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ARCHAEOLOGICAL RADIOCARBON DATES AS A POPULATION PROXY: A SKEPTICAL VIEW

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INTRODUCTION

Exploitation of proxy data is typical for disciplines that are studying past environmental issues. A proxy is a dataset through which it is possible to draw conclusions on another subject. For example, tree ring records can be used as proxy data to estimate changes in past annual temperatures because of the scientifically verified knowledge on the causality between annual temperature and the thickness, and other attributes, of annually grown tree rings.

Proxy data is at the heart of the natural sciences. At the moment, a lot of environmental data is available to gain a more comprehensive description of past environmental conditions. The reason for writing this discussion is that the prehistoric population model based on 14C proxy data presented by Tallavaara et al. (2010) has gained more weight than other slightly different variations on the theme (Siiriäinen 1981; Hertell 2009), and a number of recent studies rely on a recent view of Stone Age demographic development (Sundell et al. 2010; 2014; Kammonen et al. 2012; Onkamo et al. 2012; Tallavaara & Seppä 2012; Sundell 2014). I think that the case of 14C data as a population proxy is not as simple as it has sometimes been proposed (see Mökkönen 2011: 63–5), and there is urgent need for discussion.

The basis of the idea to use 14C dates from Finnish archaeological contexts as a proxy for population studies, the 'dates-as-data' approach, is presented in the article by Tallavaara et al. (2010), and a parallel article displays the data in detail (Oinonen et al. 2010). The idea, put simply, is that the summed probability distributions of 14C dates correlate positively with the number of prehistoric inhabitants. Following their thesis, the researchers have proposed significant fluctuation in Stone Age populations: the maximum peak in population size was reached during Typical Comb Ware period (4000–3400 calBC, 5400–4600 BP), and the minimum at the very end of the Stone Age, c 1800 calBC (Tallavaara et al. 2010; Oinonen et al. 2010).

The simple idea of 14C proxy data for demographic development, however, requires the support of a number of preliminary assumptions. The article on population history in eastern Fennoscandia by Tallavaara et al. (2010) deals with the archaeological 14C dates as belonging only to the natural sciences, and nearly all the cultural/archaeological motives have been omitted from the discussion.

HUMAN AGENCY ON RADIOCARBON DATA

Human agencies have had serious influence on the build-up of 14C data. For sure, there is a wish to use some archaeological data in the same way as the proxy data of the natural sciences, but human agency (through past cultures and recent research interests, etc.) is always involved in archaeology, and the effects it has on the data should be included in the discussion. Although the following arguments are focused on Finnish archaeological material, some of the criticism is likely to be valid regarding similar studies made in other geographical areas.

In the studies by Oinonen et al. (2010) and Tallavaara et al. (2010: 253), the *fundamental assumption* (1) 'that the site or radiocarbon date frequency correlates positively with the number of people that originally created such a signal' is followed by several additional presuppositions in order to validate the use of archaeological 14C data as a proxy for population measurements. From my point of view, the most essential further assumptions are: (2) 'the known sites represent a random sample of all the existing sites in relation to their age', (3) '… that researchers have also made the radiocarbon determinations randomly in relation to their age', and (4) that time-dependent destructive processes have not affected the age distributions. In the original studies, the discussion of possible biases in the data concerns primarily natural scientific causes (dated material, transgression phases in lakes and shores), and only mobility pattern is incorporated as a cultural motive that affects archaeological data (i.e. to the number of sites and 14C dates). Next I will explore what Finnish archaeological radiocarbon data is about, and how different factors clearly have worked on the accumulation of current archaeological 14C dates.

Archaeological visibility

The archaeological visibility of different cultures relates to cultural practices, and it is not dictated by any natural law-like causality. The manufacture of different objects of different materials is a cultural variable. Put simply: not all cultures produce similar amounts and standardized quality of matter *per capita*. For example, in southern Finland, medieval (13th–15th centuries AD) peasants were sedentary, dwelling in houses and cultivating the fields around their villages, and according to written sources and conclusions based on textual information, the number of inhabitants and villages was greater by then than during the 16th century AD – still, the Middle Ages remains a period of poor material visibility in the archaeological record (e.g. Haggrén 2005; 2011).

