Demography of the Đerdap Mesolithic–Neolithic transition

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Abstract: Models for the Mesolithic–Neolithic transition are critically dependent on demographic variables. A major issue has been whether Mesolithic populations were stationary or increasing in demographic terms. The development of methods allowing for palaeodemographic comparison among archaeological skeletal samples provides the opportunity to test assumptions about the adequacy of samples and about changes in fertility during the European Late Mesolithic and Early Neolithic. Previous work has suggested that the Mesolithic was a period of stationary population in the far west and north of Europe, while the Neolithic brought with it a significant increase in fertility. We apply our standardized palaeodemographic methods to data from Đerdap skeletal samples to examine whether period assignments need reassessment, and whether the Neolithic brought increased fertility to the Iron Gates region. Our conclusions indicate that continuing reassessment of the assignment of Lepenski Vir skeletons to archaeological periods is needed, that Mesolithic populations were stationary, and that there is a high probability for increased fertility rates in the Neolithic at Lepenski Vir.

Keywords: Đerdap, demography, Mesolithic, Neolithic, transition, Lepenski Vir

Introduction

The shift to food production and the Neolithic is one of the great transitions in human history. In this paper we will examine the evidence provided by skeletons excavated from the Đerdap sites in order to test whether, prior to the introduction of agriculture, the Đerdap Mesolithic population was increasing or was stable and stationary.

Demographic factors are central to how we view the transition. Arguments about the social or environmental basis of the shift return repeatedly to the issue of the relative size of Mesolithic and Neolithic populations in Europe. The analyses underlying the 'demic diffusion' model are dependent upon the relative population densities of 'indigenous' and 'colonizing' groups. For Greece and the Balkans other than in the Đerdap much is made of the invisibility of the Mesolithic population. As a result, a key question is whether the apparent peak and concentration of population in the early Holocene Đerdap is real, especially in the Mesolithic. This is a major problem both for archaeology and demography.

General paleodemographical methodology: the questions that can be answered by demographic data

Demography deals with variables such as birth rates, death rates, and their mutual relationship in figures such as growth rates. Demographers studying modern populations have the advantage of a relatively complete data base. Errors are minor and hidden within the statistical power afforded by large samples. Those who study prehistoric populations are less fortunate. Reconstructions must be based on a single set of connected variables, related to death, and extended with an unknowable degree of accuracy to breakdown by sex and age. As a result, studies of prehistoric demography focus on the distribution of ages at death.

A key element of osteological work relates to the accurate determination of demographic variables. Problems involved in the determination of skeletal age, especially in adults, are important here (Jackes 1992, 1994, 2000). Whereas markers of sex in adult skeletons are relatively consistent throughout the life span, age markers are dependent on the process of ageing itself. Since this process is gradual and dependent upon factors such as health and physical condition, the determination is problematic. Individuals who are both healthy and in good physical condition show slower rates of change. As a result, ageing methods tend to provide 'physiological' age as opposed to 'chronological' results. The exception to this is in subadults, where the nature and rapidity of age-dependent changes allows for quite accurate determination.

Parameters used in this analysis and the relationships among them

Because of variability among adults in the expression of age-dependent characteristics, there is debate over the determination of prehistoric demographic variables that require the accurate estimation of skeletal age. There have been proposals that archaeological settings require an approach different from the full adult age profiles used in demographic analysis. Jackes (1986, 1992) has suggested the conjoint use of two values that may provide insight into overall population structure, the juvenile to adult ratio (J:A) and mean childhood mortality (MCM). The J:A (the Indice de Juvenilité, or IJ, introduced by Bocquet & Masset 1977) is the ratio of children 5 to 14 years of age to adults over 20 years, both readily determined from skeletal samples. MCM (Jackes 1986) is the mean mortality for ages 5 to 19: the mean of the life table mortality quotients is a summary value of the probability of death before reaching adulthood among those surviving to age 5. It is calculated from the q values across the three five-year age categories, 5–9, 10–14 and 15–19 years.

J:A and MCM can be determined with some accuracy, and seem to bear a consistent relationship to each other unless

