen 1984; Larsen et al. 1992; Lynott et al. 1986; MacNeish 1992; Palkovich 1984; Rose et al. 1984; Smith 1978,

1989; Trigger 1981; Wolf 1977). The same rule was used for dates for evidence of horticulture, archaeological publication dates of sites, and average dates of the emergence of horticulture in the region. The criteria used to distinguish forager cemeteries from those of horticulturist-farmers were the cultural subdivisions indicating hunter-gatherers (Archaic, Early Woodland) versus horticulturist-farmers using either local plants (native cultigens, as in Middle Woodland) or continental plants (maize, beans, as in Late Woodland and Mississippian). Our objective was to detect the demographic impact of the economic change on horticulturist-farmers as and when it appeared locally. The demographic interpretation of ${}_{15}P_5$ was based on a sample of 45 preindustrial mortality tables from which various demographic parameters, called estimators, were obtained by regression from simulated stable populations (Bocquet-Appel 2002; Bocquet-Appel and Masset 1996, 1977). Among these estimators, the correlations between the demographic indicator ${}_{15}P_5$ and population input variables such as the crude birthrate (b) and the growth rate (r) were $R^2 = 0.971$ and 0.877 , respectively. With regard to the population output variables (i.e., mortality), despite intensive simulations no reliable predictors (crude death rate d or life expectancy e_0) were found if growth rate remained unknown (Bocquet-Appel 2002). In the stable population model, we know that the number of deaths at age x to age $x + a$ years, ${}_a d_x$ is given by ${}_a d_x = {}_a m_x e^{-r(x + 1/2a)} {}_a L_x$, where ${}_a m_x$

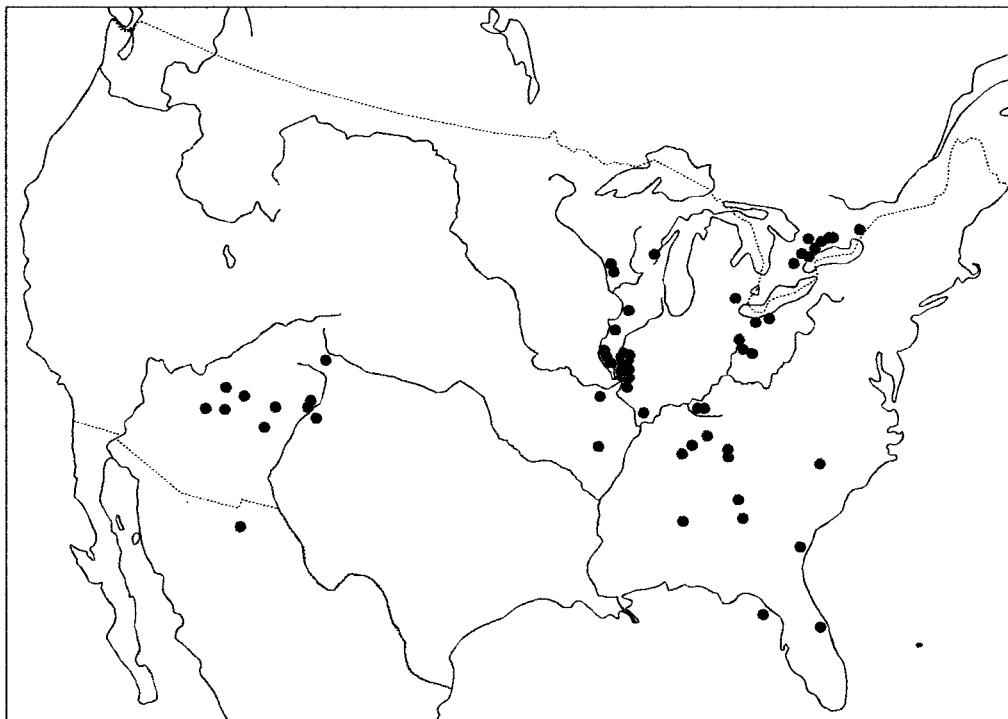


Fig. 1. Geographical distribution of the cemetery samples.

Table 1. The Forager and Horticulturist-Farmer Cemeteries Analyzed

Site	Sources	Date cal BP			Number of Skeletons				
		Front	Site	<i>dt</i>	0–4 yr	5–19 yr	20 + yr	Total	5–19/5+
Adena	Cassidy (1984), Webb and Snow (1974)	1950	2250	–300	11	25	161	197	0.13441
Albany Mounds	Herold (1971)	1950	1850	100	21	42	158	221	0.21000
Anderson	Dowd (1989), Doran (2002)	1250	6660	–5,410	18	16	39	73	0.29091
Arroyo Hondo	Palkovich (1978, 1980)	1750	587.5	1,162.5	49	18	41	108	0.30508
Averbuch	Boyd (1986), Eisenberg (1991)	1250	600	637	514.73	180.15	535.85	1,230.73	0.25161
Bedford	Buikstra (1976)	1950	1710	240	5	7	37	49	0.15909
Bird Island	Stojanowski and Doran (1998)	1350	5240	–3,890	0	4	28	32	0.12500
Black Mesa	Martin et al. (1991)	1750	975	775	46.58	33.44	84.98	165	0.28238
Carlston Annis	Mensforth (1990)	1950	4675	–2,725	105	58	191	354	0.23293
Carrier Mills	Buikstra and Mielke (1985)	1950	6200	–4,250	47	15.4	96.8	159.2	0.13725
Casas Grandes	DiPeso (1974), Storey (1985, 1992)	1250	650	600	61.2	220.32	330.48	612	0.40000
Cowling	Kreissa (1986), Vradenburg (1999)	850	550	300	13.5	10.87	32.63	57	0.24989
Dickson Mounds LW/MALW	Goodman et al. (1984), Lallo, Rose, and Armelagos (1980)	1950	875	1,075	91	60	200	351	0.23077
Dickson Mounds MM	Goodman et al. (1984), Lallo, Rose, and Armelagos (1980)	1950	700	1,250	83	50	88	221	0.36232
Duff	Sciulli and Aument (1987), Sciulli (1990)	1950	2950	–1,000	24	20	46	90	0.30303
East St. Louis Stone Quarry	Milner (1983)	1950	625	1,325	29.84	12.88	77.28	120	0.14286
Elizabeth	Charles, Leigh, and Buikstra (1988)	1950	5300	–3,350	8	9	31	48	0.22500
Etowah Mound C	Blakely (1977)	950	955	–5	3	32	136	171	0.19048
Fairty Ossuary	Katzenberg (1992), Jackes (1986)	1350	550	800	41	45	102	188	0.30612
Florence Street	Emerson, Milner, and Jacks (1983)	1950	625	1,325	11	5	32	48	0.13514
Garland	Jackes (1986), Pfeiffer and Fairgrieve (1994)	1350	425	925	20	46	100	166	0.31507
Gibson-Klunk	Buikstra (1976), Buikstra and Mielke (1985)	1950	1775	175	137.7	61.2	334.1	533	0.15482
Glen Williams	Jackes (1986), Pfeiffer and Fairgrieve (1994)	1350	500	850	33	29	101	163	0.22308
Grasshopper	Berry (1985), Wilma, Merbs, and Birkby (1985)	1750	612.5	1,137.5	339	90	189	618	0.32258
Gunderson	Vradenburg (1999)	850	575	275	2.5	16.29	26.21	45	0.38329
Hatten	Klepinger and Henning (1976)	1950	2750	–800	32	12	78	122	0.13333
Hawikku LA37	Stodder (1994)	1750	387.5	1,362.5	41	44	103	188	0.29932
Hiwassee	Storey (1985), Doran (2002)	1250	750	500	166	140	127	433	0.52434
Indian Knoll	Kelley (1980), Doran (2002)	1950	5360	–3,410	256	150	407	813	0.26930
Irene Mound	Larsen (1984), Larsen et al. (1992)	950	700	250	21	69	80	170	0.46309
Joe Gray	Atwell and Conner (1991)	1950	1200	750	29	35	102	166	0.25547
Kane	Buikstra and Mielke (1985), Buikstra and Milner (1991)	1950	750	1,200	30.3	33.49	79.74	143.53	0.29577

Table 1. (Continued)

Site	Sources	Date cal BP			Number of Skeletons				
		Front	Site	<i>dt</i>	0–4 yr	5–19 yr	20 + yr	Total	5–19/5+
Kleinburg	Jacks (1986), Pfeiffer and Fairgrieve (1994)	1350	350	1,000	14	19	83	116	0.18627
Koster	Droessler (1981)	1950	1250	700	63	40	126	229	0.24096
Kuhlman Mounds	Atwell and Conner (1991)	1950	1300	650	98	33	129	260	0.20370
Ledders	Atwell and Conner (1991), Buikstra and Milner (1991)	1950	900	1,050	56	50	72	178	0.40984
Ledford Island	Boyd (1986)	1250	505	745	124.86	58.38	268.77	452.01	0.17845
Libben	Howell (1982)	1950	1000	950	396	303	590	1289	0.33931
Mesa Verde	Bennett (1975)	1750	1050	700	25	56	121	202	0.31638
Moundville	Powell (1988)	1050	650	400	77	63	424	564	0.12936
Norris Farms	Vradenburg (1999), Buikstra and Milner (1991)	1950	650	1,300	124	34	106	264	0.24286
Ocmulgee	Powell (1994)	950	750	200	6	9	56	71	0.13846
Pearson	Sciulli, Giessen, and Paine (1996)	1950	800	1,150	119	105	199	423	0.34539
Pecos Pueblo	Hooton (1930), Mobley (1980), Storey (1992)	1750	475	1,275	439	265	1018	1722	0.20655
Point of Pines	Bennett (1973)	1750	675	1,075	156	37	296	489	0.11111
Pueblo Bonito	Palkovich (1978, 1984)	1750	925	825	9	24	62	95	0.27907
Rivière au Vase	Bender (1979)	1350	900	450	0	42	188	230	0.18261
Roebuck	Knowles (1937), Pfeiffer and Fairgrieve (1994)	1350	460	890	19	22	43	84	0.33846
San Cristóbal	Stodder (1994)	1750	447.5	1,302.5	65	55	148	268	0.27094
Schild 1	Buikstra and Milner (1990), Droessler (1981)	1950	1139	811	63	40	118	221	0.25316
Schild 2	Buikstra and Milner (1991), Droessler (1981)	1950	881.5	1,068.5	132	68	146	346	0.31776
Seip 1 Mound	Konigsberg (1985), Doran (2002)	1950	1600	350	11	14	62	87	0.18421
Serpent Mounds, Mound	Anderson (1968), Katzenberg (1992)	1350	1830	–480	14	11	56	81	0.16418
Serpent Mounds, Pit	Anderson (1968), Katzenberg (1992)	1350	750	600	8	6	46	60	0.11538
Sundown	Merbs and Miller (1985)	1750	800	950	11	6	10	27	0.37500
Tabor Hill	Churcher and Kenyon (1960)	1350	625	725	5	33	40	78	0.45205
Toqua	Boyd (1986), Parham and Scott (1980)	1250	525	725	156	102	181	439	0.36042
Town Creek	Driscoll (2001)	1150	600	550	60	30	107	197	0.21898
Tremaine	Vradenburg (1999)	850	525	325	17.58	34.42	40.22	92.22	0.46115
Turner	Black (1979)	1250	650	600	5.1	16.3	42.6	64	0.27674
Uxbridge Ossuary	Pfeiffer (1984), Pfeiffer and Fairgrieve (1994)	1350	460	890	93	54	310	457	0.14835
Windover	Stojanowski, Seidman, and Doran (2002)	1350	8435	–7,085	10	27	67	104	0.28723

represents age-specific mortality (m rate) and ${}_aL_x$ the number of person-years, the values being obtained from the life table. The variation in $d(5-19)$ (or ${}_{15}P_5$) in the distributions (%) of deaths in the simulated stable populations¹ can be broken up

1. 1,125 stable populations simulated at $\pm 3\%$, with a step of 0.025%, from 45 preindustrial life tables (Bocquet-Appel 2002).

into two fractions, one determined by the input variables and one by the output variables. Two analyses of variance (two-factor)² show that three-quarters of the variance in $d(5-19)$

2. By breaking down the variation into two models—(1) $\text{var}(d[5-19]) = \text{var}(e_0) + \text{var}(b) + \text{var}(e_0 \times b) + \text{error}$ and (2) $\text{var}(d[5-19]) = \text{var}(e_0) + \text{var}(r) + \text{var}(e_0 \times r) + \text{error}$ (table 2)—we find that in model

(or ${}_{15}P_5$) is determined by the variance in the birthrate (b) or the growth rate (r) (table 2). This reflects the fact that the impact of the shape of the population pyramid on the distribution of deaths, which is essentially determined by the growth rate (and, further, by the birthrate), is much greater than the impact of mortality (see McCaa 2002, 105, fig. 4.3; Johansson and Horowitz 1986; Sattenspiel and Harpending 1983). Again, it should be emphasized that under normal circumstances (i.e., those of most cemetery populations) the influence of inputs (birthrate and growth rate) on death distributions will mask the influence of mortality.³ When there is no direct information on mortality, it can be introduced by means of the density-dependent Malthusian model, which makes it possible to formulate biodemographic predictions about mortality that should be falsifiable with the skeletal data from cemeteries.

Relative Chronology of the Change

The demographic change is set in the framework of economic change. Because it cumulates transition processes from foragers to farmers which occurred at different times in different places, the space-time distribution of the data obscures the uniqueness of the phenomenon, which goes beyond absolute chronology and occurred at its own pace. Instead of an ab-

solute chronology, we have placed the data in the framework of a relative chronology (Bocquet-Appel and Dubouloz 2004; Bocquet-Appel 2002) in order to bring out the underlying patterns in the relatively scarce, spatially and temporally scattered archaeological information. Under the hypothesis that the Neolithic demographic transition was a process independent of geographical location and the absolute date of the sites sampled, geography can be removed from the space-time distribution of the data, leaving just the time distribution in relation to the local starting date of the process. We have called this starting date the “economic shift front.” Thus a demographic profile common to all the data, excluding the influence of geography or absolute chronology, is obtained. The chronological distance of a cemetery from the economic shift front, both situated on X , is the time interval dt separating the date of the front, $t_0(X)$, from the date of the cemetery, $t(X)$, or $dt(X) = t_0(X) - t(X) = dt$. (When dt is negative, the site is earlier than the economic shift front, that is, in the forager period.) Since $dt = 0$ represents the introduction of horticulture-agriculture, the variation of the indicator ${}_{15}P_5$ on the dt axis represents the demographic variation directly with regard to the chronology of the change in the production system. The date of the economic shift front is that of the cultures arising from the local introduction of the shift to horticulture (in the present Midwest: Ohio, Illinois, and Kentucky) or farming elsewhere, as explained above.

Analysis of the North American Data

The profile in figure 2 shows the underlying trend of ${}_{15}P_5$ within the relative chronological frame dt . It was obtained by the Loess fitting procedure (kernel-weighted robust polynomial regression of degree 1, proportion parameter $\alpha = 0.3$),⁴

4. We can demonstrate that by simulating cemeteries of various densities on dt , the variation of the α value of 0.3 to 0.4 does not significantly

1, 75% of the variation of $d(5-19)$ is determined by the variation in the birthrate (b) and a negligible quantity (0.7%) by mortality (e_0), while in model 2, 76% of the variation of $d(5-19)$ is determined by the variation in growth rate (r) and only 15% by mortality (e_0).