Cultural practices in artefact production and habitation affect archaeological visibility. A large dwelling site with material spread all over it is much easier to detect than a smaller site with a few finds or a tightly clustered find distribution. Similarly, it is simpler to discover a housepit that is visible on the ground than a site that leaves no traces on the surface. In areas where housepits have been recorded, the co-occurrence of housepits and other cultural practices produced a period (4000–3000 calBC) with a high visibility of archaeological material, which culminated during the Typical Comb Ware period (hence TCW, 4000–3400 calBC, 5400–4600 BP). Compared to other Stone Age cultural phases, the habit of using material culture during the TCW period is clearly anomalous in terms of the diversity of material and high quantity that is left at dwelling sites (see Mökkönen 2011: 64; Seitsonen et al. 2012).

During the post-TCW period, the late 4th and the early 3rd millennia calBC, archaeological visibility declined continuously till the end of Stone Age. By then, settlements had become more sedentary and did not follow retreating shorelines as closely as before, and thus, the number of dwelling sites reduced. After the TCW period, several other changes occurred: (1) the size of houses increased, and indoor activities connected with the house gained strength at the expense of outdoor activities; (2) many things altered in pottery: sizes reduced, production technology became less time-resistant, and probably function altered too; and, finally, (3) pithouses were replaced by above-ground dwellings (Mökkönen 2011: 55–62, 64–5; see also Seitsonen et al. 2012).

Destructive processes, unlike Tallavaara et al. (2010) concluded, have an effect on the age distributions of sites and 14C dates. The choice of materials in artefact production has a spatiotemporal variation, and it could vary within a culture, too. In Finland, nearly imperishable quartz was the main material in knapped tool production during the Stone Age, and at the other extreme, the preservation of organic materials is extremely poor in Finland, and un-charred Stone Age organic matter decomposes totally in normal conditions. The authors claim (Tallavaara et al. 2010: 253), that also ceramics are 'nearly imperishable'. However, there is significant variation in preservation of different pottery types. TCW, that is typically compact, sand- and stone-tempered, relatively thick and well-burned, lies strongly on the side of the best preserved Stone Age ceramics. Porous and heavily organic-tempered ceramics, with low resistance against destruction by roots and frost, lies at the opposite end of the spectrum, and other thin-walled asbestos-tempered and partly organic-tempered ceramics with varied firing-grade get their place somewhere in between. All these types of pottery are present in the Finnish Stone Age. Thus, there is a lot of variation in the preservation of different ceramic types, which affects directly the archaeological visibility of sites of a certain age, and the ease of detecting or dating a site.

Current archaeological knowledge

Current archaeological knowledge – the current state of fieldwork and awareness of the past cultures (do we really know all of them, and where to find them?) – affects the data. This is especially true in Finland, where isostatic land uplift has greatly moved the shorelines of seas and major lakes, and therefore, sites of different ages are currently found at very different altitudes. In archaeological surveys, there is never enough time to search through all the places, and investigations are typically directed first at those altitudes where the sites with the best cultural visibility lie, and then to areas and periods where the number of new sites in relation to survey hours has less potential. Consequently, in surveys, prehistoric sites of different ages are not subjected to similar magnitudes of archaeological research interests (cf. Tallavaara et 2010: 253 ; Oinonen et al. 2010: 394), and the known archaeological sites do not represent a 'random sample of all the existing sites in relation to their age' (see also Seitsonen et al. 2012).

In order to test the 14C proxy, Tallavaara et al. (2010: 252) crosschecked the result with a ceramic database, which shows the frequency of typologically dated Neolithic and Bronze Age sites. The ceramic database shows a similar peak in TCW sites as can be seen in 14C dates. However, the ceramic database and the 14C database are not published, which makes evaluating the data used impossible. It is notable, that there are still many cultural phases, the material culture of which is weakly studied and possibly incorrectly dated (e.g. Mökkönen 2008; Mökkönen 2011: 51–4), or not dated at all.