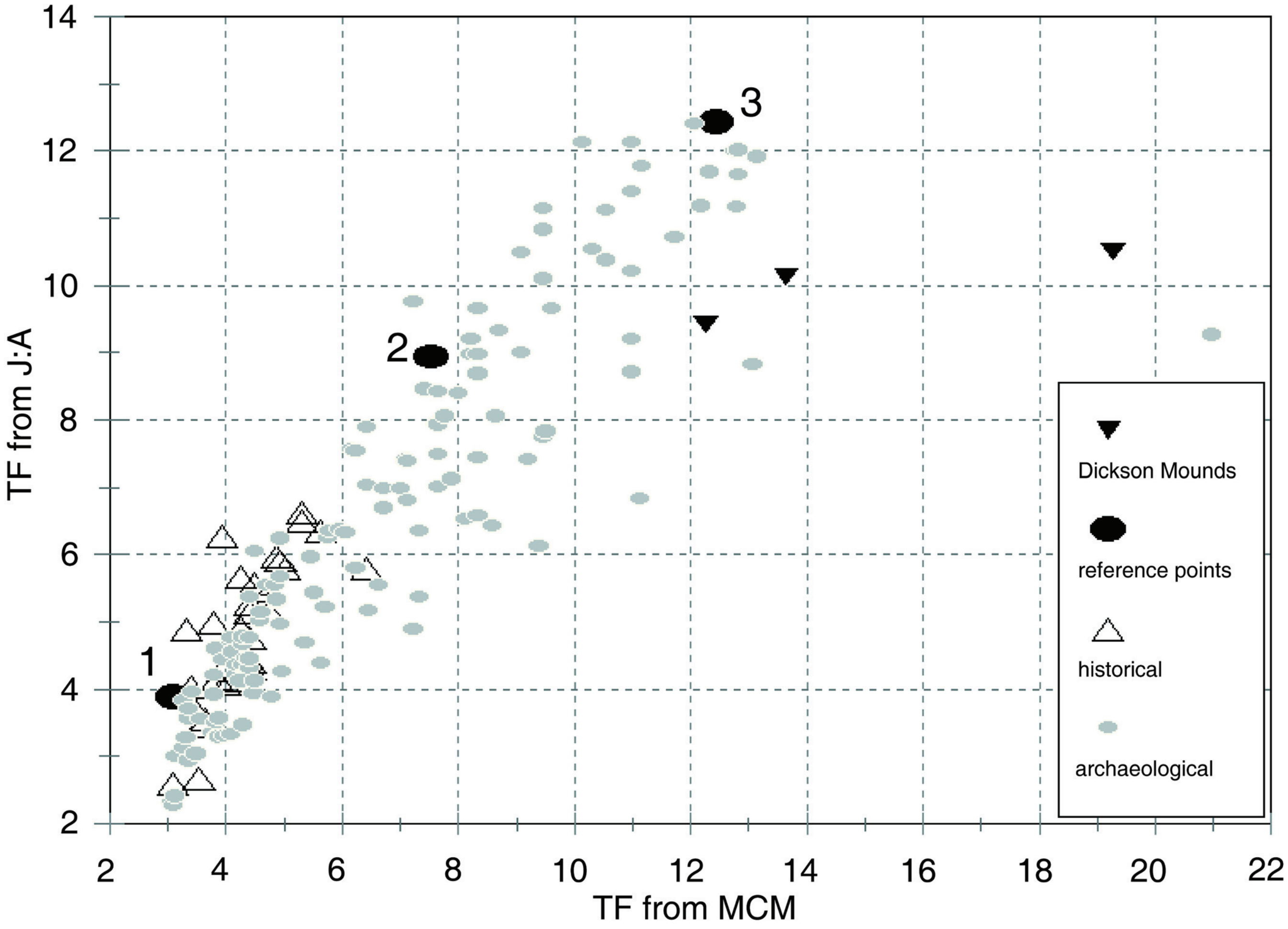

Figure 1 *Total fertility (TF) estimates derived from mean childhood mortality (MCM) and juvenile:adult ratio (J:A). Plot of 170 points: reference points 1. Dobe !Kung, 2. Hutterites dying between 1941 and 1950, 3. Coale's Index of Marital Fertility; grey circles 132 archaeological samples (excludes the Đerdap material); solid triangles three archaeological samples from Dickson Mounds; open triangles 31 historical data sets.*

perturbed by special circumstances, such as migration or sample bias. Model demographic data (Coale & Demeny 1983) provide the basis for estimates of population fertility. For each of a large number of pooled sex West model tables, increasing, decreasing and stationary, we calculate J:A, MCM and the total fertility rate (TF). These three variables are very highly correlated and allow us to estimate the TF values for archaeological populations by regression: J:A and MCM, which express the relative numbers of subadults among the dead, provide a reflection of population fertility. While there is a perception that human fertility without contraception would lead to an average woman who survives to menopause having 15 to 20 children, this does not seem to be true. This is reflected in the fertility values we use here, which derive from West model tables 1 to 8, at levels of increase up to 5% for West 1.[1]

We can demonstrate the validity of the approach by testing the values derived from the Coale and Demeny model data against modern populations that show high and low fertility. Since fertility has biological and behavioural constraints, it is clear that normal unbiased samples must have J:A and MCM values which have their own limits and a biologically determined relationship among the variables can be assumed. If shown to be valid, the estimates will provide us with a method of examining past population demography.

Is the use of West model tables valid?

It may be argued that the West model tables are not appropriate bases for conjectures on the fertility of past populations; the fertility estimated from West model tables could be too low because the West tables specifically exclude data with high infant and early childhood mortality, and are derived from 129 sets of data from, in general, industrialized countries, mostly northwestern Europe or countries colonized from the British Isles. The West tables might therefore largely represent a part of the world with low fertility because of factors like late marriage and a high incidence of unmarried people (Hajnal 1982).

Are the fertility estimates used here plausible? To test this, we compare the Coale and Demeny model fertility predictions (incorporating also United Nations model data: United Nations 1982) with data for American Hutterite women, considered the best example of 'natural fertility' under almost ideal conditions. The total fertility (TF)[2] value for Hutterite married women aged 15 to 49 from 1921 to 1930 was estimated as 12.44 live-born children. This figure is normally given as the value of Coale's Index of Marital Fertility, by which the Hutterites of this period are taken to represent the highest overall level of childbearing, exceeded only under rare conditions (e.g. Weeks 1996). Figure 1 demonstrates that the samples used for reference in this study have an estimated total fertility below this limit (marked by reference point 3). A TF of 12.44 is markedly above the TF of other historical data sets from Europe, Asia, North and South America covering the period 1650 to 1950.

While reference point 3 marks maximum Hutterite fertility in the 1920's, reference point 2 on Figure 1 marks the estimated level of fertility derived from the 309 Hutterite deaths between1941 to 1950 (age at death reordered from Eaton & Mayer 1953: table 16). The calculated J:A of 0.278 for this decade gives an estimated total fertility of 8.9 liveborn children for women aged 15 to 44; TF would be 7.5 when estimated from MCM. The higher estimated TF value for Hutterites dying between1941 and 1950 may be more correct, because the summed age-specific fertility rates of all Hutterite women of reproductive age between 1936 and 1940 gives a TF rate of 9.4 (see also Jackes & Meiklejohn 2004). A more conservative estimate would be influenced by the 8.1 value for Hutterite TF from 1946 to 1950 (Eaton & Mayer 1953). This was obviously a period of change, one disturbed by World War II, as is probably evidenced by the lack of accord between the J:A and MCM estimates of TF. Nevertheless, it is clear that the estimated values give a sense of Hutterite fertility even for a time of transition.

Bocquet-Appel (pers. comm. 2000) has suggested that Hutterite fertility is lower than it might be, because infant mortality is low; when infant mortality is high, fertility is high. The relationship between infant mortality and fertility is, in fact, complex (see, e.g., Montgomery & Cohen 1998). Infant mortality may lead to shorter birth intervals, but this in turn is associated with an increased risk of adverse effects perinatally (Zhu *et al.* 1999) and maternal mortality (Andersson *et al.* 2000; Conde-Agudelo & Belizán 2000).

