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Food supply strategies in the Romanian Eneolithic: sheep/goat husbandry and fishing activities from Hârşova tell and Borduşani-Popină (5th millennium BC)

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Abstract

Previously observed specialisation in sheep/goat kill-off patterns from Romanian Eneolithic sites raises the question of a limited duration of the slaughtering period. In order to provide reliable month of death distribution for sheep/goats, the approach developed here takes into account uncertainties regarding the age-at-death and the month of birth, based on classical archaeozoological techniques. We show that sheep slaughtering rarely occurred from late spring to early autumn or from summer to mid-fall, both at Hârşova-tell and Borduşani-Popină. Conversely, it is very likely that fishing activities took place primarily from spring to early autumn. This points to the existence of seasonal and complementary food supply strategies at both sites. Several possible explanations for these seasonal strategies are discussed. We also highlight the homogeneity in the management of domestic herds between the two sites, raising the question of a certain standardisation in pastoral practices on a larger scale.

Key-words

South-eastern Romania, Gumelniţa culture, sheep/goats, fish, season of death, seasonal strategies

1. Introduction

In south-eastern Europe, Eneolithic cultures represent a crucial period in the evolution of prehistoric societies as they are characterized by the development of copper metallurgy, specialised workshops (ceramic and flint-processing areas are the most common in Romania; Ellis, 1984; Marinescu-Bîlcu, 2002; Manolakakis, 2007; Chapman, 2010; Popovici, 2010), and accentuated social differentiation (Renfrew, 1978; Todorova, 1978; Marinescu-Bîlcu, 2001; Chapman et al., 2006; Guilaine, 2007; Slavchev, 2008). In south-eastern Romania and north-eastern Bulgaria, the Eneolithic period is also marked by the appearance and the increasing density of tell-dwelling. These tells can be highly structured settlements (e.g., Todorova, 1978; Bailey, 2000; Ştefan, 2010). As for animal management, a first analysis of husbandry practices developed for sheep in south-eastern Romania during the Late Eneolithic showed that they were consistent and specialised (Bréhard & Bălăşescu, 2012). This homogeneity is quite unexpected given both the wide diversity in the faunal spectra that characterises this period and the differences, in location and size for instance, between the studied sites (op. cit.). This raised the question of a possible standardisation in pastoral practices, which would be somewhat reminiscent of the similarities in settlement organisation observed between Eneolithic tell sites, especially in north-eastern Bulgaria (e.g., Todorova, 1978; Bailey, 2000).

We also pointed out that specialisation in sheep/goat management is not common in the European Neolithic and Eneolithic (op. cit.). During this period in Europe, sheep births occurred, in all likelihood, during a rather restricted period (Balasse & Tresset, 2007; Blaise & Balasse, 2011; Balasse et al., 2012a, 2013). Therefore, the specialised practices observed for this species – the main product sought out by the inhabitants of the studied tell sites was tender meat – could be imputed to or could result from the limited duration of the slaughtering period. In this case, the question arises as to whether this was linked to the availability of other resources (wild resources especially) or to other constraints, and did Eneolithic communities develop strategies to ensure the supply of animal protein throughout the year?

The objective of our study is to analyse the seasonal timing of animal deaths, to explore the existence of seasonal slaughtering for domestic species and of seasonal fishing/gathering activities, and consequently examine whether complementary food supply strategies were developed by Eneolithic communities. We also aim to check whether the similarities observed between the kill-off patterns established for sheep point to similar distributions for season of death, and therefore if the hypothesis of a certain standardisation in husbandry practices during the Late Eneolithic is plausible.

Numerous studies dealing with the seasonal slaughtering of mammals have been published (e.g., for the Holocene, Legge & Rowley-Conwy, 1991; Rowley-Conwy, 1993; O'Connor, 1998; Ervynck, 2005; Halstead, 2005; Helmer et al., 2005; Frankel et al., 2013), but reliable and accurate information concerning the season/month of death distribution is rarely obtained for domestic species. Apart from a few studies using skeletochronology techniques (e.g., Kasparov, 1994; Pike-Tay et al., 2004), this is partly due to methodological and zootechnical factors (see O'Connor, 1998; Milner, 2005). In order to reliably attribute a season/month of death to archaeological samples, methods conducive to precise age-at-death estimates are necessary, and birth season(s) must be known. Moreover, for the European Neolithic, the season of death for domestic species is often studied to provide evidence for permanent or temporary occupation. In this way, the presence/absence of data per month/season is often targeted, rather than quantitative distributions per month/season.