Research interests and technological innovations

Research interests and technological innovations can easily modify the distribution of 14C dates. The development of 14C dating methods have shifted the focus from indefinite charcoal dates with high contextual uncertainty towards smaller, often human-modified samples, with much better temporal resolution and a more confident find context. In 1994, when AMS dating was launched at the Dating Laboratory in Helsinki (Oinonen et al. 2010: 395), it created a situation where the volume of datable material from the Neolithic contexts multiplied in relation to the Mesolithic period. Following new technologies, researchers really seized the opportunity, and a number of new datings of both birch bark tar for repairing vessels and charred food crusts attached to Neolithic pottery were carried out (see Pesonen 1999; Pesonen 2004). In the case of TCW, for example, the higher occurrence of datable material compared to other pottery types, and the interest of one researcher in dating this ware type produced a concentration of dates. It is notable that other prehistoric ceramic types have not been subjected to any such abundant dating scheme.

The number of Mesolithic dates was at low level before the AMS dating, probably because of the contextual problems of charcoal samples that led often to random dates (see Takala 2004: 49, Fig. 44). At the turn of the 21st century, the picture altered again, when the advance in dating of burnt bones (Jungner 2004) offered a lot of new datable material from Mesolithic contexts. Hence, a large proportion of the Mesolithic dates, especially of the oldest pioneer settlement, have been obtained during the last 15 years[1] (Takala 2004; Pesonen 2005; Oinonen et al. 2010: 402, Figs. 3, 4, 5c; Pesonen et al. 2014; Tallavaara et al. 2014).

The Stone Age peak period of 14C dates, which roughly equals to the TCW period, is clearly visible in the data of the 16 most active suppliers (Oinonen et al. 2010: 399–400, Fig. 3). The examination of unpublished 14C data[2] from Northern Ostrobothnia, the Lake Saimaa area and Karelian Isthmus (Russia), which roughly equals the 'central area' with the clearest peak of 14C dates (Tallavaara et al. 2010), reveals that 57% of the sites with dated birch bark pitches and charred crust on TCW have been submitted by one researcher (see Pesonen 1999; 2004). Relative to all 14C dates connected to the TCW period in the examined data, Pesonen alone has produced 24%, and with other researchers another 14% of the dates.

Another reason for the peak of 14C dates in the 'central area' c. 4000–3000 calBC (see Tallavaara et al. 2010), is probably the boom in Neolithic housepit research. During the 1990s, a great number of housepits were excavated in both the

Lake Saimaa area and in Northern Ostrobothnia (see Pesonen 2002; Vaneeckhout 2009; Mökkönen 2011: 22–9). An absolute majority of the excavated housepits dates to the 4th millennia calBC, which is clearly reflected in the distribution of submitted radiocarbon dates during 1990–99 (see Oinonen et al. 2010: Fig. 4b). Comparing the 1990s date distributions to those of the 1980s (before the AMS technique and the boom in housepit studies), the latter shows a less pronounced peak during the TCW period (Oinonen et al. 2010: Fig. 4c).

As the peak in temporal distribution of 14C dates during the TCW period is visible (with varying magnitude) even if the data is divided based on the submission decade, the authors argue (Oinonen et al. 2010), that this excludes possible data biases caused by research interests, and confirms the positive correlation between date distributions and past population levels. From the viewpoint of archaeological visibility, however, the pattern could be read differently: due to cultural practices in material culture and habitation as well as the best preservation rate of Stone Age ceramics, the archaeological visibility of the TCW period has always been highlighted in relation to other cultural phases (see also Mökkönen 2011: 63–5; Seitsonen et al. 2012). Further, the transgressive lakes and sea level have diminished the visibility of archaeological sites before the TCW period, or the 5th millennia calBC, which was an acknowledged presupposition in the studies, but poorly represented in the conclusions.

It is reasonable to ask, too, what has been left undated. Before AMS dating, the conventional 14C dating method and the dating based on shore line displacement, which was fixed in time with 14C dates (e.g. Siiriäinen 1969; 1974), were quite equivalent to each other in the means of temporal precision. Especially in areas with fast land uplift rates, such as Ostrobothnia, the dating of sites based on shore displacement chronology was often substituted for expensive 14C datings (see Mökkönen 2011: 54). Another reason to not to perform any 14C dating may have been, for example, so strong typological dating that there was no need for further analysis.