If we move to the opposite extreme, low fertility, then excluding such recent contraceptive regimes as twentieth century USA, the Dobe !Kung lie at the bottom of the scale of known fertility levels as shown on Figure 1. The location of the Dobe !Kung (reference point 1) marks the total fertility as estimated from the age at death distribution. The Dobe !Kung fertility is estimated by the J:A fit as 3.9, a reasonable approximation of the Dobe !Kung TF for the 1963–1973 period of 4.3 (Howell 1979) given the small sample size and unstable conditions.

Constraints on fertility

Obviously there are behavioural restraints on high fertility, even in non-contracepting societies, and we must add biological factors to any discussion on fertility: higher risks of foetal loss or stillbirth with increasing age and parity; the adverse effects on mother and foetus of short birth intervals; the possibility of longer postpartum amenorrhoea with high parity or age (Larsen & Vaupel 1993).

While 35 years of continuous exposure to sexual intercourse could theoretically lead to 26 children per woman, each newborn enjoying 6 months of breast feeding, this model is not plausible, even if there were no disease, death, famine, marital separation, behavioural constraints, no sterility, and no age specific variation in fertility. In fact, foetal wastage due to chromosomal abnormalities is high, and thus the chance of a live birth resulting from intercourse is surprisingly low. Holman *et al.* (2000) show that 50% of a 20-year-old woman's pregnancies result in foetal loss and that this increases with age. The general proposition is that over 70% of conceptions result in lost pregnancies. As a result, both this foetal loss (detected and undetected) and, of great importance for small archaeological populations, the effects of inbreeding (Dorsten *et al.* 1999; Ober *et al.* 1999) must be taken into consideration.

While acknowledging that our fertility estimates for past populations could be conservative, we point out that they seem very realistic. Even in a situation encouraging rapid population growth, such as the southern region of North America during the first half of the eighteenth century, total marital fertility was 8.1. Yet here high fertility could be expected, especially because of the possibility of wet nurses reducing the period of lactational amenorrhoea (Houdaille 1995).

Fertility in archaeological populations

We cannot know details of the fertility of archaeological populations: the type of evidence available for the seventeenth century Huron (Jackes 1994) is surely almost unique. But that evidence does indicate low fertility. Even Colyton, the seventeenth century English parish studied for over 30 years, from written records, and determined to have 'natural fertility', is still under discussion (Vann 1999); the evidence suggests that age at marriage determined the period of highest fertility, and that there was family limitation towards the end of a woman's reproductive period. Archaeological demography will, then, always present us with questions, but translating the J:A and MCM values into fertility estimates using quadratic regression provides a method of deriving a basic demographic parameter from skeletal remains, and acknowledges and circumvents the central problem of our inability to provide correct ages for adult skeletons. We may, in this way, recognize archaeological demographic trends.

The database collected by Jackes, together with selected data from the database of Steckel *et al.* (2002; McCaa 2002), demonstrates that under normal conditions J:A and MCM values for historical and archaeological samples, of reasonable size and without obvious bias, will not fall beyond certain limits. We therefore consider that there are normal biological limits which are reached at slightly under J:A = 0.4 and MCM = 0.14, and that at this point TF must be below 14. Only seven problematical samples of the 142 archaeological samples in our database (which is taken to exclude the Đerdap material for the purpose of this discussion) fall beyond this limit on both axes.

When the estimates derived from J:A and MCM are plotted against each other, we have a method of identifying samples which are probably flawed by errors and biases in such a way that an adequate TF estimate cannot be made. Some examples of problematic data appear on Figure 1, which illustrates the fertility estimations derived from archaeological skeletal age distributions. The two extreme outliers are one of the Dickson Mounds samples discussed in