3. From the indicator ${}_{15}P_5$, it may be thought that it is possible to obtain mortality by subtracting the two estimators, $b - r = d$. It is worth noting that trying to estimate two independent demographic variables when we have only the information ${}_{15}P_5$ is like trying to solve an undetermined system of equations (with more unknown than known values). To estimate a second independent demographic variable, additional information would be necessary, and this cannot be obtained from skeleton distributions using existing techniques.

Table 2. Two Two-Factor Analyses of Variance of the Percentage of Deaths at 5–19 Years according to Mortality and of Two Demographic Input Variables

Model and Factor	Sum of Squares	d.f.	Mean Square	F Ratio	P
Model 1: $\text{Var}(d[5-19]) = \text{var}(e_0) + \text{var}(b) + \text{var}(e_0 \times b) + \text{error}$					
e_0 group	0.03843	4	0.00961	8.08721	0.00000
b group	4.35783	4	1.08946	916.97631	0.00000
e_0 group \times b group	0.08792	16	0.00549	4.62480	0.00000
Error	1.30691	1,100	0.00119		
Model 2: $\text{Var}(d[5-19]) = \text{var}(e_0) + \text{var}(r) + \text{var}(e_0 \times r) + \text{error}$					
e_0 group	1.49104	4	0.37276	545.94100	0.00000
r group	7.48810	5	1.49762	2193.40428	0.00000
e_0 group \times r group	0.06985	20	0.00349	5.11521	0.00000
Error	0.74765	1,095	0.00068		

Note: Mortality is represented by life expectancy at birth e_0 (five groups: < 20 years to 35 years+, classified by five-year intervals). The two input variables are birth rate (b) (five groups: < 0.02 to > 0.05, classified by intervals of 0.010) and the growth rate (r) (six groups, of -3% to +3%, classified by intervals of 1%). A total of 1,125 simulated stable populations, with intervals of \pm 3% and a step of 0.025%, was generated from 45 preindustrial life tables (Bocquet-Appel 2002). Using ${}_{15}P_5$ instead of $d(5-19)$ gives an identical result.

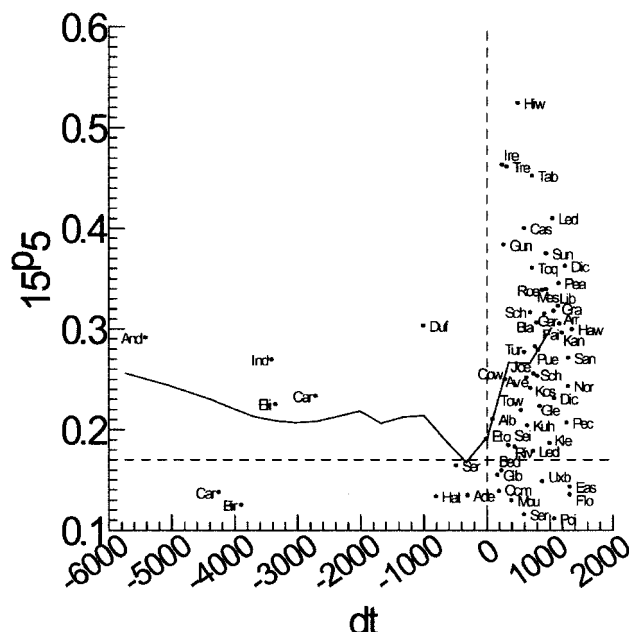


Fig. 2. Observed profile of ${}_{15}P_5$ in 62 North American cemeteries (vertical axis) with chronological distance from the economic shift front from forager to horticulturist-farmer (horizontal axis) obtained by the Loess fitting procedure ($\alpha = 0.3$). The horizontal dotted line represents the expectation for ${}_{15}P_5$ under the growth-rate hypothesis of zero, given by the estimators: inverse regression of $r = f({}_{15}P_5)$.

which is similar to a moving average (Bocquet-Appel 2002). The hypothesis of no change in the profile was tested by means of the Wald-Wolfowitz nonparametric runs test, which measured the sequential randomness of 25 Loess-fitted values equally spaced on dt ($=250$ years) on both sides of the median ($=0.222$; Z adjusted $= 4.4939$; P (two-tailed) < 0.00001) (Asatryan and Safaryan 1986), and was rejected. The horizontal dotted line in figure 2 represents the expected value of ${}_{15}P_5$ under the hypothesis of a stationary³ growth rate of $r = 0$. In the segment between $-5,800$ and $-1,000$, the value of ${}_{15}P_5$ is high, corresponding not to a stationary population but to a slightly increasing one. This may reflect the dynamics of New World colonization (for a summary, see Surovell 2000). Of particular interest is the region around the economic shift. The distance from the front to the first maximum of the curve is a relatively brief 400 years. The smoothed value corresponding to ${}_{15}P_5$ ($\times 100$) increases from 19% to 26%, an increase of 37%. Thus the North American data indicate a shift in the proportion of immature skeletons similar to the one observed in European and North African data during the transition from forager to horticulturist-farmer populations.

change the estimated profile. This estimated profile is thus able to detect a change in the archaeological data (Bocquet-Appel 2002; Bocquet-Appel and Paz de Miguel Ibáñez 2002).

5. Obtained through inverse regression of $r = f({}_{15}P_5)$.

Figure 3 shows the profiles for the European and North African (updated)⁶ and the North American data. For the common (relative) chronology of the two groups, in the interval from $dt = -3,500$ to $dt = 1,000$, which framed the start of the economic change, the initial ${}_{15}P_5$ ($\times 100$) for foragers at $-3,500$ is relatively high, roughly 23%. The two profiles then decrease continuously, lowering the estimated bottom value of a stationary population (17%, $b = 36 \pm 6\%$ with a prediction interval of 95%) to around $-1,100$ for Europe and North Africa and -400 for North America, where a kind of dip forms for about 1,000–500 years. After the dip, the proportion of immatures increases significantly to 30% ($b = 57 \pm 6\%$ and $r = 0.0164 \pm 0.0124\%$) during the relatively brief period of 600–800 years. The degree of coincidence of the two profiles can be shown by plotting the pairs of Loess-fitted values (Europe and North Africa and North America) with the same intervals (here $dt = 250$ years) onto the (relative) chronological common window (fig. 4). The profiles are very similar in terms of tempo and range, as

6. Paleoanthropological data from three Portuguese sites labeled Cabeço da Arruda, Moita do Sebastião, and Casa da Moura and radiometric data for the first two were updated in order to include the new inventory of Jackes and Meiklejohn (2004). The influence of the update on the observed profile was trivial.

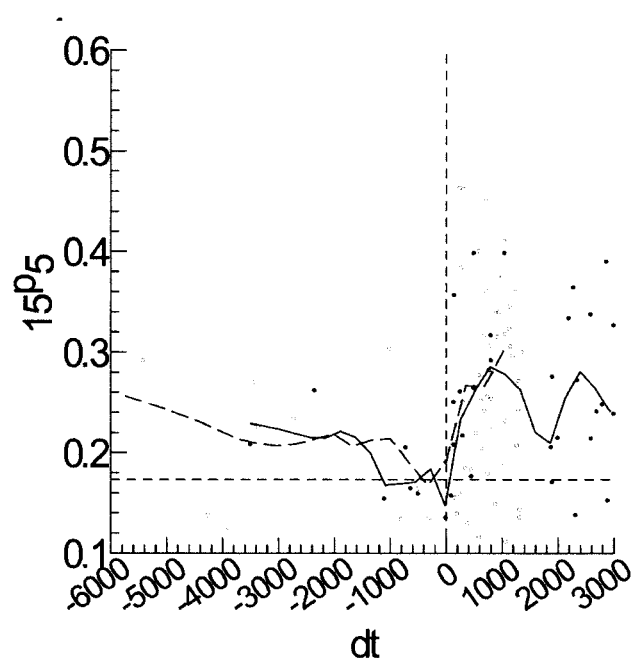


Fig. 3. Observed profiles of ${}_{15}P_5$ (vertical axis) with chronological distance from the economic shift front from forager to horticulturist-farmer (horizontal axis) in Europe (38 cemeteries) (black dots and continuous line) and in North America (62 cemeteries) (gray dots and dotted line) obtained by the Loess fitting procedure ($\alpha = 0.3$). The horizontal dotted line represents the expectation for ${}_{15}P_5$ under the growth-rate hypothesis of zero, given by the estimators: inverse regression of $r = f({}_{15}P_5)$.

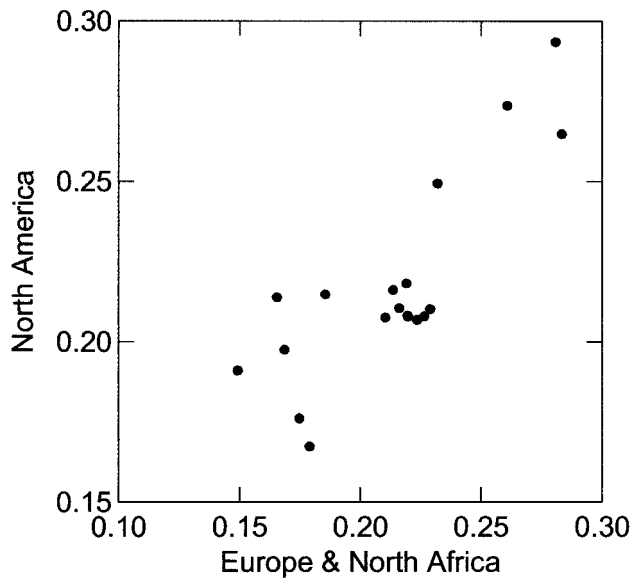


Fig. 4. Coincidence of the two profiles as measured by the correlation between the paired Loess-fitted values (Europe and North Africa and North America) on the intervals $dt = 250$ years, in the chronological window $dt = -3,500-1000$ ($R = 0.825$).

indicated by their coefficient of correlation ($r = 0.825$), despite an average chronological shift of about 3,500 years and substantial geographical distance.

This outline of continental signatures of a worldwide Neolithic demographic transition rests on an average of currently available data. The tempo was not necessarily the same everywhere, especially in the centers of independent agricultural invention. Important regions such as the Levant have so far produced no demographically exploitable paleoanthropological samples (Eshed et al. 2004), but the Levantine archaeological data suggest, in addition to a reversal of our interpretation of the causal hierarchy (the demographic change following the economic change [Bar-Yosef and Meadow 1995]), a slightly slower tempo (Kuijt 2000, fig. 4) than the one observed in the cemeteries presented here. It may be that in the initial zones the tempo of the transition was much slower than in the secondary ones. In the former, the tempo would have followed the slow pace at which the emerging economic toolkit was adopted by the population, while in the latter a ready-made toolkit would have spread rapidly, with a demographic impact corresponding to this rate of social transformation. This is what we observe in the contemporary demographic transition, which took 100–150 years in the initial western regions in the eighteenth and nineteenth centuries but just 30–40 years in the Indian subcontinent 200 years later (Bocquet-Appel et al. 2002).

Outlining a Pattern for the Neolithic Demographic Transition

Visualizing the chronological demographic change relative to the economic change is a first step toward an empirical answer to the recurrent question of the causes of cultural change in the context of the adoption of agriculture (Boserup 1965; Service 1968; Cohen 1977; for a summary see Graber 1997). As we have said, $dt = 0$ indicates the introduction of an economic change locally. Depending on whether the signal of the beginning of the demographic change, as represented by a long-term and abrupt positive variation of ${}_{15}P_5$ on dt , precedes ($dt < 0$), coincides with, or follows ($dt > 0$) the introduction of the economic change, we could say, as a first approach, that population growth is respectively the cause or the consequence of the economic change.

To determine the chronology of the demographic change more accurately, we grouped the European and North African and American cemeteries belonging to the (relative) chronological segment of $dt = -3,500$ to $dt = 1,000$ ⁷ together (56 cemeteries: 13 foragers and 43 horticulturists-farmers). In doing so, we hypothesized that the continental samples belonged to the same population event, thus limiting the influence of their specific histories on the pattern we wanted to demonstrate. In order to estimate the beginning of the signal of the transition on dt more precisely with the Loess fitting procedure, we varied the proportion parameter, looking for a profile that depended on a smaller range of information around the estimated value of ${}_{15}P_5$. With an α -value < 0.3 , the profile becomes sensitive to the sampling effect of individual cemeteries, and its representation becomes erratic. Both estimations of the signature of the transition are represented in figure 5. The two are very similar: in both profile estimations (*a* and *b*), viewed over the long time duration of 4,500 years in relative chronology dt , there is a remarkable degree of coincidence between the economic and demographic changes. The hypothesis of a flat profile is rejected (Wald-Wolfowitz nonparametric runs test: median = 0.218; Z adjusted = 4.4939; P (two-tailed) < 0.00001). Because this concerns a test using the same device (25 values estimated on the Loess made with the same 250-year intervals), it should be noted that the two tests of both profiles (figs. 3 and 5) produce identical results. Because we have two paleodemographic estimators expressing inputs but only one profile for data ${}_{15}P_5$ (fig. 5), this has been subdivided into two segments—before and after the beginning of the shift—to help with its interpretation. The first segment is interpreted in terms of pretransition variation in the growth rate, while the second is interpreted as a signal of the abrupt change in the birth rate during the transition. In segment $dt < 0$ of the forager production system, the ${}_{15}P_5(\times 100)$ value at $dt = -3,500$ is

7. In order to match the North American data with previously analyzed European cemeteries (see Bocquet-Appel 2002), only North American cemeteries with $d(5+) \geq 50$ were included.