NON-HUMAN-INCLUDED NATURAL BIASES

There is one important natural phenomenon which has not even been touched upon in previous articles (Oinonen et al. 2010; Tallavaara et al. 2010). It has to do with charcoal dates that cover 60.8% of all Finnish prehistoric 14C data (Tallavaara et al. 2010).[3] In Finland, the prevailing poor stratigraphy gives little possibility to judge the context of the dated charcoal in relation to human activity at the site. In practice, many of the charcoal dates fall randomly outside the archaeologically verified occupation period. This means that many charcoal samples, especially in cases of a piece of charcoal found in a cultural layer and not connected to any structures, do not necessarily date any human action at the site but might be rather related to natural forest fires. In the Finnish population proxy studies (Oinonen et al. 2010; Tallavaara et al. 2010; Tallavaara & Seppä 2012), all 14C dates have been included, and the obviously incorrect charcoal dates that do not overlap with other archaeological nor other scientific datings obtained from a site have not been removed from the proxy data.

In Stone Age 14C data, the charcoal dates peak contemporaneously with the beginning of the interpreted population peak (Oinonen et al. 2010: Fig. 6&7). It is noteworthy that the peak period is parallel with the warm and dry climatic period that is most susceptible to natural forest fires. In eastern Finland, charcoal layers in mire deposits are evidence of Stone Age forest fire frequencies. According to Pitkänen et al. (2003), during the moist and warm Atlantic chronozone (7000–4300 calBC), the intervals between forest fires lasted 700–900 years. Around 4200 calBC, equal to the transition from the Atlantic to Subboreal chronozone, an overwhelming change took place. Then, there was a warm and dryer climatic period half a millennium long that increased the frequency of forest fires approximately 85–90% compared to the previous Atlantic period. This means intervals of only 100 years between fires during the transition, after which the frequency stabilized to c. 200 years between the fires (c. 75% higher than during the Atlantic period). Although the absolute increase in fires has changed from place to place, the increase of forest fires caused by the Holocene climatic optimum has been observed in southern Europe, too (Rius et al. 2012).

The spread of spruce (*Picea abies*) to Finland c. 4500–2500 calBC (Giesecke & Bennet 2004; Seppä et al. 2009) has something to with the fire regime. Although the increased fire frequency might have favoured the spread of spruce (Hörnberg et al. 2011), in the long run, the established presence of spruce made the boreal forest less vulnerable to natural fires (Pitkänen et al. 2003; Ohlson et al. 2011; Clear et al. 2014). Even though the wild fire frequency is partly regulated by vegetation as well as topography, the warmer climate is suggested as the major component that propagates fire frequencies (Pitkänen 2000). It is suggested that the present global warming may cause a 24–29% increase in forest fires in southernmost Finland by the end of the current decade (Kilpeläinen et al. 2010).

If we compare the distribution of the 14C charcoal dates from archaeological contexts with the frequencies of natural forest fires, the pattern that emerges is clear. In 14C dates used as a population proxy (Oinonen et al. 2010: Fig. 7), a clear increase in charcoal data starts c 4300 calBC, culminates 3700 calBC, and c 2800 calBC regresses back to the same level where it was before the increase started. Apparently, the charcoal data used in the proxy quite neatly follows the main trends of natural forest fire frequencies, and therefore, it may be possible that part of the charcoal data used in the 14C proxy is likely not to have anything to do with human activities.

DISCUSSION

Although radiocarbon dates have been used as a proxy for population in a number of studies (e.g. Gamble et al. 2005; Shennan & Edinborough 2007; Riede 2009; Wang et al. 2014), there is no straightforward cause and effect mechanism for the patterns. Some studies have found correlations between population proxies and climatic changes (Riede 2009; cf. Gamble et al. 2005), while others have not detected any correlation with climatic fluctuations (Fiedel & Kuzmin 2007; Miller & Gingerich 2013), or emphasized the role endogenic causes (Shennan et al. 2013). The bond between the 14C proxy and population history is not set in stone, and it is vital that studies are done with caution and a thorough understanding of the factors affecting the archaeological data (Hinz et al. 2012; Miller & Gingerich 2013: 184; Crombé & Robinson 2014).