In order to propose reliable season of death distributions for domestic mammals, we developed an approach, based on classical archaeozoological techniques (recording eruption and wear stages in mandibles), that takes into account uncertainties specific to archaeological data. Simulations (1000 random runs) were performed to take into consideration both the ranges of age estimates and the existence of different possibilities for the month of birth. We applied this approach to sheep/goats as modern data sets allow both reliable and exact age-at-death estimates for these species (Deniz & Payne, 1982; Jones, 2006), unlike cattle for which age estimates remain quite wide (Jones & Sadler, 2012a, 2012b). Moreover, recent studies provided information on seasonality and season of birth for Neolithic sheep (Balasse & Tresset, 2007; Blaise & Balasse, 2011; Balasse et al., 2012a, 2013) whereas for pigs, only hypotheses based on modern or historical references can be used for the moment (e.g., Frémondeau, 2012). Finally, sheep/goats played an important role in the animal economy during the Eneolithic period in south-eastern Romania (Bréhard & Bălăşescu, 2012).

Two Eneolithic tell sites from south-eastern Romania were selected for this study: Hârşova tell and Borduşani-Popină. They both provided large assemblages of exceptionally well-preserved sheep/goat remains (complete hemimandibles are common). The two sites display similar characteristics in that they are both large tells, located close to the Danube River, with Eneolithic occupations from the Gumelniţa culture, and large game was not a pivotal component of the animal economy. At the same time, clear differences between the sites exist: sheep/goats were the main domestic species at Hârşova tell whereas there was a more balanced representation of cattle and sheep/goats at Borduşani-Popină and a significant proportion of domestic pig.

Along with the sheep/goat season of death, we also examined fishing seasons as this activity played an important role at both sites (Bălășescu et al., 2005; Radu, 2011). Fish were readily available sources of animal protein, given the location of these settlements. In order to provide information on fishing seasons, we studied the biological and ecological characteristics of the identified fish species (such as spawning periods) and size distribution, following Pike-Tay et al. (2004) and Bartosiewicz (2007). At Hârșova tell, these results are compared with those already obtained from skeletochronology analyses.

2. Archaeological contexts

Figure 1 indicates the location of the two sites selected for this study. They are among the largest Gumelnița tell sites excavated in Romania to date. Hârșova tell is located on a Danube river terrace. The base measures 60 x 200 m and archaeological levels are preserved over a thickness of 12 m in the central part of the site (the Gumelnița levels represent a height of about 7 m). The original area of the tell is estimated at about 2 ha, but it has been partly destroyed by the Danube River. The studied faunal remains come from the excavations conducted since 1993. Altogether, about 4 m in height and 400 m² have been excavated for the Gumelnița A2. Bordușani-Popină is located in a large island bordered by the Danube River and by a branch of this river (Borcea). The area is periodically flooded. The base measures 118 x 188 m and preserved archaeological levels (Boian and Gumelnița A cultures) represent a thickness of about 7 m. The studied faunal remains are from the excavations conducted since 1993. Approximately 3 m in height and 800 m² have been excavated for the Gumelnița A2. Both tells are excavated using the same methodology (Randoin et al., 2000; Popovici et al., 2001).

Both tell sites yielded dwellings (sometimes gutted by fire) characterized by floors made of loess or fine sandy sediments, often mixed with vegetal materials (e.g., Haită, 2012). They are placed in rows with alleyways running between them (Popovici et al., 2001; Popovici, 2010). Areas of household refuse have also been identified. These result from mammal, fish, mollusc and cereal processing, amongst others (e.g., Moise, 2000; Monah, 2000; Haită & Radu, 2003). Some burials have also been excavated and skeletons were often concealed under the floor of a building (Marinescu-Bîlcu, 2001; Popovici et al., 2001, 2003). The fact that buildings were often rebuilt at the same place, according to the same plan (and with almost the same dimensions), suggests that these tell sites were highly organized settlements (Marinescu-Bîlcu, 2001; Popovici et al., 2001; see Bailey, 2000 for similar cases

in north-eastern Bulgaria). Based on this organization and the different types of archaeological structures identified, a permanent settlement function is proposed for both tells (Popovici et al., 2000, 2001; Marinescu-Bîlcu, 2001; Haită & Radu, 2003).