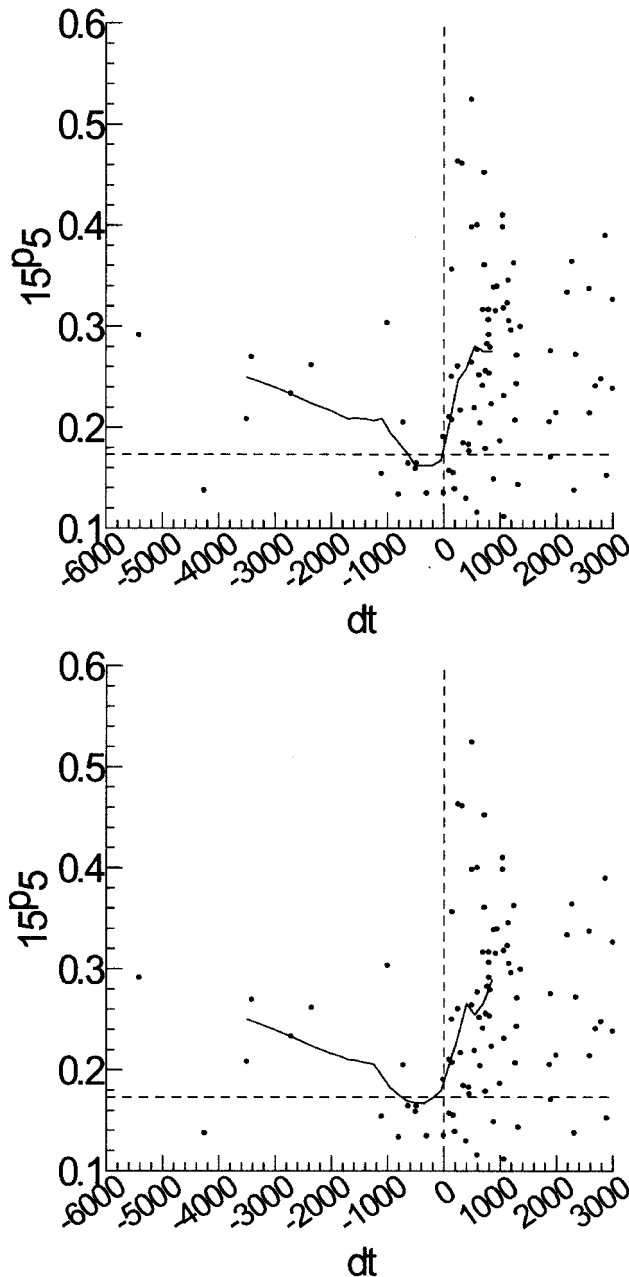


Fig. 5. Observed profiles of ${}_{15}P_5$ with chronological distance from the economic shift front for 56 European and American cemeteries (13 forager and 43 horticulturist-farmer) belonging to the chronological segment $dt = -3,500$ to $dt = 1,000$ corresponding to the transition from forager to horticulturist-farmer) obtained by the Loess fitting procedure ($a, \alpha = 0.3$; $b, \alpha = 0.4$). The horizontal dotted line represents the expectation for ${}_{15}P_5$ under the growth-rate hypothesis of zero, given by the estimators: inverse regression of $r = f({}_{15}P_5)$.

roughly equal to 25%. This rather high value corresponds not to a stationary population but to a growing one. ${}_{15}P_5(\times 100)$ then continuously decreases and lowers the estimated bottom value (17%) of population replacement to a stationary equilibrium. It then reaches a low value (${}_{15}P_5[\times 100] \cong 16\%$) around $dt = -600$ years, which corresponds to a slightly decreasing demographic population around ${}_{15}P_5$ becomes stable. Following a period indicating (decreasing) growth, this period can be interpreted as a time of stagnation of the metapopulation at the level of the carrying capacity of the forager production system. From the viewpoint of population biology, in the cemeteries corresponding to this period of pretransition stagnation (Hatten, Adena, and Serpent Mounds in North America, Moita do Sebastião and Djerdap in Europe) we would expect a reduction in the stature of individuals (as observed from the average lengths of long bones) and in sexual dimorphism, as well as the appearance or increased frequency of deficiency pathologies, relative to cemeteries from the earlier, more favorable period (Columnata and Tafalalt in North Africa, Carlston Annis and Indian Knoll in North America). The period ends with the introduction of horticulture-agriculture at $dt = 0$. The metapopulation's prompt reaction to the new system, in what must be called an explosion of the birthrate, could be a sign of disruption of the old forager fertility regulation system, along with an increase in the carrying capacity of the new system. Here we concur with the Malthus and Boserup model scenario (Wood 1998; Lee 1987) in which the population is alternately the cause and the consequence of the economic change effect: the cause as population pressure on the carrying capacity of the forager system increases the probability of change and the consequence as population growth tends toward the new carrying capacity once the horticulturist-farmer system is introduced (Wood 1998).

What was the role of mortality in the transition? This question raises two further sets of questions. The lack of adequate paleodemographic information makes it unlikely that the first set will be answered for some time, but answers to the second set may be found in the near future, using a population model. The ${}_{15}P_5$ profile of the last pretransition phase may be interpreted as indicating an increase in mortality in that it drops below the expected growth rate for a stationary equilibrium. The questions that cannot be answered at present, then, include how long this apparently relatively high level of mortality was maintained after the onset of the demographic transition and whether the horticulturist-farmer system generated an increase in life expectancy that might have made a modest contribution to the initial demographic growth. The answers to these questions will depend on whether the density-dependent Malthusian model is an accurate reflection of reality. In the course of the transition, during or after the period showing a steep increase in the birthrate, the model predicts stabilization of the population at the stationary equilibrium where $b = d$. The term "return to equilibrium" is generally used in preference to the term "stabilization" because after a

disturbance the population returns, roughly, to the same long-term trend for a (very) long time. This seems well attested in the historical data for the past two millennia (Wilson and Airey 1999), but the profile of figure 5 seems to show that during the pretransition period the stationary state lasted less than a millennium. It may be that the forager data in the profile are influenced by the cemeteries reflecting the expansion of settlements in North America—those in which growth was positive. Nevertheless, the question then becomes how long after the beginning of the demographic transition equilibrium was reached.

The rise in mortality in the Old World must have been caused by the emergence of new pathogens, mainly infectious diseases resulting from zoonoses among domesticated animals (cattle, sheep, goats, and pigs) and from the anastomosis of village units, which facilitated their spread (Bocquet-Appel 2002). It is less clear which domestic animals are candidates for zoonoses in the New World. The two continents should perhaps be differentiated here. Mortality primarily affects children under 5 years old. Candidates would include viral diseases (smallpox, measles, mumps, rubella, chickenpox, and poliomyelitis) and bacterial diseases (whooping cough, diphtheria, meningitis, and typhoid). The signal and timing of demographic stabilization to a state of equilibrium should be detectable by the discovery of genetic markers for these candidate diseases in a population's skeletons, for instance, in the pulp cavities of the teeth of child skeletons (see, e.g., Drancourt et al. 1998).

Another important question is what it was in the Neolithic toolkit that was responsible for the unprecedented increase in the crude birthrate (a collective index, which is influenced by the age distribution) and, beyond that, the increase in fertility (an individual index, which is independent of the age distribution). The influence of reproductive age via age at marriage must be excluded. Although marriage was a variable of historical fertility control in Western preindustrial populations (Hajnal 1953), it is based on long-term matrimonial traditions that cannot easily be modified. It is simpler to look for the cause of increased fertility in a mechanical consequence of the new system of production. Given that fertility increases when the birth interval decreases through an earlier weaning age and vice versa, what in the Neolithic toolkit could have lowered the weaning age? A farmer's diet is one hypothesis (Bocquet-Appel 2002; Molleson 1996; Bentley, Goldberg, and Jasienska 1993; Binford and Chasko 1976; Binford 1968), but we lack information on diet and fertility rate comparisons and it is unclear what domesticated animals in North America provided the dairy products suggested in the Levant and in Europe. A simple comparison between populations divided into "agricultural" and "nonagricultural" societies creates a confounding variable that obscures a hypothesis probably first formulated by Malthus (1926 [1798], 13) and then by other researchers (Carr-Saunders 1922; Sussman 1972; Roth 1981), namely, nomadism versus sedentarism. It could be that the increase in Neolithic fertility was caused by a by-product of the Neolithic toolkit represented

by sedentarism. In nomadic societies, women carry children up to 3–4 years of age and almost continuously before that (Lee 1972, 1979). Tied to their mothers, children are able to suckle, which, along with near-exclusive breastfeeding, is known to delay the return of menstruation (Rosner and Schulman 1990; Short 1976; Rivera 1996). The duration of lactational amenorrhea is highly variable and depends upon the pattern of suckling. Intensive suckling can delay the onset of menses for one to two years (McNeilly 1988; Brown, Harrison, and Smith 1985; Stern et al. 1986; Hennart et al. 1985; Howie and McNeilly 1982). "The suckling of the baby is the major regulator of the duration of infertility, and nutrition, unless extreme, has a limited effect" (McNeilly 2001, 583). The longer period of lactational amenorrhea for foragers, correlated with a late weaning age, is the result of their mobility. With a decrease in mobility, the mechanics favoring suckling are reversed. Sedentarism reduces the time women carry children past 1–2 years old, which in turn reduces suckling frequency, and the result is a reduction of a few months in lactational amenorrhea. To avoid energy loss in children, the weaning age must be lowered, and this accelerates the return of the mother's reproductive cycle and thus increases her fertility. According to this hypothesis, the increase in fertility was the mechanical consequence of a mobility shift in foragers. We are currently trying to test this hypothesis, although demographic data for sedentary/nomadic foragers are hard to find. The hypothesis nevertheless deserves mention for the potential strength of its impact, its simplicity, and its ubiquity in the available data.

In the Malthusian model, the population grows mainly via a relaxation of mortality, which in turn results from an increase in carrying capacity. But the visible signal of the Neolithic demographic transition in the paleodemographic data is interpreted as a steep rise in fertility. How can this fact be reconciled with the Malthusian model? We might think that the shift to sedentarism of nomadic forager populations—the formation of sedentary or quasi-sedentary forager communities for reasons to do with the permanence of local resources—occurred many times during prehistory. Some instances are indeed attested in recent prehistory (shellfish in the mouth of Tagus in Portugal [Jacks and Lubell 1999], fish along the Dniepr in Ukraine [Telegin et al. 2003]), but the demographic impacts of these instances were transitory. They may have caused episodic bursts of population growth in ecologically favorable zones, but they did not produce any enduring demographic change. For the steep increase in fertility to become a systemic demographic explosion, it would have had to take place in the context of a production system with the potential for a considerable increase in carrying capacity.

Discussion and Conclusion

The prediction that if a Neolithic demographic transition occurred in Europe, then it should have occurred in all the world's centers of agricultural invention and that its signal should then be detectable in the corresponding regional cem-

eteries is corroborated by the data from North American cemeteries. We have described the observed range and tempo of the transition by indicating that the pace may have been slower in the centers of the economic shift and faster toward the expanding peripheries. In fact, the pace may even have corresponded to the time it took for forager mobility to disappear in a new local system. In the aggregated data for both northern continents, using paleodemographic estimators,⁸ we obtained crude birthrates and growth rates of b forager = 42.7‰ (PI 95% = 50.7–33.1) and r forager = 0.6% (PI 95% = 1.96–0.91%) and b farmer = 51.5‰ (PI 95% = 58.7–43.4) and r farmer = 1.26% (PI 95% = 2.57–0.09%). Although the prediction interval is large, because it includes the binomial variability of ${}_{15}P_5$ as well as the standard error of the estimator, the estimation of r for foragers includes the widely accepted stationary hypothesis, whereas for farmers the r estimate points to a growing metapopulation, although it does not exclude the stationary assumption. With no information on mortality but with an unambiguous signal of a birthrate explosion, it seemed less speculative to build a scenario for the transition starting from the latter. The birthrate explosion can easily be integrated into the Malthusian model as a primary factor of demographic growth. Simply put, not only did the horticulture-farming system increase the carrying capacity but the production system itself, resulting in the sedentarization of society, increased individual fertility in women and raised the birthrate to an extent that is possibly unprecedented on this scale. The discovery of a Neolithic demographic transition in North America reinforces the idea that this transition was the beginning of the preindustrial agrarian population regime (Bocquet-Appel and Dubouloz 2004) of high fertility and mortality, also known as the “high-demographic-pressure” regime (McCaa 2002, 2000). This system is now coming to an end with the completion of the n th demographic transition in human history.

Acknowledgments

We thank Maggie Dittmore and James Haug for their valuable assistance at the Smithsonian Anthropology Library, as well as Alice Berkson (Public Service Archaeology Program, University of Illinois at Urbana-Champaign), Jeffrey A. Burse (University of Toronto at Mississauga), Clark Spencer Larsen (Ohio State University), Ann L. W. Stodder (The Field Museum), Christopher Stojanowski (Southern Illinois University), and Sara Randall (University College London) for the information they kindly and swiftly provided and the three anonymous referees for their detailed comments on an early draft. This work was supported by a grant from the Fonds National de la Science, ACI 3T, “Globalization.”

8. Sample of 56 cemeteries (13 forager, 43 farmer) on the segment $dt = -3,500$ to 1,000 with $d(5+) \geq 50$: ${}_{15}P_5 = 404/1,885 = 0.2143 \pm 0.0094$ for the foragers and ${}_{15}P_5 = 2,124/7,933 = 0.2677 \pm 0.0049$ for the horticulturist-farmers.

Comments

George J. Armelagos and Kenneth C. Maes

Department of Anthropology, Emory University, Atlanta, GA 30321, U.S.A (antga@learnlink.emory.edu). 21 X 05

Bocquet-Appel and Naji state that comparison of demographic trends between continents provides hypotheses that “go beyond regional ecology.” Focusing on such hypotheses frees the discussion of ecological particulars, but at some point the discussion must return to the pertinent ecological factors that varied among Neolithic agricultural centers. The researchers ask whether the demographic transition will be detected in North America as in Europe and North Africa even though the transition to agriculture occurred 7,000 years later there. Time is, however, not necessarily the interesting variable. Instead, some of the variables of interest are the crops that were domesticated, the use of domesticated and/or wild animals and other resources, and the social structure. Understanding how nutritional and infectious disease environments vary among Neolithic Europe, North Africa, and North America may lead us to question whether we will find similar signals of the demographic transition in each region. Might these factors in some cases prevent rapid population growth in agricultural societies despite the mechanisms that lead to reduced birth spacing? Several analyses suggest that the answer is no.

The transition to agriculture in many places resulted in an increase in nutritional and infectious disease (Cohen and Armelagos 1984). Analysis of the skeletons at Dickson Mounds, which make up part of Bocquet-Appel and Naji’s database, provides an illustrative example. At Dickson Mounds, as the population shifted to intensive agriculture, there was a fourfold increase in iron-deficiency anemia as indicated by porotic hyperostosis and a threefold increase in systemic infectious disease as indicated by periosteal lesions (Goodman and Armelagos 1985; Goodman et al. 1984). While the nutritional and infectious disease load affected all segments of the population, infants and children were at greatest risk (Goodman and Armelagos 1989). The growth of the population in spite of an increase in disease load indicates that the population was able to reduce birth spacing. The chronology of enamel hypoplasia shows that the Dickson Mounds population experienced peak stress between the ages of two and four (Goodman, Armelagos, and Rose 1980, 1984), which may correspond to the period of weaning. The comparison of the chronology between the earlier groups and the intensive agriculturalists shows a decrease in the age at onset of hypoplasia, suggesting an earlier age at weaning (Goodman, Armelagos, and Rose 1980, 1984). The stress of childhood also affected the survivorship of adults (Goodman and Armelagos 1988).

In summary, the population at Dickson Mounds suffered

biologically from the shift to intensive agriculture. The success of the cultural system in capturing more energy through economic intensification had its biological costs. The ability to reduce birth spacing allowed the population not only to meet the increase in mortality but also to meet the increased labor needs of intensification, but there was an increase in nutritional and infectious disease load that affected all segments of the population, with infants and children at especially great risk.

Neolithic populations undoubtedly experienced an increase in mortality from infectious disease and nutritional deficiencies (Cohen and Armelagos 1984). The pattern of mortality (with the very young and the very old at highest risk) was not as socially or reproductively disruptive as the pattern of zoonotic diseases among hunter-gatherers (which primarily affected the producers in the economy). The predictability of mortality in an agricultural society and the presence of economic producers who are immunologically mature would have allowed them to meet the increase in mortality by reducing birth spacing, while the reduction of birth spacing would have had a negative impact on the health and nutrition of infant and mother.

Bocquet-Appel and Naji treat the reduction of interbirth intervals as a simple unconscious mechanism involving sedentism and lactational amenorrhea. They miss an important piece of the demographic-transition puzzle: the *active* shortening of the interbirth interval in response to increased infant mortality and an economic need for producers (Armelagos, Goodman, and Jacobs 1991). These need not be treated as separate, mutually exclusive mechanisms. It would be unwise to exclude the operation of one or the other in bringing about a reduction in birth spacing.