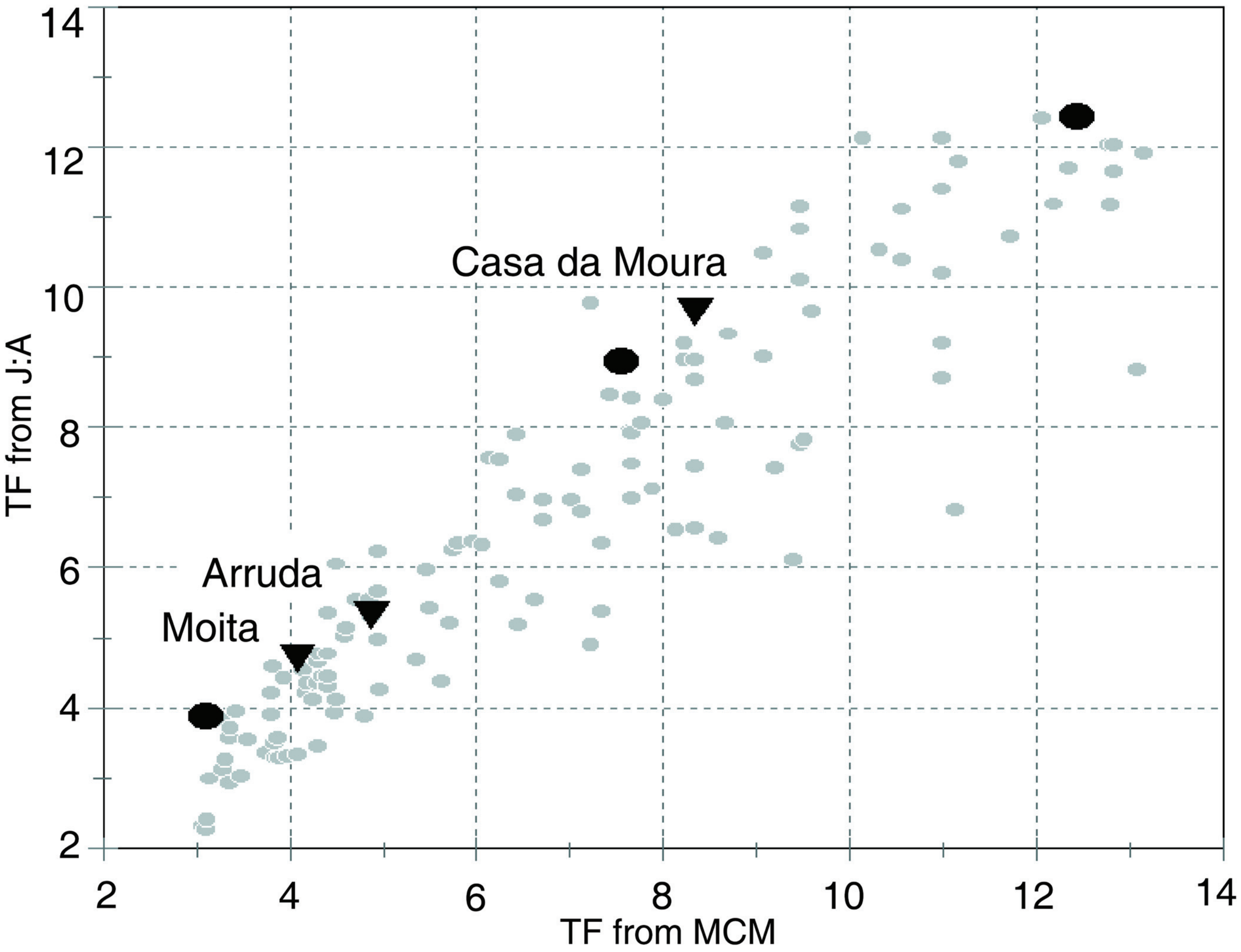

Figure 2 *Total fertility (TF) estimates derived from mean childhood mortality (MCM) and juvenile:adult ratio (J:A). General archaeological samples (excluding the Đerdap material) and the three reference points provide the background context for estimates for Portuguese Mesolithic and Neolithic samples, suggesting fertility increase in the Neolithic.*

Jackes (1993) and a sample of 170 individuals from Irene Mound (Steckel *et al*. 2002). The method demonstrates that the Irene Mound sample, representing *c*. 61% of the original excavated, must be considered inadequate.

Thus, while we acknowledge that biases inherent in methods of adult age assessment may weaken the value of palaeodemography as an instrument of interpretation in bioarchaeology, we propose that the use of the J:A and MCM will provide a method of estimating population fertility and allow us to determine whether a sample is unsuitable for analysis (Jackes 1993), because of biases which may derive from incomplete excavation or reporting, taphonomic factors or selective burial.

Demography and the Mesolithic–Neolithic transition

Previous assumptions

It is forty years since Deevey (1960) outlined the concept of demographic transition and applied it to the appearance of agriculture, postulating that the scale of modern overall population size could be traced to the agricultural transition. What was not clear, however, was the actual relationship between the two transitions: agricultural and demographic. Deevey assumed the appearance of agriculture to come first, with demographic change being the dependent variable. However, by the late 1960s and 1970s, based on the demonstration that sedentary settlement preceded agriculture in the Near East, several scenarios (e.g. Binford 1968; Smith & Young 1972; Cohen 1977) argued that the prime mover was the demographic transition, and Meiklejohn argued forcibly over many years for a 'population pressure' driver to the agricultural transition (Meiklejohn 1978, 1979; Meiklejohn *et al*. 1984). It now seems that one of the key assumptions behind the population pressure model, the presence of high fertility levels prior to the transition, may be demonstrably false (Jackes 1988; Meiklejohn *et al*. 1997). This paper will discuss this possibility and the place of the Đerdap samples in the debate.

Analysis of Portuguese data — the Mesolithic is not a high growth population

In the 1980s, Mesolithic skeletal samples excavated in the nineteenth and earlier twentieth centuries from the shell midden sites at Muge in central Portugal were re-examined