The critique of the method of studying population history based on 14C proxy data has concerned especially taphonomic issues and on controlling the effects of different processes, software issues, and methods (sample size, calibration, etc.) (Surovell & Bratingham 2007; Surovell et al. 2009; Williams 2012). Attention has also been paid to evaluation of stratigraphic contexts and sample composition, and their effects on the accuracy of the 14C dates (Kuzmin & Tankersley 1996; Kuzmin & Keates 2005), while others highlight other biases, such as the discovery bias (see Ballenger & Mabry2011; Crombé & Robinson 2014). In one recent study, the reliability of the whole idea of a population proxy based on summed radiocarbon calibrations has been questioned, even if there were an ideal situation without any biases in the data (Contreras & Meadows 2014).

The accumulation of archaeological radiocarbon data is affected by numerous past and present human agencies, and natural causes. Thus, there is no natural law-like universal causality that could be verified, and that could prove the 14C datasets as a reliable proxy for past demography. In the Finnish studies (Oinonen et al. 2010; Tallavaara et al. 2010), the possible biases in the 14C data have been discussed with an emphasis on the natural scientific angle, but human agency is poorly presented. Similar arguments concerning research biases as presented here have been put forth also in other studies (Ballenger & Mabry 2011; Crombé & Robinson 2014). I agree with Ballenger and Mabry (2011: 1322) as they straightforwardly noted that '… radiocarbon frequency distributions are based on what researchers sample, not what exists...'.

The basic assumptions, as well as the results, of the Finnish studies of population history based on 14C proxy data (Oinonen et al. 2010; Tallavaara et al. 2010) are unconvincing. It is bothersome that the 14C dates have been dissociated from the archaeological context, which has been, in a sense, replaced in the study by some ethnographic data on hunter-gatherers. Moreover, it seems that the possible biases have not been explored in full; rather, there is a tendency to explain them away, or deny the existence of presumable biases (e.g. bias caused by research interests). In addition, the major disadvantage of the studies is the unpublished databases, as the ceramic database is totally unpublished and only part of the 14C data used is published (e.g. Jungner 1979; Jugner & Sonninen 2004).[4]

In previous studies, incorrect dates have been considered exceptions that will not determine patterns in the 14C data (Shennan & Edinborough 2007: 1340; cf. Crombé & Robinson 2014). However, the poor preservation of organic material in acidic Finnish soils makes a dramatic difference to the datable materials compared to areas with better conditions for natural preservation. As the dated material is charcoal in over half of the dates, and the frequency distribution of these dates follows the main trends in natural forest fires, a more critical evaluation of the taphonomy of Finnish data should have been done. The Finnish data is likely biased by natural forest fires to a larger extent than what is typical for other similar datasets, and dates that are not associated with anthropogenic features should have been omitted.

In another study on 14C data from northwestern Russia and southeastern Finland, the authors (Seitsonen et al. 2012) have paid more attention to contextual record of the 14C dates ('dates are not just data'). They scored the dates according the contextual properties, and conclude that taphonomic and research-related factors are clearly present in the data, and they have caused more and more biases in the dates towards the end of the Stone Age (Seitsonen et al. 2012). Comparing the Finnish study on population history by Tallavaara et al. (2010) with the study based on southern Scandinavian and northern central European data (Hinz et al. 2012), it is obvious that in 14C population proxy studies other archaeological information cannot be ignored if one wants to focus on getting reliable results; a multi-proxy approach supported by other archaeological data is needed (Crombé & Robinson 2014)

Another question to discuss is the meaning of regional variations in 14C date frequencies. The Finnish data from the 'north', 'central', and 'south' areas described by Tallavaara et al. (2010: Fig. 3) shows partly opposing trends. Since there is lot of regional environmental variation as well as fluctuations in 14C date frequencies, more detailed regional descriptions are needed. Therefore, I wonder why the large combined picture of 14C frequencies was used instead of the regionally tuned 14C proxies in a study (Tallavaara & Seppä 2012) which in particular seeks a correlation between population history and regional environmental proxies. I could understand this method if the regional data displayed similar tendencies everywhere, but that is not the case. As a result, the population proxy based on supra-regional data and the regional environmental proxies (Tallavaara & Seppä 2012) are not at the same scale for a reliable comparison.