Andrew T. Chamberlain

Department of Archaeology, University of Sheffield, Sheffield S1 4ET, UK (a.chamberlain@sheffield.ac.uk). 1 X 05

The interactions between subsistence practice and fertility are of considerable interest both to archaeologists and to demographers. Bocquet-Appel and Naji are to be congratulated on collating and validating a large palaeodemographic data set for North America and for their innovative approach to extracting the signal of enhanced fertility associated with the transition to farming. Their results corroborate and substantiate earlier demonstrations (e.g., Buikstra, Konigsberg, and Bullington 1986) of a fertility-linked increase in the proportion of juvenile remains in Native American cemeteries that appears to coincide with the development of agriculture.

The power of Bocquet-Appel and Naji's analysis lies in the standardizing of chronological time at the point of economic transition, which allows them to combine data from sites that are spatially well separated and experienced the economic transition at different times. This approach does, however, require a definition of economic transition that can be applied

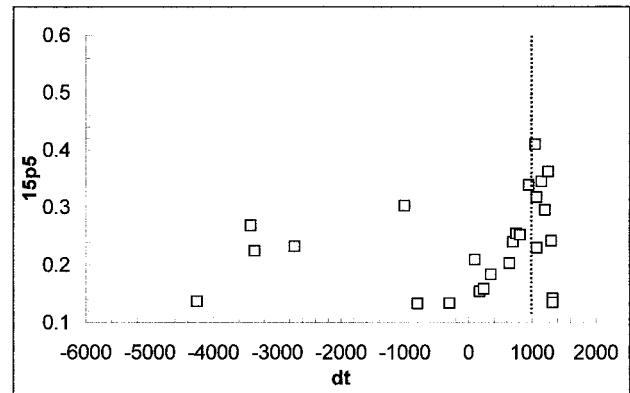


Fig. 1. Proportions of immature skeletons in 25 cemeteries from the American Midwest, arranged in time relative to the economic shift away from foraging estimated by Bocquet-Appel and Naji to have occurred at AD 0 (1,950 cal BP). No significant change in values is evident near the time of this transition ($dt = 0$), but substantially higher values occur in some cemeteries at about AD 1000, coinciding with the emergence of intensive agriculture (indicated by dotted vertical line). Data taken from Bocquet-Appel and Naji's table 1.

cross-culturally in a robust manner. Rather than choosing the inception of intensive agriculture as indicating the local starting date for the transition, Bocquet-Appel and Naji appear to have standardized their chronological data on the first appearance of domesticates, which in some parts of the Americas predate the emergence of intensive agriculture by a millennium or more. This issue is important because ethnographic data indicate that fertility rates of horticulturalists are much closer to those of foragers than to the levels observed in agriculturalists (Hewlett 1991; Bentley, Goldberg, and Jasińska 1993; Bentley, Jasińska, and Goldberg 1993), so only minor changes in fertility are expected to occur when foragers make a transition to low-intensity horticulture or non-intensive agriculture.

This effect may be seen in my figure 1, which plots the $_{15}P_5$ values for a large subsample of Bocquet-Appel and Naji's data—the 25 cemeteries for which the shift away from foraging (i.e., the arrival of the transition front) is dated at 1,950 cal BP, which conveniently equates to AD 0. The communities of the American Midwest during the first millennium AD are best described as “low-level food producers” (Smith 2001), and dramatic intensification of food production did not occur in this region until the establishment of maize-beans-squash agriculture at around AD 1000. In Bocquet-Appel and Naji's demographic data there is a time lag of about 1,000 years between the shift from foraging and the first evidence for elevated proportions of juvenile skeletal remains. This fits well with predictions of low fertility rates in horticulturalist populations. In other parts of the Americas a more accelerated transition from foraging to intensive agriculture is likely to have occurred, and in these locations high $_{15}P_5$ values would

be expected to be observed soon after the economic transition. The implication is that the shift from foraging lifestyles to food production is not necessarily the same phenomenon wherever it occurs and that it may be more appropriate to correlate demographic parameters with the emergence of intensive agriculture than with the earliest occurrence of non-foraging behaviour.

Vered Eshed

Department of Anatomy and Anthropology, Sackler Faculty of Medicine, Tel Aviv University, Tel Aviv 69978, Israel (veredes@post.tau.ac.il). 30 X 05

Bocquet-Appel and Naji present three major arguments: (1) There were more children per family in the cemeteries of farmers than in those of hunter-gatherers (because of increased fertility). This shift in age-at-death distribution may serve as an indicator of an economic transition. (2) This phenomenon is independent of geographical location. (3) The pace of this demographic change is more rapid in the zones favorable to the expansion of the economic shift than in the initial zones. I generally agree with these arguments.

Although the study is based on a large number of sites, the number of sites that represent the pre-agricultural phase is small and spread over a long time span. In contrast, the post-agricultural communities are represented by a disproportionately large number of cemeteries extending over a relatively short period of time. It may well be that much of what we see in the graphs is a statistical artifact. For example, in the case of the Levantine Natufians (hunter-gatherer communities), sites varied widely in age at death (Hershkovitz and Gopher 1990; Eshed et al. 2004), and therefore the average for the total Natufian population does not necessarily represent the "meta-Natufian population." The wide geographical distribution of the sites under study, their different ecological niches, and the fact that they were not randomly selected are some of the factors that could bias the results.

The concept of a Neolithic demographic transition is, of course, not new. (Hershkovitz and Gopher 1990), examining extensive demographic data on the late hunter-gatherers and early farming communities of the Levant, found a correlation between the child/adult ratio and food-producing strategies that they attributed (as Bocquet-Appel and Naji do) to an increase in the crude birthrate. Furthermore, they concluded that the demographic change expanded over time, a notion that is also suggested by the current researchers for the "initial zone."

The issue of mortality is dealt with very briefly. This is a problematic issue that paleodemographic studies, including the current one, try to avoid, but it has a tremendous impact on data analysis and interpretation. From our experience with the Mesolithic-Neolithic populations of the Levant, the factors that promoted mortality changed considerably from one economic phase to another. Finally, in our study we did not find

a dramatic change in life expectancy between the Natufian and the Neolithic population (Eshed et al. 2004).

The issue of fertility raises questions as well. For example, Bocquet-Appel and Naji comment that children were weaned earlier in the Levant because of the availability of dairy products. This old claim has been rejected (Hershkovitz and Gopher 1999); dairy products became available in the Levant only some 3,000 years after the agricultural revolution, and during the Neolithic period most children probably suffered from lactase deficiency.

Mary Jackes

Department of Anthropology, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada (mkjackes@watarts.uwaterloo.ca). 16 XI 05

Bocquet-Appel and Masset (1977, 1982) have helped palaeodemographers to understand results which seemed to make no sense: when I was attempting to test methods by comparisons across transitions, they demonstrated why age-assessment techniques unexpectedly produced almost identical age distributions (Jackes 1985). Other methods allowing comparisons became necessary, and, besides their index of juvenility (J:A), I used mean childhood mortality (MCM) as a proxy value (Jackes and Lubell n.d.; Jackes 1986). *P*, proposed here, is basically the equivalent but simpler to derive and possibly less error-prone.

Bocquet-Appel and Naji have made a brave attempt to discern a fertility shift in North America with the introduction of subsistence change, but there must be close attention to key concerns: (1) Were there specific-purpose burial areas, excluding adults or children differentially? (2) Was the site completely excavated? Are all skeletons available for analysis? Is period attribution correct? (3) Was there migration and/or aggregation in the context of, for example, warfare and/or climatic change?

For example, there are few children in Etowah Mound C, and Blakely's (1977) caution against its use for demographic reconstruction seems reasonable given the difference between the Etowah Village and Mound C components ($P = .359$ vs. 190).

The extremely low totals given for many Ontario sites apparently result from the summing of cumulative percentages. However, for a number of sites not all excavated individuals were included in the analysis. There are many sources of information on Indian Knoll, with sample sizes ranging from 813 (used here) to 880 (Webb 1974) to 1,132 (Snow 1948; Howells 1960). A test of seven such studies shows *P* to range from .229 (Webb 1974) to .358 (Snow 1948).

MCM values suggest population increase for several Late Woodland sites (Jackes 1993), but Dickson Mounds appears to be an exception since the Middle Mississippian apparently exhibits signs of higher fertility. However, the attribution to periods and other characteristics of the research require scru-

tiny; sources other than that used here suggest a reduction in fertility in the Mississippian at Dickson Mounds.

Even if the first and second concerns are not relevant, a sample may be unsuitable for demographic comparisons. Hiwassee and Irene Mound, the outliers in the data set, need consideration: when the Hiwassee fertility levels are predicted from J:A and MCM, the results are discrepant, with large error ranges, and beyond the bounds of biological probability. Using the MCM, the 95% range of total fertility rate is 27 to 31, and the prediction from J:A is higher still. Lewis and Kneberg (1970) date the majority of subadult burials at Hiwassee to the Dallas component, possibly from the early historic period, perhaps comparable to an early-contact cemetery where apparent high fertility occurs within the context of ethnohistorically confirmed low fertility rates (Jackes 1994). The age distribution of parts of this cemetery probably results from influxes of refugees during population/economic disruption, drought, famine, warfare, and epidemics (Jackes 1996).

Exploring whether the European Mesolithic-Neolithic transition would provide a more clear-cut situation than that in North America, Meiklejohn, Lubell, and I studied Portuguese samples from one of the few regions with samples of sufficient size (cf. Meiklejohn et al. 1997; Jackes, Roksandic, and Meiklejohn n.d.) within a circumscribed geographic zone and a tight time-frame (our limit was 1,000 years before and after the transition, confirmed by stable-isotope values for radiometrically dated individuals). We had expected that the Neolithic population would be less healthy than the Mesolithic and were proven wrong (Jackes, Lubell, and Meiklejohn 1997). We had no preconceptions regarding fertility, but our demographic conclusions seem well-based and have been confirmed by detailed reanalysis (Jackes and Meiklejohn 2004, n.d.; Jackes and Alvim n.d.).

For central Portugal I suggest that population increase began before any radical subsistence change. I do not assume that fertility increase and crop domestication bear a simple relationship to each other (Jackes, Merrett, and Meiklejohn n.d.), but it is possible that increased sedentism and intensified use of local resources, prior to the wholesale introduction of agriculture, could have initiated fertility increase, with variable consequences after agricultural intensification: in terms of health and perhaps fertility there seem to have been different outcomes in Europe and North America. This should be tested in specific regions, with close attention to chronological, sample, and migration concerns.

Bocquet-Appel and Naji provide a means by which age distributions at death can be compared, but the variability in P is such that closer regional examination seems desirable. Recognizing this led me to abandon an equivalent attempt 20 years ago, my major concern being chronology. Regional expertise is all the more necessary now: research has shown that the continuum of plant use in North America makes simple categorization almost impossible; the complex mosaic even within one area is formidable (Schroeder 2004), espe-

cially given the possibility of porous and shifting boundaries (e.g., in Ontario); and even where knowledge is deepest, we lack understanding of vital facts about burial practices (e.g., Sutton 1988). Very fine-grained research must be the next step.

Morongwa N. Mosothwane

Department of Archaeology, University of the Witwatersrand, Private Bag 3, Johannesburg 2050, South Africa (mosothwanem@science.pg.wits.ac.za). 17 X 05

Tracing the Neolithic demographic transition in a context other than North Africa and Europe is an important step towards an understanding of world populations in specific contexts. While generalizations are often acceptable, I find Bocquet-Appel and Naji's attempt to test the model on a different continent appealing in that it allows students of palaeodemography to see the uniqueness of world populations operating with similar challenges. Unfortunately, the methods used appear to be a bit problematic and are probably not well explained. For instance, the researchers begin with a sample consisting of 24 forager cemeteries and 38 horticulturalist-farmer cemeteries, classified on the basis of cultural subdivisions, and use mathematical equations to place these cemeteries either before or after the economic shift front: " $dt = 0$ represents the introduction of horticulture-agriculture," a negative dt value placing the site in a forager period and a positive dt value placing it in the horticulture-agriculture period. However, table 1 and figure 2 show a slightly different picture, in which only 11 of the 24 forager sites have negative dt values. The authors do not say why the number of forager sites differs so much when using archaeological artifacts versus the calculation of dt . One then wonders whether the archaeological interpretation of the sites was wrong or whether dt is only 50% accurate in distinguishing foragers from farmers. An alternative interpretation could be that the 13 sites continued to be foragers while undergoing the transition, but the problem with this interpretation is that they had positive dt values, which automatically means they had shifted from foraging to horticulture. If there is a logical explanation for having 11 instead of 24 sites with negative dt values, then Bocquet-Appel and Naji have not told us what it is. Perhaps the calculation of dt needs to be reviewed and its level of accuracy clearly stipulated.

The researchers report that "the smoothed value corresponding to ${}_{15}P_5 (\times 100)$ increases from 19% to 26%, an increase of 37%," and "thus the North American data indicate a shift in the proportion of immature skeletons." How they arrived at an increase of 37% instead of 7% (which is the mathematical difference between 19% and 26%) is not explained. If this 37% is an error, then the increase in the

proportion of immature skeletons is not as “substantial” as they would like us to believe and their interpretation of the results will have to be reviewed.

Aside from these methodological issues, I strongly believe that the research is of great importance for palaeodemographers around the world. In my view, the attempt to test the idea of a Neolithic demographic transition in North America using European and North African methods is not only a test for patterns of population change around the world but also a test of the reliability of the methods used previously and therefore an important contribution to our field of study.

Amy Sullivan

Research Laboratories of Archaeology, Campus Box 3120, 108 Alumni Bldg., University of North Carolina, Chapel Hill, NC 27599-3120, U.S.A. (asullivan@email.unc.edu). 17 X 05

Bocquet-Appel and Naji use a global approach to explore the manifold demographic and socioeconomic changes associated with the transition from foraging to farming. After identifying a common demographic profile that exists in both New and Old World foraging and farming populations, they argue that this shared profile reveals a general pattern of slow fertility-driven population growth in pretransitional forager societies, a period of population stagnation characterized by increased strain on carrying capacity and elevated mortality levels just prior to the transition to farming, and a subsequent population explosion that emerges as both a cause and a consequence of agricultural innovation. While the stated intent of this piece is narrowly focused although sweeping in geographic and temporal scope, it brings to light both the challenges of developing complex understandings of this global demographic transition and the methodological and interpretive tensions that exist within paleodemography and bioarchaeology as a whole.

Archaeological and historical inquiries conducted in diverse contexts have linked the emergence and intensification of farming practices with growing social complexity, socioeconomic stratification, population growth and aggregation, and a transformation of gender relations. Despite these general shared traits, the variability in experience among and within pretransitional, transitional, and posttransitional societies is high, and a quick scan of the $^{15}P_5$ data in this paper shows substantial temporal, spatial, and sociocultural variation that is obscured by looking solely at the highly abstracted aggregate trend. While the global approach espoused by Bocquet-Appel and Naji takes an overarching long-term view of population flows, an emphasis on explaining variation and similarity within and among historically rooted societies is equally crucial in that it draws us closer to an understanding of human experience through the specificities of daily life.