The duration of the Gumelnița A2 occupations is difficult to estimate for these sites. To date, there are not enough radiocarbon dates (4 per site) to advance accurate estimates. Currently available dates indicate occupations between c. 4350 and 4050 cal BC at Hârșova tell (Bréhard & Bălășescu, 2012), and between c. 4500 and 4250 cal BC at Bordușani-Popină (Table 1 and Gillis et al., 2013).

2.1. Archaeozoological contexts

Generally speaking, this type of site is conducive to the good preservation of animal remains. Tell sites are stratified settlements conserved in very specific conditions (in particular a dry climate) that reduce the process of erosion and preserve evidence of human activities. Hârșova tell and Bordușani-Popină have yielded several wooden platforms (Popovici et al., 2000, 2003), which are evidence of the low level of degradation characteristic of tell sites.

Both sites provided large amounts of fish and mollusc remains along with mammal bones. Based on NISP, fish represent 92 per cent of the archaeozoological remains at Hârșova tell and 33 per cent at Bordușani-Popină; mammals represent 2 per cent and 43 per cent, and bivalves 5 per cent and 20 per cent, respectively (Bălășescu et al., 2005: Table 1; NISP=283,492 and 32,893). Due to the large size of the assemblages, about 20 species have been identified for fish. The wels catfish, the pikeperch, the common carp and the northern pike are the most common species (op. cit.). For mammals, both sites are characterized by the important role of husbandry. Game (wild boar and deer mainly) represents 23 and 21 per cent of mammal remains. Within domestic species, sheep/goats are predominant at Hârșova tell (26 per cent of the mammal remains whereas cattle represent 11 per cent) while there is a more balanced representation of cattle and sheep/goats (21 and 17 per cent respectively) at Bordușani-Popină (Bréhard & Bălășescu, 2012).

3. Material

Large assemblages of archaeozoological remains are available at both sites and sample size always exceeds 5000 NISP, regardless of the group (mammals or fish; and in 3 cases out of 4, it exceeds 10,000 NISP; Bălăşescu et al., 2005). All the archaeological structures with a high archaeozoological potential have been sieved, which partly explains the large size of the fish assemblages (Bălăşescu et al., 2005; Table 6, see below). At the site level, large dental assemblages are also available for sheep/goats. Hemimandibles and isolated lower teeth with broad age estimates represent 240 NISP at Hârşova tell and 154 NISP at Borduşani-Popină. These assemblages contain about 180 complete hemimandibles.

The studied fish and sheep/goat remains come from several archaeological structures, and of different kinds: areas of household refuse (e.g., C136, C521, C952, C963, C1027), foundation trenches (e.g., C33, C98, C349, C237, C279, C281), dwellings (e.g., SL68), alleyways (e.g., C332), etc. (each structure comprises several or hundreds of stratigraphic units). These different kinds of structure have been described in Popovici et al. (2000, 2001, 2003), Radu (2000), Haită & Radu (2003), Tomescu et al. (2003) and Haită (2012). Data presented in this study are global data. It is not possible to provide several large samples per site, each characterizing one archaeological structure or one occupation, as the stratigraphic profiles are not completed. It will be possible to work on a smaller scale and compare the different structures excavated for one occupation (and compare the different occupations) when the final stratigraphic data is available. However, for sheep/goats, we individually analysed several small samples to check whether the global data analysis masks the existence of different practices in some archaeological structures, but given the very small size of the samples, only tendencies can be proposed.

Concerning the published skeletochronology results for Hârşova tell, the analysis of fish vertebrae was conducted for two archaeological structures where large samples were available: areas of household refuse C521 (N=1906) and us1523 (N=256). For both structures, 4 mm sieves were used.