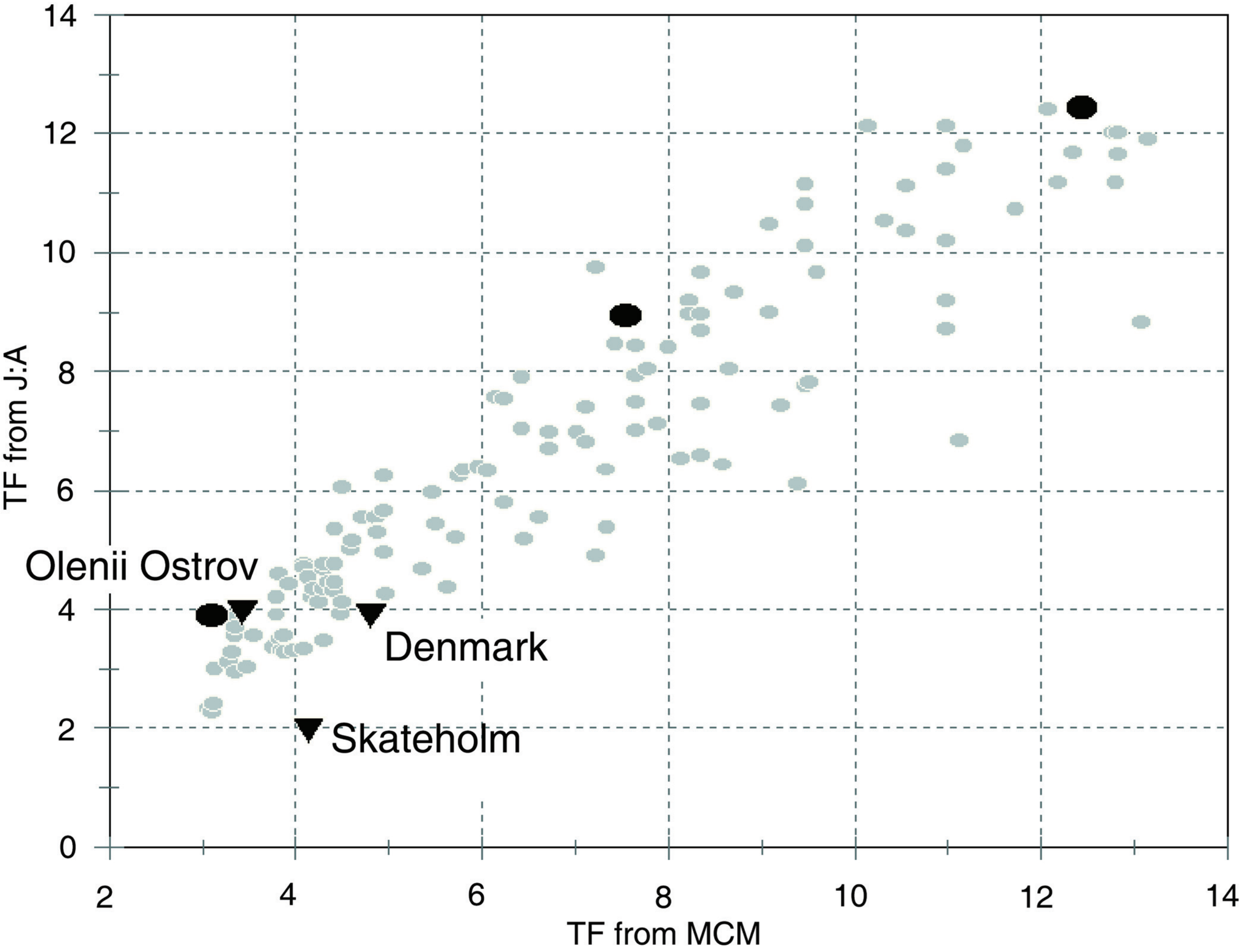

Figure 3 *Total fertility (TF) estimates derived from mean childhood mortality (MCM) and juvenile:adult ratio (J:A). General archaeological samples (excluding the Đerdap material) and the three reference points provide the background for estimates for northern European Mesolithic samples (Skateholm in Scania, Olenii Ostrov in Russian Karelia and combined data from sites on the Danish island of Sjælland) indicating a stationary population.*

(Jackes 1988; Jackes & Lubell 1999a, 1999b; Lubell *et al.* 1994; Jackes 1992; Meiklejohn *et al.* 1997; Jackes *et al.* 1997a, 1997b). As part of that study, there was an attempt to understand the demographic structure of the samples from the Mesolithic sites Cabeço da Arruda and Moita do Sebastião and the Neolithic site Casa da Moura. While the analysis concentrated on mortality profiles, showing that the Mesolithic samples had lower mortality than the Neolithic sample, the clear implication was that mortality also reflects fertility (as with Figure 2). The Mesolithic samples did not show marked signs of population growth.[3] while the Neolithic sample did. Our work does not support 'population pressure' as the prime impetus for the agricultural transition in Portugal, nor do we see evidence that immigration fuelled the Neolithic population growth (see Jackes *et al.* 2001), leading to the conclusion that fertility increased during and/or after the period of transition.

Analysis of north European Mesolithic data in accord with Portuguese results

The ideas in Jackes' (1988) paper were not tested until almost a decade later, when Meiklejohn was asked to discuss his work on Danish Mesolithic samples (Meiklejohn *et al.* 1997). The Danish material was excavated, mostly under the Vedbæk Project, on the island of Sjælland. Because the Danish sample was small and therefore had to be pooled, other north European Mesolithic material (primarily Skateholm in Scania and Olenii Ostrov in Russian Karelia) was compared with the Portuguese results. The comparison demonstrated that, despite the problems of mixed samples and the absence of juveniles in both the Danish and Skateholm groups, the results were reasonably consistent with those found in Portugal. None of the Mesolithic samples was in the high mortality, high fertility grouping. Though often treated as a population whose 'complexity' prefigured the Neolithic (e.g. Price & Brown 1985; Tilley 1996), the Mesolithic population of southern Scandinavia could be interpreted as "...a stationary population, with both low mortality and fertility" (Meiklejohn *et al.* 1997: 320). This conclusion still seems valid (Fig. 3), indicating a stationary population in Mesolithic northern Europe.

The Đerdap samples — their importance to the question

Questions arising from the above analyses

Confirmation of the pattern of lower Mesolithic fertility and higher Neolithic fertility requires examination of further large Mesolithic samples. Work on material from four Đerdap sites (Roksandić 1999, 2000) provides the opportunity. Meiklejohn *et al.* (1997) concluded that the data from Nemeskéri's (1978) study of the Vlasac sample were closely comparable to Olenii Ostrov, suggesting that the Đerdap samples would conform to the pattern. Furthermore, Meiklejohn & Zvelebil (1991), based on previously published data, suggested that the general health of the Đerdap population was similar to that found in southern Scandinavia.

Roksandić (1999, 2000) studied four Đerdap samples: Hajdučka Vodenica, Lepenski Vir, Padina and Vlasac. She demonstrates that the data used by Nemeskéri and others are incomplete. We present a new set of demographic profiles here, and also examine whether the revised Đerdap data support our model of low mortality and fertility in Mesolithic populations and higher fertility in Neolithic populations.

The basic demographic profiles: methods specific to the Đerdap site analysis

The burial practices of Mesolithic peoples are characterized by great variability, and this is certainly true for the Đerdap Mesolithic. The burial practices include cremation, primary inhumation and secondary interment including removal and re-organization of body parts, with re-burial of skulls and fragmentary remains.

The Đerdap sites were excavated as a rescue operation, and re-analysis of the excavation records continues. Further study of burial practices planned by Roksandić will include detailed consideration of taphonomic factors. This will no doubt alter the period assignments used here, especially in light of new analyzes already published (Bonsall *et al.* 2000; Radovanović 2000) and others in progress.

In this paper we use the previously accepted archaeological assignment of the burials (Radovanović 1996a; Roksandić 2000). Our method of demographic analysis provides a contribution to the on-going discussion about the validity of the attribution of burials to archaeological units.

Within any single burial, the assessment of the MNI followed the common procedures of establishing recognizable osteological elements that were doubled, as well as those that presented incompatibility of age and sex markers. Pairing of bones on the basis of age and general robusticity was accepted only in cases of good preservation and obvious similarities. Since the burials usually comprised one or a few individuals already recognized as separate entities in the field, and since there was some mixing of the smaller elements, all burials were treated as units. For Lepenski Vir, assessment was limited because field documentation was not available, but for Vlasac we could rely on published drawings (Srejović & Letica 1978) and for Padina and Hajdučka Vodenica on unpublished documentation provided by B. Jovanović. Since the MNI in any single burial unit did not exceed eight individuals, it was not necessary to use the procedures appropriate for ossuaries.

While 'extra individuals' within any of the burials could be the result of the inclusion in the grave of earth from disturbed burials, these 'extra bones' are so common in Đerdap burials that their patterning requires more detailed analysis in order to allow their incorporation into the paleodemographic reconstruction (Roksandić, in preparation).