In their global interpretation of the Neolithic demographic transition, Bocquet-Appel and Naji focus almost exclusively on changing fertility regimes and depend heavily on isolating

the prime movers responsible for these shifts. When considering the mechanisms behind a global trend toward declining birth spacing, lactational amenorrhea is posited as the likely causative agent of change while other general aspects of human fertility remain unexamined. An expansive literature on human reproductive ecology has shown that biological sensitivity to environmental stresses such as inadequate nutrition and high levels of physical exertion can suppress ovulation independent of lactation and can also result in the inability to maintain pregnancy to term. Shifting from a foraging to a farming lifestyle precipitated general societal, gendered, and status-related changes in diet and activity, so it is reasonable to believe that these changes, along with patterns of nursing, combined to produce not only the global increase in crude birthrates identified by the researchers but also other important transformations in human fertility, morbidity, and mortality.

According to their narrative, decreased contact between mother and child in sedentary farming societies is the key behavioral change that shortened periods of lactational amenorrhea. However, this assertion is not fully discussed outside the context of a general decline in physical mobility among farming groups and does not tackle variation in these shifts by specifying whose fertility changed, when, and why. For example, if this is a key explanatory variable, we must ask how and why mother-child contact diminished across a range of farming societies and what these changes tell us about the evolving relationship between mother, child, and community in local, regional, and global contexts. If understanding human experience is the goal of bioarchaeology, the question becomes: How did maternal and societal experiences of infant birth and death, cultural ideas about growth into personhood, local perspectives on gender and sexuality, and experiences of social inequality and difference combine to produce the ways in which mothers in a range of situations invested time, energy, and resources bearing and caring for their children?

Examining the shift from foraging to farming affords us the opportunity to think synthetically about interlinked multiscalar sociodemographic phenomena and to move away from reductive prime-mover explanations of human behavior and experience. Studying these complex processes foregrounds the need for tapping into a wide range of academic knowledge to explore the breadth of variation and points of commonality that emerged as part of this transition. Instead of black-boxing analyses of morbidity/mortality, sexuality/union formation, and migration because of a perceived lack of contextual information, paleodemographers should continue improving their reconstructions of the past by embracing the collective methodological, analytical, and interpretive strengths of interdisciplinary research. Within a rigorous interdisciplinary research program, bioarchaeologists will be better able to elucidate the influences of and links among heterogeneous global, regional, and local socio-

demographic processes as well as the relationships that developed among individuals, social groups, and their societies in the past. Ultimately, local experiences of the transition from foraging to farming were far from monolithic. Any powerful interpretive framework must meaningfully articulate these diverse, intensely human local experiences with the global trend identified by Bocquet-Appel and Naji.

Gary Warrick

Contemporary Studies, Brantford Campus, Wilfrid Laurier University, Waterloo, ON, Canada N2L 3C5 (gwarrick@wlu.ca) 26 X 05

Bocquet-Appel and Naji view the Neolithic demographic transition as a worldwide phenomenon (Bocquet-Appel 2002). Their model is Malthusian, with paleodemographic evidence supporting a 600–800-year period of population growth after the transition to agriculture in secondary centres. In their view, population growth resulted from shorter birth intervals as a result of increased sedentism and decreased nursing of infants. Their model also posits an increase in mortality from disease to account for the cessation of population growth about 800 years after the onset of agriculture. The general model is compelling, but one is left wondering if it actually explains every case.

The transition to agriculture amongst the Wendat-Tionontate (Huron-Petun) is a well-documented case of the Neolithic demographic transition in North America, and data from certain Wendat-Tionontate cemeteries were used by Bocquet-Appel and Naji to construct their model. Prior to the arrival of maize agriculture in Ontario ca. AD 500, ancestors of the Wendat-Tionontate lived from broad-spectrum foraging in semi-sedentary settlements. While cemetery data are limited, the population is generally interpreted as stable for 800 years prior to the arrival of maize agriculture (Ferris 1999). The Wendat-Tionontate first experimented with maize agriculture about AD 600–900 in south-central Ontario, Canada. By AD 1000 they were living in year-round villages of 75–100 people and growing and eating maize. The number and size of archaeological settlements permit estimates of absolute population for the Wendat-Tionontate from AD 500 to 1650, revealing population growth from AD 900–1450, with a century of rapid growth at over 1.0% per year AD 1300 to 1400 (Warrick 2000, 2003). (The 600–800-year post-agricultural period of population increase noted by Bocquet-Appel and Naji is remarkable and implies that the population of most transitional forager-agricultural societies (like the Wendat-Tionontate) probably followed a three-phase sigmoid growth curve: (1) gradual population increase for four or five centuries as agricultural foods replaced foraging foods, (2) a century of rapid increase (1–2% per year) coinciding with full reliance on agricultural foods and minimal foraging, and (3) a gradual cessation of growth and stabilization at a new equilibrium lasting less

than a century.) Paleodemography suggests that fertility-rate increase was primarily responsible for population growth. The cessation of growth around AD 1450 is associated with paleopathological indicators of tuberculosis, a density-dependent disease. Thus, at first glance, the Wendat-Tionontate seem to fit the Bocquet-Appel and Naji model—population stagnation prior to agriculture, 600–800 years of population growth following the onset of agriculture, population growth fueled by increased fertility, and cessation of growth due to mortality increase from density-dependent diseases. However, other factors were probably responsible for both population growth and decline amongst the Wendat-Tionontate.

First of all, population growth was probably due to both decreased birth spacing (increased fertility) and decreased juvenile mortality. However, decreased birth spacing was the result not of sedentism (i.e., reduced togetherness of mother and infant) but of increased reliance on maize soup, a suitable weaning food not available to earlier foragers in Ontario. Furthermore, storage of surplus maize would have reduced mortality associated with late spring famine, a period of food scarcity in pre-agricultural Ontario. Secondly, cessation of population growth AD 1450 in south-central Ontario was most likely due to population numbers' having reached the limits of sustainability for a critical natural resource—white-tailed deer, which was the main source of hide clothing—rather than the carrying capacity of the agricultural system (Warrick 2000). While there is evidence of tuberculosis, it is unlikely that mortality rates increased significantly (Pfeiffer 1986). Instead, limits to population growth in the mid-fifteenth century were likely the result of family-planning decisions to conserve deer populations, not disease or food scarcity. Seventeenth-century Jesuit missionaries observed that the Wendat-Tionontate practiced post-partum sexual abstinence for three to four years after a birth. Also, prolonged breastfeeding was also witnessed, and mothers carried their infants from village to agricultural fields and on firewood-gathering forays as forager mothers with nursing children did (Engelbrecht 1987). Prolonged breastfeeding and post-partum abstinence effectively limited post-contact Wendat-Tionontate family sizes to fewer than three children, effectively a population replacement rate (Warrick 2003). It is likely that the same population control methods used by seventeenth-century Wendat-Tionontate were applied in the mid-fifteenth century to stabilize population.

In summary, Bocquet-Appel and Naji's model is a powerful explanatory tool for characterizing the demographic response to the transition from foraging to agriculture. Like any generalization, however, it cannot explain the specific details of all of the complex and unique situations of the past. Individual case histories of the Neolithic demographic transition should be guided by Bocquet-Appel and Naji's model but are best illuminated by independent data sets from history, demography, and archaeology in addition to paleodemography.

Reply

We thank all those who have responded with comments. To avoid duplication, we have grouped our answers into two main sections concerning data quality and scenarios for the Neolithic demographic transition and a final three sections addressing specific points.

Reauditing the database. Jackes's criticisms relate to the auditing of the database, the regional deviation from the tendency of the transition in Portugal, and the apparent clouding of the North American data. Concerning the cemetery data, the two basic assumptions are (1) that the mortality regime of the horticulturist-farmer population is part of the demographic world of preindustrial populations and (2) that the distributions of skeletons observed in the cemeteries can be regarded as random samplings of local mortality. We would emphasize that ${}_{15}P_5$ does not derive from the mechanics of a life table as does the value used by Jackes. The life table implies the costly assumption of a stationary population when what is sought is the nonstationary rate of variation of population.

Jackes's comment on Etowah Mound C is justified, and we have now eliminated this site. Four Ontario sites have indeed been reported erroneously. The data were taken from cumulated frequencies in Jackes (1986), and the age-class frequencies were therefore decumulated and the ${}_{15}P_5$ calculated with the wrong total. It should be stressed, however, that this total is nowhere used in the analysis and that the ratio of the decumulated age-class percentages produces a value identical to the ratio of the missing raw values. This error therefore does not relate in any way to Jackes's generalization that "not all excavated individuals were included in the analysis." The corrected data are given in table 3. For Indian Knoll, as for most of the sites, we used the most recent estimated distribution (Kelley 1980). With regard to Dickson Mounds, Jackes (1993) mentions a discordance in age estimates for immature skeletons of 4.8% in cumulated frequencies at 20 years. There are, in addition, a larger number of chronological subdivisions in Blakely's (1973) article than in Goodman et al.'s (1984). Here we also used the most recent estimated distribution (Goodman et al. 1984), which has only two chronological subdivisions. Jackes finds these data suspect because "sources

Table 3. Corrected Data from Four Cemeteries in Ontario

Site	0-4 yr.	5-19 yr.	20+yr.	Total	${}_{15}P_5$
Kleinburg	67.3	89.8	403.9	561	0.1819
Glen William	56.6	50.9	175.5	283	0.2248
Garland	23.8	55.4	118.8	198	0.3180
Fairty Ossua	112.6	122.9	276.5	512	0.3077

Source: Jackes (1986: tables 1 and 3).

Note: The ${}_{15}P_5$ values are, up to the round-off, identical to those in table 1.

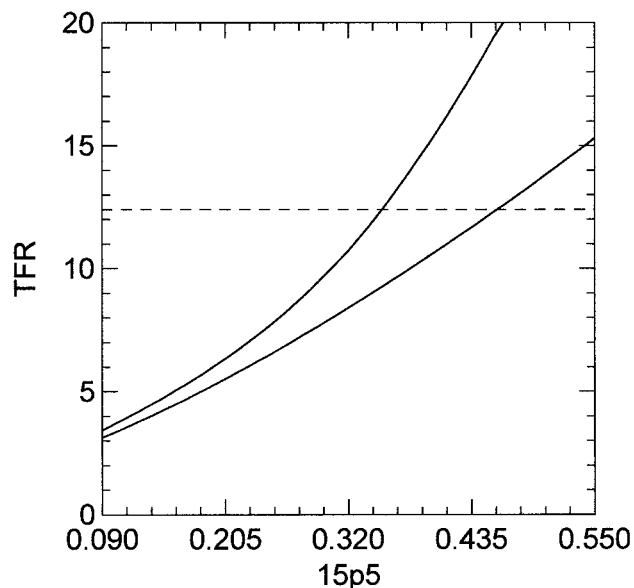


Fig. 6. Relationship between ${}_{15}P_5$ and the total fertility rate in two population models. *Left curve*, extrapolated industrial model of Coale and Demeny (West model, Level 1-10). *Right curve*, model of 45 preindustrial life tables (Bocquet-Appel 2002). The horizontal line (*hatched*) represents the total fertility rate (= 12.4) of Hutterites (Coale, Demeny, and Vaughan 1983). This level is reached when ${}_{15}P_5 = 0.352$ in the first model and 0.458 in the second.

other than that used here suggest a reduction in fertility." We do not know these sources, but they seem to relate to a demographic interpretation of fertility rather than to the issue of random sampling of ${}_{15}P_5$.

It is a good idea to use a fertility index such as the total fertility rate to determine a threshold for rejection of a juvenility ratio, because it makes it possible, for instance, to take the historically recognized value of the Hutterites (12.4) as the upper limit. The difficulty lies in the determination of the corresponding value of the juvenility ratio, which depends on a historical population model. As we have repeatedly indicated (Bocquet-Appel 2002; Bocquet-Appel and Masset 1996, 1977), Coale and Demeny's West model, used by Jackes and Meiklejohn (2004) and other researchers, is inadequate because it does not include any life tables prior to 1870 (Coale, Demeny, and Vaughn 1983, 12). If, instead of this *extrapolated* (1983, 24) historical model, we use the more sensible model derived from the 45 preindustrial life tables of paleodemographic estimators (Bocquet-Appel 2002), the relationship is different (fig. 6). The test for rejection of an observed value above the limit value $p_{\text{observed}} > P0$ is the usual unilateral critical-ratio test: $Z = (p - P0) / \sqrt{(p(1-p)/N)} \geq \frac{1}{2}Z(\alpha)$, where p , $P0$, and N respectively represent the observed value ${}_{15}P_5$ in a cemetery, the theoretical preindustrial limit value, and the sample size. For Hiwassee and Irene Mound we find, respectively, $Z = 2.754$ ($P = 0.006$), and $Z = 0.12709$ ($P =$

0.898). This leads us to eliminate Hiwassee from the database but to keep Irene Mound. The limit of binomial variability for Irene Mound even makes it possible to reach, at the threshold of $\frac{1}{2}Z(\alpha > 0.05)$, the theoretical value $P_0 = p - \sqrt{p(1-p)/N} \times Z(\alpha) > 0.40018$, corresponding to a total fertility rate of 10.8, which is appreciably lower than the level corresponding to the Hutterites.

With regard to the data from central Portugal, in spite of significant variations in the sample sizes of the latest revaluations (see table 4), the various sampled values $_{15}P_5$ within-site remained close to each other.¹ In the absence of an identified systematic archaeo-historical bias, this experiment with the Portuguese sites demonstrates the random nature of the sampled variable $_{15}P_5$.

Chamberlain raises the issue of the cross-cultural robustness of our criterion for the onset of the change in production system as opposed to the one he prefers. The date of onset seems easier to identify archaeologically than the establishment of intensive agriculture. Simple criteria such as those used in ethnographic fertility references, in which hoes = extensive and ploughs = intensive (Bentley, Goldberg, and Jasińska 1993; Bentley, Jasińska, and Goldberg 1993), are detectable archaeologically only a long time after their invention. If we look at the trend produced by the 25 Midwest cemeteries selected by Chamberlain, the same pattern appears as that in our paper (fig. 7). If we considered only the peak value rather than the whole curve as the demographic change, we would not be treating the change as a sociocultural process associated with the pace of sedentarization during which the value of $_{15}P_5$ increased. It is the demographic dimension of this process of historical stabilization of sedentarization that we call the Neolithic demographic transition. In short, we agree with Chamberlain that the “shift from foraging lifestyles to food production is not necessarily the same phenomenon,” ranging from an emerging to a ready-made economic toolkit, from locality to locality during the expansion in terms of the impact of its innovative content (from local cultigens to

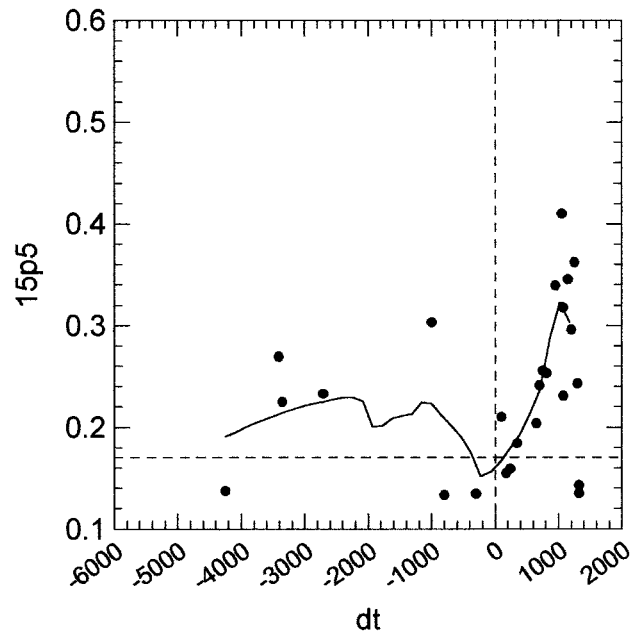


Fig. 7. Observed trend in the sample of 25 Midwest cemeteries selected by Chamberlain, showing the pattern of the Neolithic demographic transition.

maize-beans-squash), but the archaeological (i.e., historical) data show that when this shift occurs, it produces an immediate increase in the birthrate.