4. Methods

4.1. Sheep/goat dental assemblages

4.1.1. Taxonomic identification

It is essential to determine the species of archaeological mandibles in order to propose age estimates as differences exist between sheep and goat. Jones' observations (2006: 167)

confirmed that 'the striking difference [...] is in the wear rate of dP4 and the timing of eruption of P4'. This is a deciding factor for both of the selected sites as two-thirds of the studied dental remains (65 and 69 per cent of the teeth, respectively; Bréhard & Bălăşescu, 2012) are concerned by one of the stages of dP4 life, from eruption to shedding (dP4 lifespan corresponds to age classes A to D from Payne, 1973).

The identification of dentition to the species-level has already been published for Hârşova tell and Borduşani-Popină (Bréhard & Bălăşescu, 2012). Taxonomic identifications were based on the premolars and we did not identify isolated dP4. As two recent studies confirmed that some of the criteria published for molars are reliable (Zeder & Pilaar, 2010; Gillis et al., 2011), we analysed both assemblages once again. Given that complete hemimandibles were numerous and that several criteria have thus been taken into account at the same time, the number of remains identified to species level has clearly increased: from 43 to 58 per cent at Hârşova tell and from 38 to 58 per cent at Borduşani-Popină (Table 2). The percentage of sheep increased slightly at Borduşani-Popină.

4.1.2. Age-at-death estimates

Precise age-at-death estimates as well as extensive data are required in order to provide reliable information on month of death distribution. The most common data are dP4 crown height (149 data with known species; few measurements are available for molars as that would require breaking the hemimandibles). However, the theoretical formulae proposed by Klein et al. (1983) to estimate an age based on dP4 crown height (linear and quadratic formulae) are not suitable for this study. First, for sheep/goats, correlation between dP4 crown height and age has never been demonstrated based on individuals of known ages. Secondly, Klein et al. (1983) and Pike-Tay et al. (2000) tested this relationship for wapiti (N=83) and caribou (N=152), based on large samples (like sheep/goats, these two species are characterized by deciduous teeth with lifespans of about 2 years; see Legge & Rowley-Conwy, 1991 for discussion about the speed of replacement). They both concluded that dP4 crown height is not a very accurate predictor of individual age (in general, crown heights methods cannot provide precise estimates of age; e.g., Ducos, 1968; Klein et al., 1983; Gifford-Gonzalez, 1991; Twiss, 2008).

On the other hand, methods providing reliable age-at-death estimates based on eruption and wear stages exist for sheep (Jones, 2006) and goats (Deniz & Payne, 1982), and narrow age ranges can be obtained for the youngest specimens when hemimandibles are complete. As about 130 complete hemimandibles of known species are available at Hârşova tell and

Bordușani-Popină for the first age classes (A to D; age classes after Payne, 1973), we used these two modern data sets to estimate age-at-death, with some adjustments (see below).

Despite the problems described above, dP4 crown heights are sometimes used to determine precise age-at-death for sheep/goats in order to provide month of death distributions. These studies postulate a linear relationship between age and height (Kasparov, 1994; Helmer et al., 2005, Blaise & Balasse, 2011). Based on our large sample of hemimandibles of known species and estimated age, we examined the relationship between dP4 crown height and age (see subsection 4.1.5. for details concerning the methodology).

We based our study of archaeological teeth on the stages described by Ewbank et al. (1964) for eruption and the codes proposed by Payne (1987) for wear (Table 3, see below). For sheep, we applied the age estimates proposed by Jones (2006), based on 1611 observations of live sheep from the UK (including Soays and unimproved breeds). She showed that mandible stages depending 'on early wear of the latest-erupted tooth provide information almost as reliable as for eruption' (Jones, 2006: 170). As a precaution, we used all records, except outliers (except when the number of observations was less than 20), because 'there is a regular tendency for some Soays to be at earlier stages, and none at later stages of each age class' (Jones, 2006: 166 and appendix). For goats, we used the estimates based on 1256 observations of live Angora goats from Turkey (Deniz & Payne, 1982). We applied the figures given in Figure 24 (Deniz & Payne, 1982: 180) where age ranges encompass 95 per cent of cases (following Halstead, 2005).