In this discussion, my point is not to neglect the effects of past natural conditions on Stone Age human populations. Rather, I am about to underline that the current method of using 14C dates as a direct proxy for population measurements disparages the cultural dimensions of man and the archaeological context of the data, and incorrectly uses the radiocarbon data as if it were just another set of natural scientific proxy data. The diversity of the cultural spectrum created by prehistoric modern humans is magnificent, and thus it is highly suspicious to ignore the influence of cultural motives on the temporal distribution of archaeological sites and radiocarbon dates. After all, archaeology is about studying humans and archaeological data is never of a purely natural scientific nature.

CONCLUSIONS

The effects of multiple human agencies and natural causes have increased the number of Finnish 14C dates related to the late Early Neolithic and the early Middle Neolithic era. In a study of Finnish Stone Age population size based on 14C proxy data (Oinonen et al. 2010: Tallavaara et al. 2010), the following main failures exist: (1) The discourse on the data biases is incomplete. Cultural change and cultural practices that have great effects on the build-up of material have been, for the most, omitted from the discussion. The known archaeological sites are not a random sample of all the existing sites in relation to their age. (2) The development of 14C dating technology has shepherded the research, which is not admitted in the studies. The available technology has led the archaeologist to do research and dating on materials allowed by the most up-to-date technology. The radiocarbon determinations have not been submitted randomly in relation to their age. (3) The archaeological contexts of the dates have been excluded. (4) The influence of forest fires on charcoal data has not been discussed at all. (5) The data used in the studies is largely unpublished.

Therefore, I disagree with the fundamental assumption 'that the site or radiocarbon date frequency correlates positively with the number of

[Stone Age] people that originally created such a signal' (Tallavaara et al. 2010: 253). I propose that the 14C data represents only the material that has been dated, and there is no positive correlation between 14C proxy and past population levels. Similarly, I do not believe that any positive correlation exists either between the population size and the amount of preserved material culture.

The studies of the prehistoric population history of eastern Fennoscandia by Tallavaara et al. (2010) and Oinonen et al. (2010) represent the 'dates-as-data' approach in which evaluation of the archaeological context has not gained much attention. The research is done in a manner that treats archaeological data as representing a monolithic culture producing a standardized amount of waste *per capita*, and which reacts through natural law-like unchangeable standards to environmental changes like animal populations. However, material culture is not standardized, and there is high variability in the archaeological visibility of different periods. It follows that there is significant divergence in general knowledge and in the number of known sites concerning different periods, and that affects the temporal and geographical distribution of 14C dates.

The peak in 14C dates, which is seen as a signal of a high population level, is actually formed by two successive peaks (see Oinonen et al. 2010: Fig. 7). The first is produced by charcoal data that follows the highest frequency of natural forest fires, and the second by the dates made on birch bark pitches and charred crusts on Typical Comb Ware chards. It seems evident that the high frequency of radiocarbon dates that culminated at the beginning of the TCW period slightly after 4000 calBC is not about population growth initiated by increased environmental productivity (Tallavaara et al. 2010), but rather the creation of such co-operative factors as good archaeological visibility of the TCW phase, well-preserved pottery with good opportunities for dating, large-scale research interests (pottery and housepits), and fluctuations in forest fire frequencies.

NOTES

[1]The radiocarbon data used in the study of postglacial colonization in eastern Fennoscandia by Tallavaara et al. (2014) comprises 107 dates, of which 82% have been dated after the year 2000. The proportions of dated material of the 21st century radiocarbon data is as follows: 63% burnt bone, 28% charcoal, and the remaining 9% is of other materials (birch bark pitches and wooden objects such as sledge runners, etc.). This finely illustrates the boom of Mesolithic dates after the advance of the AMS dating technique.

[2]In the project 'The use of materials and the Neolithisation in North-Western Europe (c 6000 – 1000 BC)', we received from Petro Pesonen (Lic.Phil.) in autumn 2013 part of the radiocarbon data used in the proxy studies, in order to get a full understanding of the present 14C data and to direct the new dates efficiently within current project.

[3]In the whole 14C database included the historic dates as well, the charcoal samples comprise 55% (Oinonen et al. 2010: 395).

[4]Publishing of the database is, of course, problematic since much of the unpublished data used in the study is financed by other researchers. However, the data used in scientific studies should be open for those who may be willing to explore the basis in detail, and to evaluate the validity of the drawn conclusions.

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