The anomaly noted by Mosothwane concerning the positioning of foragers on $dt > 0$ originates from an initial classification of 13 sites (11 “Middle Woodland” sites and 2 sites in the Southwest) in the forager group instead of the horticulturist/farmer group. For the “Middle Woodland” sites, as for those of the Southwest, local cultigens were found in the toolkit (Buikstra 1984; Buikstra, Konigsberg, and Bullington 1986; Cassidy 1984; Palkovich 1984), which in fact made them forager-horticulturists and not strictly foragers. We neglected to correct the number of forager sites in the initial classification (24 instead of 11) in the text. From 19% to 26%, the

1. The usual χ^2 test for equality of within-site $_{15}P_5$ frequencies accepts this hypothesis. The χ^2 values for the three sites are, respectively, 0.267, 0.009 (each with 2 d.f., $P \geq 0.40$), and 1.015 (with 1 d.f., $P = 0.238$).

Table 4. Age Distribution and $_{15}P_5$ Values in Three Portuguese Cemeteries in Various Studies

Site	Other than Jackes			Jackes et al. pre-2002			Jackes and Meiklejohn (2004)					
	0+ yr	5+ yr	5–19 yr	$_{15}P_5$	0+ yr	5+ yr	5–19 yr	$_{15}P_5$	0+ yr	5+ yr	5–19 yr	$_{15}P_5$
Cabeço da Arruda	71	64	11	0.1718 ^a	97	79	14	0.1772 ^c	105	88	18	0.2045
Moita do Sebastião	136	113.3	17.33	0.1529 ^b	77	64	10	0.1562 ^d	77	63	10	0.1587
Casa da Moura	–	–	–	–	214	187	61	0.3262 ^e	340	298	82	0.2752

^aSilva (1999).

^bFerenbach (1974).

^cM. Jackes, personal communication, June 14, 2001.

^dJackes, Lubell, and Meiklejohn (1997).

^eJackes (1988).

rise in the proportion of immature skeletons from foragers to horticulturist-farmers is $(26/19) - 1 \times 100 = 37\%$. The growth rate of the proportion of immature skeletons accounts more fully for the change in the age pyramid than the difference between the two proportions.

To summarize, after corrections and the elimination of two sites, the sample, with 60 cemeteries, includes 11 forager and 49 horticulturist sites. The changes have no discernible effect on the signal of the transition (see figure 8). The horizontal axes of the figure has been extended to plot Windover, previously omitted from the graphs but not from the computation. To save space, figures 3 and 5 have not been redrawn.

Simulations show that a pattern of change representing an abrupt increase in the growth rate is detected using the Loess fitting procedure with a density of 2 cemeteries per subdivision of 500 years (Bocquet-Appel 2002; Bocquet-Appel and Paz de Miguel Ibáñez 2000). The observed density for the pooled forager segment (for example, figure 5: $-3,500 \leq dt < 0$) is slightly lower than the simulation conditions (1.86 vs. 2 cemeteries per 500-year unit), and therefore we do not think that this influences the Loess fit (see also Simonoff 1996). Furthermore, we do not know the true space-time distribution of ${}_{15}P_5$ underlying the observed data. The issue, then, is whether there is any suspicion of systematic bias in the ${}_{15}P_5$ sample. We think that this broad geographical distribution offers a guarantee as to the sampling of the main trend underlying the data. Archaeological information almost always comes from fortuitous discoveries. We can therefore consider it to represent a random sampling of a larger whole of vestiges that are inaccessible at present. Once gathered, the pairs of values $({}_{15}P_5, dt)$ produce a coherent pattern that is reminiscent of the contemporary demographic transition, which shows an abrupt change in fertility transcending both geography on a continental and intercontinental scale and ecological niches. Eshed suggests that we argue that "this shift in age-at-death distribution may serve as an indicator of an economic transition," but our article is centered on the detection not of the economic but of the demographic transition. Nowhere do we mention the paleodemographic use of the indicator as an economic proxy. Further, we do not say that children in the Levant "were weaned earlier because . . . of the availability of dairy products." On the contrary, we question this assumption, even though it is valid for the LBK culture in Europe, and propose an alternative assumption of sedentariness.

Scenarios for the Neolithic demographic transition. We agree that influences other than the gradual settling of foragers may have contributed to the fertility variation between foragers and horticulturist-farmers. Sullivan's arguments, however, contradict other hypotheses such as the Zen economy of affluent foragers (also with low fertility [Sahlins 1972]) or the potential health consequences of the potential decline with the advent of intensive farming (with high fertility [see Armelagos and Maes]). To avoid endless hypothetical scenarios, we need experimental ethnographic data. These data are scarce

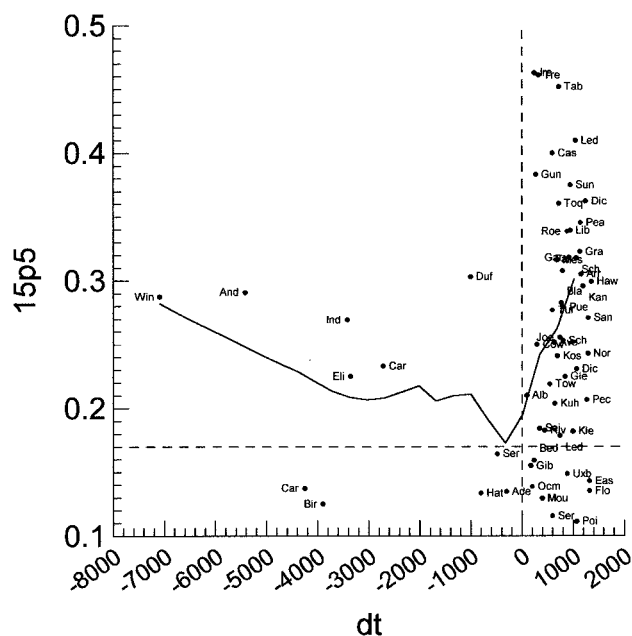


Fig. 8. Figure 2 redrawn: Observed profile of immature proportion ${}_{15}P_5$ in North American cemeteries (vertical axis) with the chronological distance to the economic shift front from foragers to horticulturist-farmers (horizontal axis) for revised database of 60 cemeteries. (Horizontal axis extended to plot Windover, previously omitted.)

and almost always mute as to the factors that may influence fertility in either of these economic systems. Nevertheless, the Alyawara (Denham 1974) may have experienced a reverse demographic transition from the current one, with a fertility burst that may have been masked as a demographic process by the Western explanation of the "sanitary impact." The fertility of these populations, with a change in mobility and a regular food supply from the government, could very well represent a sort of bioassay of what might have happened at the onset of the Neolithic demographic transition: a self-catalyzing process capable of quickly raising the growth rate locally or regionally (Bocquet-Appel and Denham 2005).

Armelagos and Maes and Eshed ask about the influence of mortality in the Neolithic demographic transition. Unfortunately, ${}_{15}P_5$ cannot answer this question. From the same skeletal distribution, the confounding influence of the birthrate on the age pyramid prevents inferences about mortality. To distinguish the influence of mortality on that of fertility and to estimate adult skeletal age are the greatest challenges in paleodemography (Hoppa and Vaupel 2002; Buikstra 1997; Bocquet-Appel and Masset 1996; Buikstra and Konigsberg 1985; Bocquet-Appel and Masset 1982). As long as these questions remain unresolved, life expectancy estimates are illusory and produce spurious results. With the Dickson Mounds example given by Armelagos and Maes, we are in the intensive phase of agriculture ($dt = 1,075$), from which we can expect

a reaction of positive checks of the Malthusian model. The skeletal evidence interpreted by Armelagos and Maes as indicating a decline in health represents a major item of information that confirms expectations. However, we are also interpreting the forager period, lasting roughly 800 years immediately before the onset of the Neolithic demographic transition, as a possibly stressful period for forager populations and not as a flourishing affluent society of the Zen economy. This should be detectable in the biological indicators, as at Dickson Mounds.

Armelagos and Maes and Warrick offer biosocial narratives of the Neolithic demographic transition pattern: In their examples, fertility variations refer to a conscious, self-regulated strategy tending toward boosting or slowing down fertility. However, we concur with the general view of demographic historians that fertility and mortality strategies designed to stabilize demographic regimes—particularly over evolutionary time—followed an unconscious rather than a conscious logic (Bengtsson and Saito 2003). The demographic model takes into account not just the Malthusian model of self-regulation as suggested by Warrick but also the idea that diminishing returns determine the probability (1) of a geographic expansion of the current system by migration into the zone where carrying capacity has not reached the saturation point (Hung Liang-Chi 1973, cited by Lee, Feng, and Bozhong 2003; Ammerman and Cavalli-Sforza 1984) or (2) of local innovations allowing either an intensification of the current system (Boserup) or the start of a systematic change (Wood 1998; Lee 1986). This explains some of the dispersion of ${}_{15}P_5$ as a measure of the systematic heterogeneity of the shift, as argued by Chamberlain.

Chamberlain's selected Midwest data set clearly shows that the Neolithic demographic transition begins not *after* the onset of the economic change ($dt = 0$) but almost *simultaneously* (fig. 7). For Chamberlain, the average fertility rate among horticulturalists is closer to the forager rate than to that of farmers in the ethnographic data. This rate does not contradict the pattern shown in figure 7. These ethnographic data must be considered with caution, however. Because of the usual scarcity of forager data, Bentley, Goldberg, and Jasińska mention the creation of the "forager-horticulturalists" group "partly to increase the sample size for the foraging category" (1993, 272 n. 19). If we consider strictly the "foragers" in this group, average fertility among foragers is curiously closer to the farmers' than to the horticulturalists'.

From local to global and vice versa. We share the concern that drove Jackes to study a region exhaustively. However, the right historical frame of reference for the Portuguese sites is not only the local Mesolithic-Neolithic chronology but the global relative chronology which allows them to be included in a space-time process that may be barely noticeable at the regional scale. Limiting the analysis to the local may obscure the global.

Apart from sampling issues, Armelagos and Mae, Jackes,

and Sullivan rightly note that the ${}_{15}P_5$ dispersion indicates deviations from the transition's trend. In Sullivan's holistic approach, no partial explanation is satisfactory, but part of her argument is anachronistic. She considers the Neolithic demographic transition outlined in this article as a scientific fact, whereas we have only detected the signal and are now, for the first time, discussing it. We are well aware of the multidimensional consequences of the Neolithic demographic transition, but we feel that they need to be considered through their archaeological markers, according to the tempo of the relative chronology, in order to be fully understood. We also concur with the idea of a "rigorous interdisciplinary research program" and are attempting to contribute to such a program.

Clouded data from North America. We do not agree with Jackes that the "continuum" of plant use in North America makes a simple classification into foragers and horticulturalist-farmers almost impossible (for the "continuum" idea, see also Bronson 1975). Everywhere on the planet, the use of a harvest grown from planted seeds, whether native or foreign, represents a qualitative leap that clearly separates foragers from horticulturalist-farmers, regardless of the proportion of the harvest used for food. America is no exception. The current demographic transition is taking place in a widely diverse cultural and economic context, which could even be wider than the "formidable" midcontinental United States mosaic in late precontact societies, especially since "in general, the Late Precontact time period is characterized by a greater reliance on and intensification through time of agricultural crops" (Schroeder 2004, 335). Finally, the intercontinental and continental geographic scales of our data do not allow us to contest the regional archaeological and ethnohistorical expertise on which we are relying in Ontario (Crawford and Smith 2003; Smith 1997; Crawford, Smith, and Bowyer 1997; Riley, Edging, and Rossen 1990; and also Warrick in this instance) or elsewhere.

The novelty of the idea of a transition. The idea of a demographic transition, specifically of an abrupt qualitative growth change, was first explicitly raised by the demographer Livi-Bacci (1992) and subsequently by Simoni et al. (2000). We reached the same idea independently after detecting a new signal in anthropological and archaeological data (Bocquet-Appel and Dubouloz 2004; Bocquet-Appel 2002; Bocquet-Appel and Paz de Miguel Ibáñez 2002). Hershkovitz and Gopher (1990) use not the ratio of children (C) to adults (A) but $C/(C + A)$, the proportion of juveniles (0–14 years of age) in the total sample. In the 1970s, because of the well-known lack of children (0–4 years of age) in cemeteries, researchers excluded this group from their demographic indicators (Jackes 1986; Buikstra and Konigsberg 1985; Bocquet-Appel and Masset 1977. A Natufian-Neolithic correlation with the proportion of juveniles is therefore demographically spurious.