Jones (2006) proposed that in archaeological samples, the wear rate can be faster than that observed on modern sheep; age estimates may therefore be adjusted. We compared the cross-tabulation of relative wear of dP4 and M1 provided in her study (Jones, 2006: Figure 15) to the Romanian records (sample size for sheep: 122 hemimandibles). This comparison shows that at every M1 wear stage, Romanian dP4 records are never less than the modern median value (except for one mandible) and for stages C1/2 and C5A, some are outside (above) the range of Jones' observations (i.e., at every M1 wear stage, Romanian dP4 are, in general, more worn than modern dP4). This strongly suggests that the wear rate is faster for the Romanian Eneolithic sheep. Therefore, for sheep, the absolute age proposed for the archaeological hemimandibles is based on the 'latest-erupted tooth'. We did not use the dP4 and then the M1 wear rate to reduce the range obtained (for example, for a mandible of sheep with M1 at stage 5A, i.e. 6-10 months, and dP4 at stage 15K, i.e. 9-21 months, the estimated age range used is 6-10 months, rather than 9-10 months).

For goats, we first compared the Romanian data with the cross-tabulation of relative wear of dP4 and M2 proposed by Deniz & Payne (1982: Figure 35). The three examples fall within

the range of their observations. Although they do not propose dP4 and M1 cross-tabulation, all twelve Romanian examples are in the range of observations for female Angora goats (summarized in Figure 24 from Deniz & Payne, 1982). Therefore, for goats, wear stages of earlier erupting teeth were used to shorten the range given by the last erupting tooth (4 cases are concerned).

For Deniz & Payne (1982) and Jones (2006), eruption stage E means “eruption through the gum”; it is therefore more advanced than the Ewbank et al. (1964) code we used for recording archaeological teeth (whereby E means “tooth erupting through bone”). For this reason, we accorded the same absolute age to the second molars recorded as “V-E” as to the teeth recorded as “V”. However, the first and second molars recorded as “E” were included in the stage “E/J” proposed by Deniz & Payne and Jones since it is not possible to rule out gum line cutting.

Finally, only hemimandibles with an age range equal to or less than 5 months were selected for the study (average range: 3.9 months) and the sample size is 110 (Table 2). Right and left hemimandibles are used. No more than four hemimandibles come from the same archaeological structure. Moreover, among the selected hemimandibles, we did not find right and left hemimandibles with exactly the same morphology and a similar wear stage in the same archaeological stratigraphic unit or structure. This suggests that one individual is unlikely to have been taken into account twice.

4.1.3. Seasonality and season of birth

To estimate the season/month of death, seasonality and season of birth must be known. Recent stable isotope analyses conducted on archaeological samples suggest that one period of birth was the norm for sheep during the Neolithic period in Europe (Balasse & Tresset, 2007; Blaise & Balasse, 2011; Balasse et al., 2012a, 2013). They also show that the birth period was relatively restricted (about 2 to 3 months). In Romania, at Măgura-Boldul lui Moș Ivănuș (beginning of the 7th mil. BC; Balasse et al., 2013), sheep births occurred over approximately three months. The first results obtained at Bordușani-Popină are consistent with this range (Balasse, oral communication 2012). For modern breeds, the observed ranges are shorter (e.g., Digard, 1981; Deniz & Payne, 1982; Jones, 2006; Blaise & Balasse, 2011; Balasse et al., 2012b), but when several years are considered together (as for archaeological samples), data can be spread out over more than two months (e.g., about 3 months in Angora goats: Deniz & Payne, 1982; about 4 months in Soay sheep: Clutton-Brock

et al., 2004). As for the season of birth, European Neolithic sheep are likely to be born at the end of the winter and during spring (Blaise & Balasse, 2011; Balasse et al., 2012a, 2013). Therefore, and as the earliest births are in February for modern unimproved sheep in Romania (Morar & Pusta, 1999; for other similar examples, see Digard, 1981; Jones, 2006; Blaise & Balasse, 2011), two possible periods of birth are used in this study: February-March-April (hypothesis A) and March-April-May (hypothesis B).

4.1.4. Process for providing month of death distributions

For each sheep/goat hemimandible, the estimated age is given in the form of a range (average range: 3.9 months) and three possibilities exist for the month of birth (see above). In order to provide reliable month of death distributions, these uncertainties must be taken into account. To achieve this goal, month of death was recalculated 1000 times, for each of the 110 hemimandibles (N=60 at Hârşova tell; N=50 at Borduşani-Popină), from values randomly taken in both the respective age range for each hemimandible and the birth period. We used uniform distributions in both cases and values are expressed in days for age estimates and in month for birth (the same process based on values expressed in days for birth led to the same conclusions). Thus, 1000 simulations, that is 1000 month of death distributions, were obtained per site. The final month of death distribution is established from the mean values (calculated for each month; $\pm 1\sigma$). This was carried out for each of the two hypotheses regarding the period of birth.