A further set of problems results from the loose human remains, bones and fragments of bone found in the archaeological deposits without any evidence of burial, a circumstance noted as a common occurrence in the Mesolithic elsewhere (Meiklejohn & Denston 1987). Theoretically such bones could belong to any of the buried individuals; verification of this would have required all individuals in the series to be checked (an impossible task given time constraints), so they were not included in the sample as separate individuals. The situation is especially complex for Lepenski Vir where the quantity of loose bones can sometimes exceed the quantity of bones present in a recognized grave. In order to see whether this situation created a bias, repeated analyses were run, both including and excluding these 'individuals' from the Lepenski Vir sample.

Sex determination was based on the pelvic bones whenever possible and included standard procedures (Phenice 1969; Workshop of European Anthropologists 1980; Buikstra & Ubelaker 1994). It is noteworthy that the preauricular sulcus was present in almost all of the examined pelves that showed female morphology. As discussed by Roksandić (1999, 2000), the degree of sexual dimorphism is remarkable and the secondary skeletal markers of sex on postcranial bones could be used with great reliability where the pelvic remains were missing. A different pattern is observed with skull remains, which could account for discrepancies between present determinations and those of Nemeskéri (1978), Zoffmann (1983) and Živanović (1975).

Age determination presented more problems. In order to avoid point age estimates in adults, since they are highly dependent on the reference population (Bocquet-Appel & Masset 1982) and unreliable in building mortality profiles (Müller & Love 1999), adult ages were assigned to two large categories, namely, 'young' and 'old'. For the present study, all individuals older than 25 were grouped (cf. Jackes 1992). The problem created by individuals represented by a single bone or a bone fragment could be only partially circumvented in this way. Although for most of these partial skeletons it was possible to establish whether they were adults over 25 or not, some had to remain in the undetermined group comprising all from 15 to 80+ years of age.

Age determination for children up to 12 years of age was based on observation of tooth formation and eruption and long bone epiphyseal union, when available. Age was assigned by reference to tables in Buikstra & Ubelaker (1994). In other cases, the general aspect of bones was used to establish that the skeleton belonged to any of the subadult groups. The precision with which the age in subadults was assessed depended greatly on preservation and the representation of different body parts, therefore some of the individuals were assigned to quite a wide age range (2–15 years, for example). All these problems had to be circumvented in the statistical analysis.

Archaeological considerations are of greatest importance.

Table 1. Lepenski Vir.

Age category	Mesolithic	Meso-Neo	*M & M-N*	Neolithic	*M-N & N*	**All**
0	20.6	34.4	*55.0*	5.3	*39.7*	**60.3**
5	2.2	4.2	*6.4*	6.0	*10.2*	**12.4**
10	2.8	2.7	*5.5*	3.9	*6.6*	**9.4**
15	0.0	1.5	*1.5*	1.5	*3.0*	**3.0**
20	1.3	2.5	*3.8*	1.3	*3.8*	**5.1**
25	13.6	45.5	*59.1*	40.9	*86.4*	**100.0**
Total	**40.5**	**90.8**	***131.3***	**58.9**	***149.7***	**190.2**
TF estimated from MCM	7.1	4.2	*4.8*	5.9	*4.9*	5.2
TF estimated from J:A	10.8	5.1	*6.2*	7.6	*6.2*	6.8

Table 2. Vlasac.

Age category	Mesolithic	Meso-Neo	Neolithic	**All**
0	30.6	0.3	0	**30.9**
5	9.1	0.3	0	**9.4**
10	2.3	0.3	0	**2.6**
15	5.0		0	**5.0**
20	0.0	3.0	0	**3.0**
25	81.9	31.1	0	**113.0**
Total	**128.9**	**35.0**	**0**	**163.9**
TF estimated from MCM	4.6	4.2		3.8
TF estimated from J:A	4.9	5.1		4.1

Table 3. Padina.

Age category	Mesolithic	Meso-Neo	Neolithic	**All**
0	1	2	0	**3**
5	1	1	0	**2**
10	0	1	0	**1**
15	0	0	0	**0**
20	0	1	0	**1**
25	15	26	0	**41**
Total	**17**	**31**	**0**	**48**
TF estimated from MCM				3.2
TF estimated from J:A				3.4

Table 4. Hajdučka Vodenica.

Age category	Mesolithic	Meso-Neo	Neolithic	**All**
0	0	0	0	**0**
5	0	2	0	**2**
10	0	2	0	**2**
15	0	2	0	**2**
20	0	1	0	**1**
25	0	29	0	**29**
Total	**0**	**36**	**0**	**36**

Table 5. Đerdap sites grouped.

Age category	Mesolithic	Meso-Neo	Neolithic	**All**
0	52.3	36.7	5.3	**94.2**
5	12.3	7.5	6.0	**25.8**
10	5.1	6.0	3.9	**14.9**
15	5.0	3.5	1.5	**10.0**
20	1.3	7.5	1.3	**10.1**
25	110.5	131.6	40.9	**283.0**
Total	**186.5**	**192.8**	**58.9**	**438.2**
TF estimated from MCM	4.6	3.5	5.9	4.2
TF estimated from J:A	5.4	3.9	7.6	4.9

Table 6. Neolithic samples.

Age category	Neo LV	Velesnica	Ajmana	**All Neo**
0	5.3	2	4	**11.3**
5	6.0	2	3	**11.0**
10	3.9		3	**6.9**
15	1.5		2	**3.5**
20	1.3			**1.3**
25	40.9	3	5	**48.9**
Total	**58.9**	**7**	**17**	**82.9**
TF estimated from MCM	5.9			9.7
TF estimated from J:A	7.6			11.6

Table 7. Site and period groupings.

Age category	Vlasac, Padina & Hajducka Vodenica	**All**
0	33.9	**42.0**
5	13.4	**13.5**
10	5.6	**9.9**
15	7.0	**5.0**
20	5.0	**8.8**
25	183.0	**172.5**
Total	**247.9**	**251.7**
TF estimated from MCM	3.7	3.9
TF estimated from J:A	4.0	4.7

For comparison of Mesolithic and Neolithic mortality and fertility patterns, it was necessary to assign individuals to different periods within the series. The details of period definition and chronological ordering of the skeletons can be found in Roksandić (1999, 2000), which is based on Radovanović (1996a) as well as re-analysis of the documentation from Padina (Jovanović, pers. comm. to MR, 1998). To strengthen the numbers of Neolithic individuals, Velesnica (Roksandić, this volume) and Ajmana (Radosavljević-Krunić 1986) were included in the analysis.