—Jean-Pierre Bocquet-Appel and Stephen Naji

References Cited

- Ammerman, A. J., and L. L. Cavalli-Sforza. 1984. *The Neolithic transition and the genetics of populations in Europe*. Princeton: Princeton University Press.
- Anderson, J. E. 1968. *The Serpent Mounds site: Physical anthropology*. Royal Ontario Museum Occasional Papers 11.
- Armélagos, G. J., A. H. Goodman, and K. H. Jacobs. 1991. The origins of agriculture: Population growth during a period of declining health. *Population and Environment* 13: 9–22. [GJA, KCM]
- Asatryan, D., and I. Safaryan. 1986. Nonparametric methods for detecting changes in the properties of random sequences. In *Detection of changes in random processes*, ed. L. Telksnys, 1–12. New York: Optimization Software Inc.
- Atwell, K. A., and M. D. Conner. 1991. *The Kuhlman Mound Group and Late Woodland mortuary behavior in the Mississippi River Valley of west-central Illinois*. Kampsville Archaeological Center Research Series 9.
- Bar-Yosef, Ofer, and Richard H. Meadow. 1995. The origins of agriculture in the Near East. In *Last hunters – First farmers: New perspectives on the prehistoric transition to agriculture*, ed. Douglas T. Price and Anne Birgitte Gebauer, 39–94. Santa Fe: School of American Research Press.
- Bender, S. J. 1979. Paleodemographic analysis of a Late Woodland site in southeastern Michigan. *Midcontinental Journal of Archaeology* 4:183–208.
- Bengtsson, T., and O. Saito. 2003. Introduction. In *Population and economy from hunger to modern economic growth*, ed. T. Bengtsson and O. Saito, 1–20. New York: Oxford University Press.
- Bennett, K. A. 1973. *The Indians of Point of Pines, Arizona: A comparative study of their physical characteristics*. Anthropological Papers of the University of Arizona 23.
- . 1975. *Skeletal remains from Mesa Verde National Park/Colorado*. U.S. Department of Interior Publications in Archaeology 7F.
- Bentley, G. R., T. Goldberg, and G. Jasienska. 1993. The fertility of agricultural and non-agricultural traditional societies. *Population Studies* 47:269–81.
- Bentley, Gillian R., Grażyna Jasińska, and Tony Goldberg. 1993. Is the fertility of agriculturalists higher than that of nonagriculturalists? *Current Anthropology* 34:778–85. [ATC]
- Berry, D. R. 1985. Aspects of paleodemography at Grasshopper Pueblo, Arizona. In *Health and disease in the prehistoric Southwest*, ed. C. F. Merbs and R. J. Miller, 43–83. Tempe: Arizona State University Press.
- Binford, L. 1968. Post-Pleistocene adaptation. In *New perspectives in archaeology*, ed. L. Binford and S. Binford, 313–41. Chicago: Aldine.
- Binford, L., and W. Chasko. 1976. Nunamiut demographic history: A provocative case. In *Demographic anthropology*, 63–145. Albuquerque: University of New Mexico Press.
- Black, T. K., III. 1979. *The biological and social analyses of a Mississippian cemetery from Southeast Missouri: The Turner site, 23BU21A*. Ann Arbor: University of Michigan Press.
- Blakely, R. L. 1977. Sociocultural implications of demographic data from Etowah, Georgia. In *Biocultural adaptation in prehistoric America*, ed. R. L. Blakely, 45–66. Athens: University of Georgia Press.
- Blakely, Robert L. 1973. Biological variation among and between two prehistoric Indian population at Dickson Mounds. Ph.D. diss., Indiana University.
- Bocquet-Appel, J-P. 2002. The paleoanthropological traces of the Neolithic demographic transition. *Current Anthropology* 43:638–50.
- Bocquet-Appel, J-P., and J. Dubouloz. 2004. Expected paleoanthropological and archaeological signal from a Neolithic demographic transition on a worldwide scale. *Neolithic Studies* 10, *Documenta Praehistorica* 31:25–33.
- Bocquet-Appel, J-P., S. Irudaya Rajan, J. N. Bacro, and C. Lajaunie. 2002. The onset of India's fertility transition. *European Journal of Population* 18:211–32.
- Bocquet-Appel, J-P., and C. L. Masset. 1977. Estimateurs en paléodémographie. *L'Homme* 18:65–90.
- . 1982. Farewell to palaeodemography. *Journal of Human Evolution* 11:321–33. [MJ]
- . 1996. Paleodemography: Expectancy and false hope. *American Journal of Physical Anthropology* 99:571–83.
- Bocquet-Appel, J-P., and M. Paz de Miguel Ibáñez. 2002. Demografía de la difusión neolítica en Europa y los datos paleoantropológicos. *Sagutum* 5:23–44.
- Boserup, E. 1965. *The conditions of agricultural growth: The economics of agrarian change under population pressure*. Chicago: Aldine.
- Boyd, D. C. 1986. A comparison of Mouse Creek–phase to Dallas and middle Cumberland culture skeletal remains. In *Skeletal analysis in Southeastern archaeology*, vol. 24, ed. J. E. Levy, 103–27. Raleigh: North Carolina Archaeological Council.
- Bronson, B. 1975. The earliest farming: Demography as cause and consequence. In *Population, ecology, and social evolution*, 53–78. The Hague: Mouton.
- Brown, J. B., P. Harrison, and M. A. Smith. 1985. A study of returning fertility after childbirth and during lactation by measurement of urinary oestrogen and pregnanediol secretion and cervical mucus production. *Journal of Biosocial Science* suppl. 9:5–23.
- Buikstra, J. E. 1976. *Hopewell in the lower Illinois Valley: A regional approach to the study of human biological variability and prehistoric behavior*. Scientific Papers of the Northwestern University Archeological Program 2.
- . 1984. Lower Illinois Valley: Ancient diet and health. In *Paleopathology at the origins of agriculture*, ed. M. N. Cohen and G. Armelagos, 215–34. New York: Academic Press.
- . 1997. Palaeodemography: Context and promise. In *Integrating archaeological demography: Multidisciplinary approaches to prehistoric population*, ed. R. R. Paine, 367–80.

- Center for Archaeological Investigations Occasional Paper 24.
- Buikstra, J. E., and L. W. Konigsberg. 1985. Paleodemography: Critiques and controversies. *American Anthropologist* 87: 316–34.
- . 1986. Fertility and the development of agriculture in the prehistoric Midwest. *American Antiquity* 51:528–46. [ATC]
- Buikstra, Jane E., Lyle W. Konigsberg, and Jill Bullington. 1986. Fertility and the development of agriculture in the prehistoric Midwest. *American Antiquity* 5:528–46. [ATC]
- Buikstra, J. E., and J. H. Mielke. 1985. Demography, diet, and health. In *The analysis of prehistoric diets*, ed. J. H. Mielke and R. I. Gilbert. Orlando: Academic Press.
- Buikstra, J. E., and G. R. Milner. 1991. Isotopic and archaeological interpretations of diet in the Central Mississippi Valley. *Journal of Archaeological Science* 18:319–30.
- Carr-Saunders, A. M. 1922. *The population problem: A study in human evolution*. Oxford: Clarendon Press.
- Cassidy, C. M. 1984. Skeletal evidence for prehistoric subsistence adaptation in the Central Ohio River Valley. In *Paleopathology at the origins of agriculture*, ed. A. H. Goodman and G. J. Armelagos, 307–46. New York: Academic Press.
- Charles, D. K., S. R. Leigh, and J. E. Buikstra, eds. 1988. *The Archaic and Woodland cemeteries at the Elizabeth Site in the Lower Illinois Valley*. Kampsville: Center for American Archaeology.
- Churcher, C. H., and W. A. Kenyon. 1960. The Tabor Hill ossuaries: A study in Iroquois demography. *Human Biology* 32:249–73.
- Coale, Ansley, Paul Demeny, and Barbara Vaughan. 1983. *Regional model life tables and stable populations*. Princeton: Princeton University Press.
- Cohen, M. N. 1977. *The food crisis in prehistory: Overpopulation and the origins of agriculture*. New Haven: Yale University Press.
- . 1989. *Health and the rise of civilization*. New Haven: Yale University Press.
- Cohen, M. N., and G. J. Armelagos, eds. 1984. *Paleopathology at the origins of agriculture*. Orlando: Academic Press. [GJA, KCM]
- Cowan, C. W., and P. J. Watson. 1992. *The origins of agriculture: An international perspective*. Washington, D.C.: Smithsonian Institution Press.
- Crawford, G. W., and D. G. Smith. 2003. Palaeoethnobotany in the Northeast. In *People and plants in ancient Eastern North America*, ed. P. Minnis, 172–257. Washington, D.C.: Smithsonian Institution Press.
- Crawford, G. W., D. G. Smith, and V. E. Bowyer. 1997. Dating the entry of corn (*Zea mays*) into the lower Great Lakes region. *American Antiquity* 62:112–19.
- Denham, W. W. 1974. Infant transport among the Alyawara tribe, Central Australia. *Oceania* 44:253–77.
- Diehl, M. W. 1996. The intensity of maize processing and production in upland Mogollon pithouse villages A.D. 200–1000. *American Antiquity* 61:102–15.
- Dipeso, C. 1974. *Casas Grandes*. Vols. 2 and 8. Flagstaff: Dragon Northland Press.
- Doran, G. H., ed. 2002. *Windover: Multidisciplinary investigations of an early Archaic Florida cemetery*. Gainesville: University of Florida Press.
- Dowd, J. T. 1989. *The Anderson site: Middle Archaic adaptation in Tennessee's Central Basin*. Tennessee Anthropological Association Miscellaneous Paper 13.
- Drancourt, M., G. Abdoudharam, M. Signoli, O. Dutour, and D. Raoult. 1998. Detection of 400-year-old *Yersinia pestis* DNA in human dental pulp: An approach to the diagnosis of ancient septicemia. *Proceedings of the National Academy of Sciences, U.S.A.* 19:12637–40.
- Driscoll, E. M. 2001. Bioarchaeology, mortuary patterning, and social organization at Town Creek. Ph.D. diss. University of North Carolina.
- Droessler, J. 1981. *Craniometry and biological distance: Biocultural continuity and change at the Late-Woodland–Mississippian interface*. Evanston: Center for American Archaeology.
- Eisenberg, L. E. 1985. Bioarchaeological perspective on disease in a “marginal” Mississippian population. *American Journal of Physical Anthropology* 66:166–67.
- Emerson, T. E., G. R. Milner, and D. K. Jackson. 1983. *The Florence Street site (11-S-458)*. Urbana: University of Illinois Press.
- Engelbrecht, W. 1987. Factors maintaining low population density among the prehistoric New York Iroquoians. *American Antiquity* 52:13–27. [GW]
- Eshed, V., A. Gopher, T. G. Gage, and I. Hershkovitz. 2004. Has the transition to agriculture reshaped the demographic structure of prehistoric populations? New evidence from the Levant. *American Journal of Physical Anthropology* 124: 315–29.
- Ferembach, D. 1974. *Le gisement mésolithique de Moita do Sebastião, Muge, Portugal*. Vol. 2. *Antropologia*. Lisboa: Direcção-Geral dos Assuntos Culturais.
- Ferris, N. 1999. Telling tales: Interpretive trends in southern Ontario Late Woodland archaeology. *Ontario Archaeology* 68:1–62. [GW]
- Goodman, A. H., and G. J. Armelagos. 1985. Disease and death at Dr. Dickson's Mounds. *Natural History Magazine* 94:12–18. [GJA, KCM]
- . 1988. Childhood stress, cultural buffering, and decreased longevity in prehistoric populations. *American Anthropologist* 90:936–44. [GJA, KCM]
- . 1989. Infant and childhood morbidity and mortality risks in archaeological populations. *World Archaeology* 21: 225–43. [GJA, KCM]
- Goodman, A. H., G. J. Armelagos, and J. C. Rose. 1980. Enamel hypoplasias as indicators of stress in three prehistoric populations from Illinois. *Human Biology* 52:515–28. [GJA, KCM]

- . 1984. The chronological distribution of enamel hypoplasias from prehistoric Dickson Mounds populations. *American Journal of Physical Anthropology* 65:259–66. [GJA, KCM]
- Goodman, A. H., J. Lallo, G. J. Armelagos, and J. C. Rose. 1984. Health changes at Dickson Mound, Illinois (A.D. 950–1300). In *Paleopathology at the origins of agriculture*, ed. M. N. Cohen and G. J. Armelagos, 271–306. New York: Academic Press.
- Graber, R. B. 1997. A rigorous approach to population pressure's contribution to cultural evolution. In *Integrating archaeological demography: Multidisciplinary approaches to prehistoric population*, ed. R. R. Paine, 263–84. Southern Illinois University, Carbondale, Center for Archaeological Investigations Occasional Paper 24.
- Hajnal, J. 1953. Age at marriage and proportions marrying. *Population Studies* 7:111–36.
- Hart, J. P. 1990. Modeling Oneota agricultural production: A cross-cultural evaluation. *Current Anthropology* 31:569–77.
- Hennart, P., Y. Hofvander, H. Vis, and C. Robin. 1985. Comparative study of nursing mothers in Africa (Zaire) and in Europe (Sweden): Breast-feeding behavior, nutritional status, lactational hyperprolactinaemia, and status of the menstrual cycle. *Clinical Endocrinology* 22:179–87.
- Herold, E. B. 1971. *The Indian mounds at Albany, Illinois*. Davenport Museum Anthropological Papers 1.
- Hershkovitz, I., and A. Gopher. 1990. Paleodemography, burial customs, and food-producing economy at the beginning of the Holocene: A perspective from the southern Levant. *Journal of the Israel Prehistoric Society (Mitekufat Haeven)* 23:9–47. [VE]
- . 1999. Is tuberculosis associated with early domestication of cattle? Evidence from the Levant. In *Tuberculosis past and present*, ed. P. Gyorgy D. Olivier, D. Judith, and H. Imre, 445–49. Budapest: Tuberculosis Foundation. [VE]
- Hewlett, Barry S. 1991. Demography and childcare in pre-industrial societies. *Journal of Anthropological Research* 47: 1–37. [ATC]
- Hooton, E. A. 1930. *The Indians of Pecos Pueblo: A study of their skeletal remains*. New Haven: Yale University Press.
- Hoppa, R. D., and J. W. Vaupel. 2002. *Paleodemography: Age distributions from skeletal samples*. Cambridge: Cambridge University Press.
- Howell, N. 1982. Village composition implied by a paleodemographic life table: The Libben site. *American Journal of Physical Anthropology* 59:263–69.
- Howells, W. W. 1960. Estimating population numbers through archaeological and skeletal remains. In *The application of quantitative methods in archaeology*, ed. R. F. Heizer and S. E. Cook, 158–85. Chicago: Quadrangle. [MJ]
- Howie, P. W., and A. S. McNeilly. 1982. Effect of breast feeding patterns on human birth intervals. *Journal of Reproduction and Fertility* 65:545–57.
- Hutchinson, D. L., C. S. Larsen, M. J. Schoeninger, and L. Norr. 1998. Regional variation in the pattern of maize adoption and use in Florida and Georgia. *American Antiquity* 63:397–416.
- Jackes, M. 1985. Pubic symphysis age distributions. *American Journal of Physical Anthropology* 68:281–99. [MJ]
- . 1986. The mortality of Ontario archaeological populations. *Canadian Journal of Anthropology* 5:33–48. [MJ]
- . 1988. Demographic change at the Mesolithic-Neolithic transition: Evidence from Portugal. *Rivista di Antropologia*, suppl., 66:141–58.
- . 1993. On paradox and osteology. *Current Anthropology* 34:434–39. [MJ]
- . 1994. Birth rates and bones. In *Strength in diversity: A reader in physical anthropology*, ed. A. Herring A. and L. Chan L., 155–85. Toronto: Canadian Scholar's Press. [MJ]
- . 1996. Complexity in seventeenth-century southern Ontario burial practices. In *Debating complexity: Proceedings of the 26th annual Chacmool Conference*, ed. D. A. Meyer, P. C. Dawson, and D. T. Hanna, 127–40. Calgary: Archaeological Association, University of Calgary. [MJ]
- Jackes, M., and P. Alvim n.d.. Reconstructing Moita do Sebastião: The first step. In *O complexo mesolítico de Muge: Passado, presente et futuro (Proceedings of the IV Congresso de Arqueologia Peninsular)*, ed. J. Rolão. Faro: Universidade do Algarve. In press. [MJ]
- Jackes, M., and D. Lubell. 1999. Human variability in the Portuguese Mesolithic. *Arqueologia* 24:25–42.
- . n.d. Where are the old folks? MS. [MJ]
- Jackes, M., D. Lubell, and C. Meiklejohn. 1997. Healthy but mortal: Human biology and the first farmers of Western Europe. *Antiquity* 71:639–58. [MJ]
- Jackes, M., and C. Meiklejohn. 2004. Building a method for the study of the Mesolithic-Neolithic transition in Portugal. *Neolithic Studies* 11, *Documenta Praehistorica* 31:89–111.
- . n.d. The palaeodemography of Central Portugal and the Mesolithic-Neolithic transition. MS. [MJ]
- Jackes, M., D. Merrett, and C. Meiklejohn. n.d. Demography of an early Neolithic sample in the Central Zagros. MS. [MJ]
- Jackes, M., M. Roksandic, and C. Meiklejohn. n.d. The demography of the Djerdap Mesolithic/Neolithic transition. In *The Iron Gates in prehistory: New perspectives*, ed. C. Bonsall, V. Boroneant, and I. Radovanovic. British Archaeological Reports International Series 1237. In press. [MJ]
- Johansson, S. R., and S. Horowitz. 1986. Estimating mortality in skeletal populations: Influence of the growth rate on the interpretation of levels and trends during the transition to agriculture. *American Journal of Physical Anthropology* 71: 233–50.
- Katzenberg, M. A. 1992. Changing diet and health in pre- and protohistoric Ontario. In *Health and lifestyle change*, ed. R. Huss-Ashmore, J. Schall, and M. Hediger, 23–32. MASCA Research Papers in Science and Archaeology 9.
- Kelley, M. A. 1980. Disease and environment: A comparative