4.1.5. Examining the relationship between dP4 crown height and age

The dP4 crown height (CH) was measured following Klein et al. (1983) and is referred to hereafter as aCH (for anterior lobe), as we also took the posterior lobe measurement (pCH; following Helmer et al., 2005).

To examine the relationship between dP4 crown height and the age estimated from modern data sets, regressions of crown heights on age were calculated. We followed the approach applied by Fernandez & Legendre (2003) for a similar context. The best fit curve was determined using the least squares method (that is a minimization of the sum of the squares of the differences between the age estimate and the value provided by the model, i.e. the residuals). Constraints were used to improve the model. In order to take into account the ranges of age estimates (Table 3, see below), we recalculated 1000 times the regression parameters from values taken randomly in the respective age range of each hemimandible. In each proposed model, the parameters used are thus the mean values. For each model,

the average coefficient of determination (R^2), the mean absolute error (that is the average of the absolute residuals; in months), and the 95 per cent interval for the fitting errors (that is 2 standard deviations from the mean of the residuals) are given.

We also compared the age estimates based on modern data sets with the theoretical formulae provided by Klein et al. (1983) and Klein & Cruz-Urbe (1983) to estimate age from crown height (these are given in Table 5, see below). Since we chose to let the two parameters of the theoretical formulae (AGEs and CHo) vary (with some constraints), the same process as for the regressions was used.

We singled out anterior crown height (aCH) as Klein et al. (1983) based their theoretical formulae on this measurement. For the regression formulae, both aCH and pCH were examined. For the parameter CHo (unworn crown height, i.e., the maximal height) used in regressions and theoretical formulae, we chose a range rather than a fixed value. It varies between the maximum height of unworn crown observed in this sample (aCH=13.5 mm; pCH \geq 16.7 mm) and a maximal estimate (aCH=15 mm; pCH=18 mm) based on Romanian Eneolithic assemblages (about 260 dP4; this study and Bréhard, unpublished) and on French Neolithic assemblages (about 180 dP4; Helmer et al., 2005; Bréhard, 2007; Blaise, 2009; Hanot & Bréhard, unpublished). As no unworn or slightly worn dP4 is available for goats, we only calculated the theoretical formulae for sheep (N=99). The parameter AGEs (age at which the dP4 is shed, i.e. the intercept) is based on Jones' (2006) observations on sheep. We used either the average value (25.5 months) or the age range (22-33 months). The same possibilities were used for the regression formulae intercepts (figures from sheep were chosen as they predominate).

As the two sites studied show similar characteristics (and are found below to show very similar season of death distributions), all hemimandibles were analysed together. Six hemimandibles were subtracted from the sample used for examining month of death distributions (no measurement available for dP4) and six were added to extend the goat sample, although the age range exceeds five months (six to seven months; Table 3; see below). For the regression formulae, sheep and goat hemimandibles are pooled in our sample because one global model must be proposed as the aim would be to provide age estimates to isolated dP4 for which reliable determination cannot be made (Zeder & Pilaar, 2010).

4.2. Fish remains

Complementary approaches were applied to determine fishing periods. Apart from the Danube shad, all the fish species identified at Hârşova tell and Borduşani-Popină were available more or less all year round. However, more profitable and favourable fishing periods may have existed. To ascertain this, we used biological and ecological characteristics of the fish species identified at Hârşova tell and Borduşani-Popină, based on modern data (Bănărascu, 1964; Ciolac, 2004). The spawning period is an important criterion (e.g., Bartosiewicz, 2007) as adults are less vigilant and most fish seek shallow waters near river banks as well as residual waters for spawning, where they become more visible and can be (more) easily caught. In this fluvial context with spring-early summer floods (Zăvoianu, 1969a), quantities of fish can also be trapped in residual pools when water levels recede and can then be easily fished or simply gathered. This type of case primarily concerns young fish (i.e. inexperienced fish; many of whom hatched and grew up in these residual pools) as most mature individuals leave pools as soon as the water level starts to recede.