Analysis of the data

Because sample sizes are small, the data were reworked so that any unknown age or unknown period individuals were included in the analysis. The unknowns were redistributed proportionately into the known cells.[4] It was immediately evident that no simple conclusions were to be derived from the Đerdap samples.

The Lepenski Vir and Vlasac samples are summarized in Tables 1 and 2. The unreliability of the Lepenski Vir Mesolithic subsample can be judged from the fact that TF

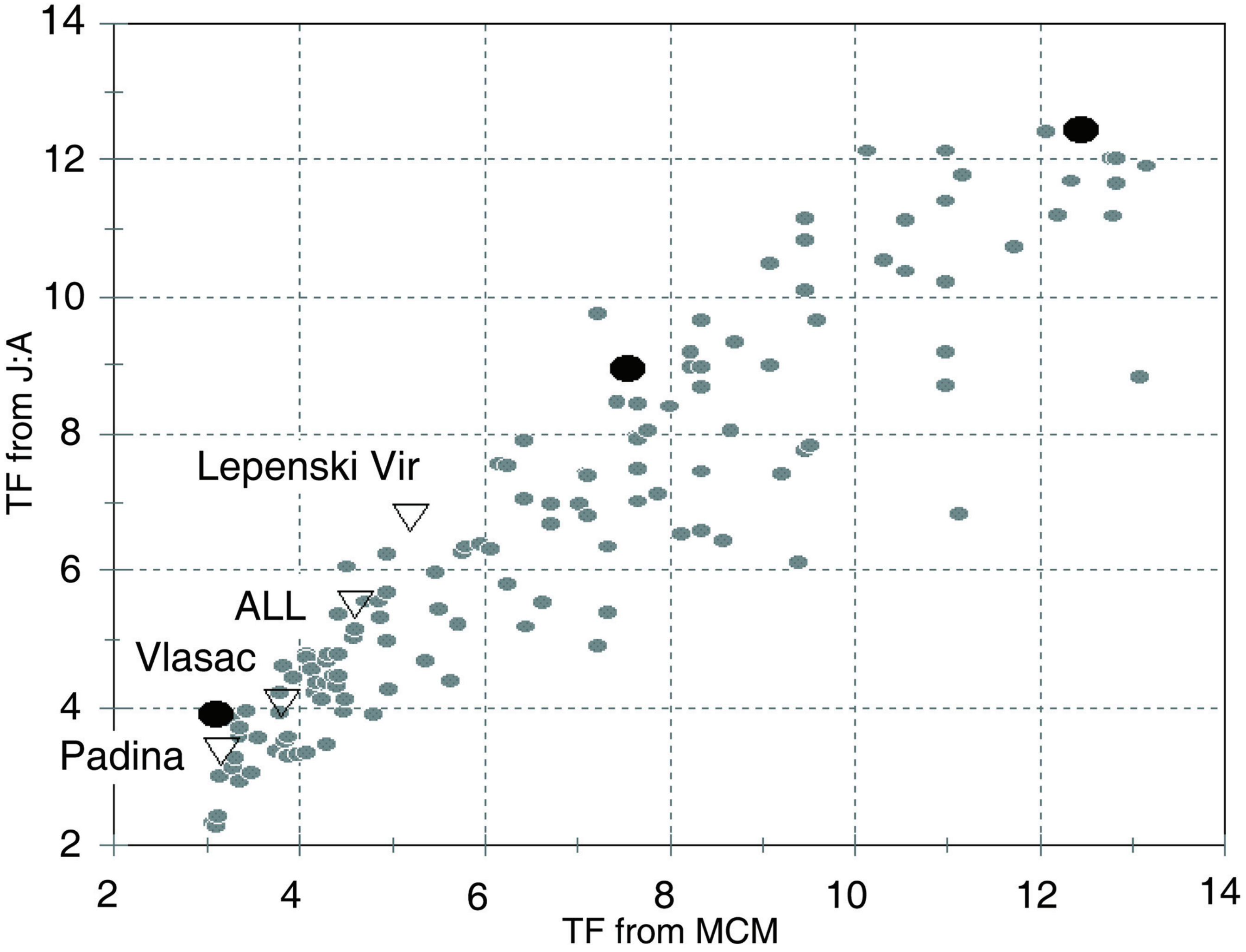

Figure 4 *Total fertility (TF) estimates derived from mean childhood mortality (MCM) and juvenile:adult ratio (J:A). General archaeological samples (excluding the Đerdap material) and the three reference points provide the background for estimates derived from pooled Đerdap data: Padina (Table 3); Vlasac (Table 2); ALL (Table 5 plus Velesnica, Ajmana from Table 7); Lepenski Vir (Table 1). The distribution shown indicates low Mesolithic fertility and increased fertility in the Neolithic.*

estimates range from 7 to 11 – such a broad range is a good indication of a problematic sample. To say that the rich riverine environment of the Lepenski Vir Mesolithic resulted in population increase would push the evidence beyond acceptable limits, because the Vlasac Mesolithic estimate, which is clearly robust, suggests that a Mesolithic woman's completed family size would be around 4 children (Table 2). The Vlasac sample is interpreted on other evidence as representing a closed and conservative population (Roksandić 2000).

Initial arguments for continuity in subsistence practices at Lepenski Vir (Radovanović 1996a, 1996b) are being reconsidered (Bonsall *et al.* 2000; Radovanović 2000), and the Mesolithic– Neolithic transition at Lepenski Vir is dated to a period of unstable climate (von Grafenstein *et al.* 1998; Barber *et al.* 1999). While it might be argued that there is a dramatic drop in fertility during the transition, so that the Lepenski Vir Mesolithic–Neolithic sample came to have a TF of between 4 and 5, it is more likely that the Mesolithic estimate is unacceptable, either because of the small sample size, or because of incorrect period assignment. Thus, the suggestion of a stable and generally stationary Mesolithic TF of 4 to 5 children seems most reasonable.