- analysis of three early American Indian skeletal collections. Ph.D. diss. Case Western Reserve University.
- Klepinger, L. L., and D. R. Henning. 1976. The Hatten Mound, a two-component burial site in northeastern Missouri. *The Missouri Archaeologist* 37:92–170.
- Knowles, F. H. S. 1937. *Physical anthropology of the Roebuck Iroquois with comparative data from other Indian tribes*. National Museum of Canada Anthropological Series 22.
- Konigsberg, L. W. 1985. Demography and mortuary practice at Seip Mound One. *Midcontinental Journal of Archaeology* 10:123–48.
- Kreissa, P. P. 1986. The Furman site (47WN216), a Lake Winnebago phase burial area near Oshkosh, Wisconsin. *The Wisconsin Archaeologist* 67:71–96.
- Kuijt, I. 2000. People and space in early agricultural villages: Exploring daily lives, community size, and architecture in the late Pre-Pottery Neolithic. *Journal of Anthropological Archaeology* 19:75–102.
- Lallo, J., J. C. Rose, and G. J. Armelagos. 1980. An ecological interpretation of variation in mortality within three prehistoric American Indian populations from Dickson Mounds. In *Early Native Americans*, ed. D. L. Browman, 203–38. The Hague: Mouton.
- Larsen, C. S. 1984. Health and disease in prehistoric Georgia. In *Paleopathology at the origins of agriculture*, ed. M. N. Cohen and G. J. Armelagos, 367–92. New York: Academic Press.
- Larsen, C. S., M. J. Schoeninger, N. J. Merwe, K. M. Moore, and J. A. Lee-Thorp. 1992. Carbon and nitrogen stable isotopic signatures of human dietary change in the Georgia Bight. *American Journal of Physical Anthropology* 89: 197–214.
- Lee, R. B. 1972. Population growth and the beginnings of sedentary life among the !Kung Bushmen. In *Population growth: Anthropological implications*, ed. B. Spooner, 319–42. Cambridge: MIT Press.
- . 1979. *The !Kung San: Men, women, and work in a foraging society*. Cambridge: Cambridge University Press.
- Lee, R. D. 1986. Malthus and Boserup: A dynamic synthesis. In *The state of population theory*, ed. D. Coleman and R. Schofield, 96–130. New York: Blackwell.
- . 1987. Population dynamics of humans and other animals. *Demography* 24:443–65.
- Lee, J. Z., W. Feng, and L. Bozhong. 2003. Population, poverty, and subsistence in China 1700–2000. In *Population and economy from hunger to modern economic growth*, ed. T. Bengtsson and O. Saito. New York: Oxford University Press.
- Lewis, T. M. N., and M. Kneberg. 1970. *Hiawassee Island: An archaeological account of four Tennessee Indian peoples*. Knoxville: University of Tennessee Press. [MJ]
- Livi-Bacci, M. 1992. *A concise history of world population*. Cambridge: Blackwell.
- Lynott, M. J., T. W. Boutton, J. E. Price, and D. E. Nelson. 1986. Stable carbon isotopic evidence for maize agriculture in southeast Missouri and northeast Arkansas. *American Antiquity* 51:51–65.
- McCaa, R. 2000. The peopling of Mexico from origins to revolution. In *A population history of North America*, ed. Michael R. Haines and Richard H. Steckel, 241–304. New York: Cambridge University Press.
- . 2002. Paleodemography of the Americas: From ancient time to colonialism and beyond. In *The backbone of history*, ed. R. H. Steckel and J. C. Rose, 94–124. Cambridge: Cambridge University Press.
- McNeilly, A. S. 1988. Breastfeeding and fertility. In *Seminar on Biomedical and Demographic Determinants of Human Reproduction, International Union for the Scientific Study of Population, Baltimore 4–8 January 1988*, 1–15.
- . 2001. Lactational control of reproduction. *Reproduction, Fertility, and Development* 13:583–90.
- MacNeish, R. S. 1992. *The origins of agriculture and settled life*. Norman: University of Oklahoma Press.
- Malthus, T. R. 1926 (1798). *First essay on population*. London: Macmillan for the Royal Economic Society.
- Martin, D. L., A. H. Goodman, G. J. Armelagos, and A. L. Magennis. 1991. *Black Mesa Anasazi health: Reconstructing life from patterns of death and disease*. Southern Illinois University at Carbondale Center for Archaeological Investigations Occasional Paper 14.
- Meiklejohn, C., J. M. Wyman, K. Jacobs, and M. K. Jackes. 1997. Issues in the archaeological demography of the agricultural transition in western and northern Europe: A view from the Mesolithic. In *Integrating archaeological demography: Multidisciplinary approaches to prehistoric population*, ed. R. R. Paine, 311–26. Southern Illinois University Center for Archaeological Investigations Occasional Paper 24. [MJ]
- Mensforth, R. P. 1990. Paleodemography of the Carlston Annis (Bt-5) Late Archaic skeletal population. *American Journal of Physical Anthropology* 82:81–99.
- Merbs, C. F., and R. J. Miller. 1985. *Health and disease in the prehistoric Southwest*. Arizona State University Anthropological Research Papers 34.
- Milner, G. R. 1983. *The East Saint Louis Stone Quarry site cemetery (11-S-468)*. Urbana: University of Illinois Press.
- Mobley, C. M. 1980. Demographic structure of Pecos Indians: A model based on life tables. *American Antiquity* 45: 518–30.
- Molleson, T. 1996. Importance of porridge. In *Nature et culture*, vol. 1, ed. M. Otte, 479–86. ERAUL 68.
- Palkovich, A. M. 1978. *A model of the dimension of mortality and its application to paleodemography*. Evanston: Northwestern University Press.
- . 1980. *Pueblo population and society: The Arroyo Hondo skeletal and mortuary remains*. (Arroyo Hondo Archaeological Series 3.) Santa Fe: School of American Research Press.
- . 1984. Agriculture, marginal environment, and nutritional stress in the prehistoric Southwest. In *Paleopath-*

- ology at the origins of agriculture, ed. M. N. Cohen and G. J. Armelagos, 425–38. New York: Academic Press.
- Parham, K. R., and G. T. Scott. 1980. Porotic hyperostosis: A study of disease and culture at Toqua (40MR6), a late Mississippian site in eastern Tennessee. In *Skeletal biology of aboriginal populations in the Southeastern United States*, ed. P. Willey and F. H. Smith, 39–52. Tennessee Anthropological Association Miscellaneous Papers 5.
- Pfeiffer, S. 1984. Paleopathology in an Iroquoian ossuary, with special reference to tuberculosis. *American Journal of Physical Anthropology* 65:181–89.
- . 1986. Morbidity and mortality in the Uxbridge ossuary. *Canadian Journal of Anthropology* 5(2):23–32. [GW]
- Pfeiffer, S., and S. I. Fairgrieve. 1994. Evidence from ossuaries: The effect of contact on the health of Iroquoians. In *In the wake of contact: Biological responses to conquest*, ed. C. S. Larsen and R. J. Miller, 47–61. New York: Wiley-Liss.
- Powell, M. L. 1988. *Status and health in prehistory: A case study of the Moundville chiefdom*. Washington, D.C.: Smithsonian Institution Press.
- . 1994. Human skeletal remains from Ocmulgee National Monument. In *Ocmulgee archaeology 1936–1986*, ed. D. J. Hally, 116–29. Athens: University of Georgia Press.
- Riley, J. T., R. Edging, and J. Rossen. 1990. Cultigens in prehistoric Eastern North America: Changing paradigms. *Current Anthropology* 31:525–41.
- Rivera, R. 1996. The use of lactational amenorrhea as fertility regulating method. *Advances in Contraception* 12:179–85.
- Rose, J. C., B. A. Burnett, M. S. Nassaney, and W. Blaeur. 1984. Paleopathology at the origins of maize agriculture in the Lower Mississippi Valley and Caddoan culture areas. In *Paleopathology at the origins of agriculture*, ed. M. N. Cohen and G. J. Armelagos, 393–424. New York: Academic Press.
- Rosner, A., E. Audrey, and S. K. Schulman. 1990. Birth interval among breast-feeding women not using contraceptives. *Pediatrics* 86:747–52.
- Roth, E. A. 1981. Sedentism and changing fertility patterns in a northern Athapascan isolate. *Journal of Human Evolution* 10:413–25.
- Sahlins, M. 1972. *Stone Age economics*. New York: Aldine de Gruyter.
- Sattenspiel, L., and H. Harpending. 1983. Stable populations and skeletal age. *American Antiquity* 48:489–98.
- Schroeder, S. 2004. Current research on late precontact societies of the midcontinental United States. *Journal of Archaeological Research* 12:311–72. [MJ]
- Sciulli, P. W. 1990. Cranial metric and non-metric trait variation and biological differentiation in terminal Late Archaic populations of Ohio: The Duff site cemetery. *American Journal of Physical Anthropology* 82:19–29.
- Sciulli, P. W., and B. W. Aument. 1987. Paleodemography of the Duff Site (33LO111), Logan County, Ohio. *Midcontinental Journal of Archaeology* 12:117–44.
- Sciulli, P. W., M. J. Giesen, and R. R. Paine. 1996. Paleodemography of the Pearson Complex (33SA9) Eiden Phase cemetery. *Archaeology of Eastern North America* 24:81–94.
- Service, E. R. 1968. The prime-mover of cultural evolution. *Southwestern Journal of Anthropology* 24:396–409.
- Short, R. V. 1976. Lactation: The central control of reproduction. *Ciba Foundation Symposium* 45:73–85.
- Silva, A. M. 1999. A necrópole neolítica do Cabeço da Arruda (Torres Vedras, Portugal): Os dados paleobiológicos. In *II Congrès del Neolitic a la Peninsula Ibèrica*, 355–60. Saguntum -PLAV, suppl., 2.
- Simoni, L., F. Calafell, D. Pettener, J. Bertranpetit, and G. Barbujani. 2000. Geographic patterns of mtDNA diversity in Europe. *American Journal of Human Genetics* 66:262–78.
- Simonoff, J. S. 1996. *Smoothing methods in statistics*. New York: Springer-Verlag.
- Smith, B. D. 1978. *Mississippian settlement patterns: Studies in archeology*. New York: Academic Press.
- . 1989. Origins of agriculture in Eastern North America. *Science* 246:1566–71.
- . 2001. Low-level food production. *Journal of Archaeological Research* 9:1–43. [ATC]
- Smith, D. G. 1997. Radiocarbon dating the Middle to Late Woodland transition and earliest maize in southern Ontario. *Northeast Anthropology* 54:37–73.
- Snow, C. E. 1948. *Indian Knoll skeletons of site Oh 2, Ohio County, Kentucky*. University of Kentucky Reports in Anthropology 4(3.2). [MJ]
- Stern, J. M., M. Konner, T. N. Herman, and S. Reichlin. 1986. Nursing behavior, prolactin, and post-partum amenorrhoea during prolonged lactation in American and !Kung mothers. *Clinical Endocrinology* 25:247–58.
- Stodder, A. L. 1994. Bioarchaeological investigation of protohistoric Pueblo health and demography. In *In the wake of contact: Biological responses to conquest*, ed. C. S. Larsen and G. R. Milner, 97–107. New York: Wiley-Liss.
- Stojanowski, C. M., and G. H. Doran. 1998. Osteology of the Late Archaic Bird Island Site (8DI52). *The Florida Anthropologist* 51:139–45.
- Stojanowski, C. M., R. M. Seidman, and G. H. Doran. 2002. Differential skeletal preservation at Windover Pond: Causes and consequences. *American Journal of Physical Anthropology* 119:15–26.
- Storey, R. 1985. An estimate of mortality in a Pre-Columbian urban population. *American Anthropologist* 87:519–35.
- . 1992. Preindustrial urban lifestyle and health. In *Health and lifestyle change*, ed. R. Huss-Ashmore, J. Schall, and M. Hediger, 33–42. Philadelphia: University Museum of Archaeology and Anthropology.
- Surovell, T. A. 2000. Early Paleo-Indian women, children, mobility, and fertility. *American Antiquity* 65:493–508.
- Sussman, R. W. 1972. Child transport, family size, and increase in human population during the Neolithic. *Current Anthropology* 13:258–59.
- Sutton, R. E. 1988. Paleodemography and late Iroquoian ossuary samples. *Ontario Archaeology* 48:42–48. [MJ]

- Telegin, D. Ya., M. C. Lillie, I. D. Potekhina, and M. M. Kovaliukh. 2003. Settlement and economy in Neolithic Ukraine: A new chronology. *Antiquity* 77(279):456–70.
- Trigger, B. G. 1981. Prehistoric social and political organization: An Iroquoian case study. In *Foundations of Northeastern archaeology*, ed. D. R. Snow, 1–42. New York: Academic Press.
- Vradenburg, J. A. 1999. Skeletal biology of late-prehistoric La Crosse-region Oneota populations. *The Missouri Archaeologist* 60:107–64.
- Warrick, G. 2000. The precontact Iroquoian occupation of southern Ontario. *Journal of World Prehistory* 14:415–66. [GW]
- . 2003. European infectious disease and depopulation of the Wendat-Tionontate (Huron-Petun). *World Archaeology* 35:258–75. [GW]
- Webb, W. S. 1974. *Indian Knoll*. Knoxville: University of Tennessee Press. [MJ]
- Webb, W. S., and C. E. Snow. 1974. *The Adena people*. Vol. 6. Knoxville: University of Tennessee Press.
- Wilma, A., C. F. Merbs, and W. H. Birkby. 1985. Evidence for prehistoric scalping at Nukawewtaqa (Chavez Pass) and Grasshopper Ruin, Arizona. In *Health and disease in the prehistoric Southwest*, ed. C. F. Merbs and R. J. Miller. Arizona State University Anthropological Research Papers 34.
- Wilson, C, and P. Airey. 1999. How can a homeostatic perspective enhance demographic transition theory? *Population Studies* 53:117–28.
- Wolf, D. J. 1977. Middle Mississippian: A prehistoric cultural system viewed from a biological perspective. In *Biocultural adaptation in prehistoric America: Southern Anthropological Society Proceedings* 11, ed. R. L. Blakely, 27–43. Athens: University of Georgia Press.
- Wood, J. W. 1998. A theory of pre-industrial population dynamics: Demography, economy, and well-being in Malthusian systems. *Current Anthropology* 39:99–135.