Analysis of size distribution can help to establish whether the most profitable and favourable fishing periods were the actual fishing/gathering periods (e.g., Pike-Tay et al., 2004; Bartosiewicz, 2007). The identification of large individuals only (i.e. adults) could suggest fishing during the spawning period, when adults are less vigilant and more easily visible. A great proportion of small individuals would indicate fishing/gathering after the spawning period. Osteometric data are available for several species (Radu, 2011). We selected two of them for this study, the common carp (*Cyprinus carpio*) and the pikeperch (*Sander lucioperca*). Both of these species were identified in most of the archaeological structures with fish remains, and osteometric data are available for both sites. Total lengths were estimated from different skeletal parts on the basis of the method described in Radu (2011).

At Hârşova tell, these approaches are compared with the results already obtained from skeletochronology analyses applied on the vertebrae of the aforementioned two species (Radu, 2000; Haită & Radu, 2003). Vertebrae from these two species are well preserved, due to their large size, and their growth rings are easy to read.

5. Results

5.1. Month of death distributions for sheep/goats

Table 3 provides data for the 110 hemimandibles for which precise age estimates were obtained (Hârşova tell: N=60; Borduşani-Popină: N=50). The average age range is 3.9 months (minimum: 1 month; maximum: 5 months).

For sheep (N=104), one hemimandible is in age class A, three in age class B, 91 in age class C and nine in age class D (age classes as described by Payne, 1973: 293). Only one hemimandible aged more than 14 months is included (Hva75) because age range increases when M2 goes beyond stage 2A. After age class D, the age ranges are always too broad to be used for this study. Age classes A to D represent 65 and 69 per cent of the dental remains (Bréhard & Bălăşescu, 2012); these figures increase to 73 per cent, at both sites, if the MNE is taken into consideration (Table 2). 76 hemimandibles out of 110 are of stage C6+ (as described by Jones, 2006). The slaughtering peak observed for age class C at Hârşova tell and Borduşani-Popină (42 and 43 per cent of the dental remains; Bréhard & Bălăşescu, 2012) is thus in the second part of the age class. Based on Jones' (2006) observations, this stage C6+ represents an age of 8 to 13 months. For goats, only six hemimandibles are included in the study, one for age class B, four for age class C and one for age class D.

Figure 2 shows how data are distributed over the year (Table 4). The first result is that whatever the hypothesis, month of death distributions observed at Hârşova tell and Borduşani-Popină are very similar. The Fisher's exact test indicates that distribution is independent of the site for both hypotheses (p -value=0.9999 and 1).

For both hypotheses, we observe that data are distributed throughout the year but some months are characterized by small numbers of hemimandibles while there is a peak around December (hypothesis A) or January (hypothesis B). Based on one standard deviation from the mean, two groups without overlap can be distinguished in both cases. For hypothesis A (birth period: February to April), the first group includes April to September with a maximum at 4.3 for Hârşova tell and at 4 for Borduşani-Popină (average number of hemimandibles: 1.9 and 1.8). The second group includes November to February with a minimum at 5.1 for Hârşova tell and at 4.3 for Borduşani-Popină (average number of hemimandibles: 9.8 and 7.7). October and March overlap these two groups. For hypothesis B (birth period: March to May), the results are the same but shifted by one month (Figure 2). Whatever the hypothesis and the site, months from the first group are always statistically different from those of the second group (dependent t -test for paired samples; Supplementary Material 1).

Based on two standard deviations from the mean (that is 95 per cent of the cases), two distinct groups still exist, but each includes fewer months: the first group comprises five months (May to September or June to October) instead of six, and the second includes two months at Hârşova tell (December-January or January-February) and one month at

Bordușani-Popină (December or January) instead of four. For both hypotheses, the first group includes more months (whatever the interval used, 1σ or 2σ) and above all is much more homogeneous than the second. Statistical equality between months (dependent t -test for paired samples; Supplementary Material 1) only exists within the first group at Hârșova tell (2 cases) and is much more common in the first group at Bordușani-Popină (six or seven cases compared to one case in the second group). This shows that the first group, which is characterized by sparse data for five months, is very reliable. Most data (more than 80 per cent in average) are distributed outside these five months, with a peak around December or January.