The sample from Padina (Table 3) is too small to give a reasonable assessment of its demography; we can simply indicate probable low fertility. The paucity of children under age five suggests sample bias, and this is even more obvious for Hajdučka Vodenica (Table 4). While the method of estimating fertility used here is specifically designed to circumvent the frequent problem of infant under-representation in archaeological sites, it is important to note instances in which childhood under-representation, beyond five years of age, may also occur as at Hajdučka Vodenica (Table 4).

Given inadequate samples, grouping sites might provide a method to get better demographic estimates by period (Table 5). The Neolithic sample is clearly the weakest, and data from two other sites are added in Table 6.

Two further groupings may be made in order to attempt to provide appropriate sample sizes. In Table 7 we examine firstly all sites and all periods pooled, but exclude Lepenski Vir because the Mesolithic data for that site suggest special circumstances. We then group all the data for the Mesolithic–Neolithic with those for the Neolithic, in order to see whether high fertility could be considered a characteristic of contact with and development of agricultural practices. Both these groupings of samples again indicate a TF of around 4.

Overall, whatever method of pooling is used, the data suggest a rather low fertility, one unlikely to lead beyond a stationary population unless circumstances were exceptional. There is, however, one set of data that is unexpected, the Lepenski Vir Mesolithic. The sample is small and the data give an indication of some bias. A special use of Lepenski Vir for the preferential burial of subadults is one possibility. On the other hand, the anomalous nature of the Mesolithic sample would be diminished by the addition of further adults, as suggested by the stable C and N isotopic values (Bonsall *et al*. 1997: table 5).

One other factor should be considered in Đerdap demography: the transition period has a slight over-representation of adults among the dead. This might occur, not because of low fertility, preservation bias against the young, or selective burial of adults, but as a result of immigration of young adults. The Mesolithic–Neolithic sample could indicate a fall in fertility consequent upon a period of instability associated with cultural change and an influx of adults from outside leading to an apparent over-representation of adults. Such an influx could result in a drop in fertility: the drop could be actual, as a result of the changing and unstable conditions, or perceived, resulting from an unbalanced sex ratio among the migrants (an excess of males).

However, it is worth pointing out that several of the Mesolithic–Neolithic sample adults might be considered Mesolithic on stable isotope values for the 33 Mesolithic and Neolithic skeletons from Lepenski Vir first analyzed (Bonsall *et al*. 1997), and that, until full details are published on the entire sample of 68 Lepenski Vir individuals analyzed for stable isotopes by Bonsall *et al*. (2000), we cannot speculate on the transition period demography.

Nevertheless, a calibration of ^{14}C dates for the Black Sea[5] suggests there may have been a change in Danube aquatic resources just before 8000 years ago. Thus, a drop in fertility might result from altered circumstances.

Figure 4 provides a summary restatement of what we can derive from the Đerdap demographic data. Firstly, the Vlasac and Padina data indicate a stationary population for the Mesolithic, just as for the northern European Mesolithic. Thus, if the contact period did have a fall in fertility, the result of resource instability, immigration or climate change, there would have been little buffering in the event of crises. Thirdly, while data for Neolithic samples are shown to be inadequate, nevertheless there is an indication of a marked increase in fertility such that population increase would occur. This can be said on the basis of Lepenski Vir data. The presence at Lepenski Vir of Neolithic material has clearly raised the TF above the previous levels. In fact, the Neolithic TF must be 7 as a minimum estimate. Overall, the 462 individuals represented in this analysis (the unlabelled triangle in Figure 4) provide a reasonable sample that will be of great value to palaeodemography once questions of period assignments are clarified.

Conclusions

The evidence is imperfect, because of inadequate sample sizes and the complication of apparent differences among sites, perhaps resulting from the difficulty of differentiating among periods. Our method has allowed us to identify those samples that must be considered as problematic. Despite uncertainties, the evidence suggests a stable and stationary Mesolithic population in the Đerdap. While a possible 'seeping in' of immigrants at the Mesolithic–Neolithic contact period, indicated by the non-metric traits in Đerdap samples (Roksandić 1999, 2000, this volume), could be indicated by a drop in fertility and/or in-migration of adults, such low fertility could not be maintained for any length of time. The Neolithic appears to be a time of population growth. In general, then, the pattern of stationary Mesolithic and increasing Neolithic population structures discerned in the far west and north of Europe is repeated and confirmed by the analysis of samples from the Đerdap.

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Notes:

1. West model tables used in the regression analysis comprise 15 decreasing tables with a mean total fertility (TF) of 3.5 (SD = 0.614); 35 increasing tables with a mean TF of 8.9 (SD = 5.967); 11 stationary tables, mean TF 3.9 and SD of 0.782. TF was calculated for 30 years of childbearing from the Cx column of the life tables (the sex ratio for these 30 years is derived from the appropriate model tables and the excess of males over females varies between 0.01 and 0.04). TF estimates are predicted values derived from quadratic model curve estimation regression (SPSS v.12).
2. The total fertility rate is the number of live births a woman might have were she to live to menopause and bear children according to the age-specific fertility rates for the population. Note that live births, not pregnancies, are counted. As Terrisse (1986) points out, this theoretical figure may be shown to overestimate fertility when tested against actual historical data.
3. The demography was based on mandibular dentition MNI estimates from collections in Lisbon and Porto. For discussion on methodology and sites, see Jackes & Meiklejohn (2004) and Jackes & Alvim (2006). The present paper was written before a complete assessment of Arruda history and MNI: new information is provided in Jackes & Meiklejohn (2004). We have also now done the same for Moita, during which process the technique of estimating fertility has been tested and confirmed as reliable, in conjunction with a complete reassessment of the demography (Jackes & Meiklejohn in press).
4. This explains why the figures for age distribution of individuals in Tables 1–2 and 5–7 are not whole numbers.

5. Data from Ballard *et al*. (2000) calibrated with OxCal 3.5 (Bronk Ramsay 1998) using R = 67±26 (Siani *et al*. 2000) and the marine curve (Stuiver & Braziunas 1993). While there are serious questions regarding the interpretation of the Black Sea data (e.g. Aksu *et al*. 2002), the reality of a period of reduced temperature and precipitation over several hundred years around 8200 BP is now well established (see, e.g., Barber *et al*. 1999; Mayewski *et al*. 2004).

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