We pointed out that 76 hemimandibles out of 110 are of stage C6+. They are all distributed from November to May (example of hypothesis B), at both sites. None of them can be attributed to the first group. A peak is observed around January and 80 per cent of the data are concentrated over four months (December-March). Thus, the slaughtering peak observed for age class C in both kill-off patterns (see above) results from the recurrent slaughter of animals from late autumn to early spring.

In order to check whether global data analysis masks the existence of different practices in some archaeological structures, we compared three different samples from Hârșova tell (one outer level of a dwelling us3244, area of household refuse C136 and trench C98). Very few data are available (3 or 4 hemimandibles per structure/unit) but the very low percentages observed from June to October for the three examples (example of hypothesis B; Figure 3) are consistent with our general conclusions.

The distributions observed in Figure 2 document patterns for sheep, given that this species largely predominate the sheep/goat assemblages (Table 2). In order to ascertain whether goats follow these global distributions, Figure 4 provides data for six goat hemimandibles. Although based on small samples, both distributions show that most data (more than 80 per cent) are situated between June and November (example of hypothesis B), which is the opposite of global distributions. This could be explained by different ages-at-death as five out of the six goat hemimandibles are younger or older than the most common stage (C6+; 8-13 months) observed for sheep hemimandibles (Table 3).

To sum up, although we proceeded with caution regarding age-at-death estimates (ranges encompassing 95 per cent of the modern cases were used to estimate an age) and the period of birth (two hypotheses were considered), the process used (simulations with 1000 random runs) leads to clear conclusions which are the same at both sites. The most

important result is that very few sheep were slaughtered during five months of the year, in late spring-early autumn or in summer-mid-autumn. Most slaughtering (more than 80 per cent on average) occurred outside these five months, with an early or mid-winter peak. For goats, which comprise a very small minority in sheep/goat assemblages, practices seem to have been distinct. This study only includes age classes A to D but as they represent three-quarters of the dental elements (MNE) at both sites, our results are thus a reliable estimate.

5.2. Relationship between dP4 crown height and age estimate in sheep/goats

Figure 5A shows the high variability in dP4 crown height in relation to age. For sheep, for example, stage C6+ (which lasts 5 months) is characterized by crown heights varying from 8 mm to 4 mm. This phenomenon can be observed from modern data: the eight lambs with the same age studied by Payne (1985; lambs from Argos) show a range of 4.2 mm. These data also suggest that the rate of attrition is not constant throughout the life of the tooth. For sheep, the rate seems to be quite high during early wear whereas a plateau is clearly observed between (at least) 7 mm and 5 mm. It is difficult to determine what happens during late wear stages (the last quarter of dP4 life) as no reliable hemimandible over 14 months old is available for sheep (fourteen 'old' hemimandibles of sheep have been added to our sample in Figure 5 to provide an idea of late wear stages, but they are not reliable as the age ranges span 9 months). Based on age estimates from modern data sets, a linear relationship between dP4 crown height and age is unlikely.

The best-fit curve is based on a natural logarithm function, adapted here to suit our data (Table 5). Contrary to linear regressions, it takes account of the variable rate of wear (Figure 5B). We imposed constraints on intercept as no dP4 exists beyond 33 months according to Jones (2006). This improves the model as it better takes the plateau into consideration (see the first and second examples in Table 5). The earlier the intercept, the better the fitting curve (Table 5). However 22 months is very early if we consider the range and the mean value (25.5 months) observed by Jones (2006). This partly results from the lack of heavily worn dP4 in our sample. This parameter remains to be confirmed. In any event, the coefficient of determination (R^2) remains quite low (from 0.412 to 0.492; Table 5), which shows that there is no strong correlation between crown height and age in sheep/goat dP4 (Klein et al., 1983 and Pike-Tay et al., 2000 obtained R^2 higher than 0.8 for wapiti and caribou molars). The mean absolute errors are acceptable but their high standard deviations indicate marked dispersion from these values (and the differences between the ages estimated from the modern data sets and the values predicted by the models extend over at least 8 months; 95 per cent intervals). The same process based on pCH instead of aCH

provides similar results (although a little less satisfactory; two examples are given in Table 5). In this sample, the lobe is not a determining factor. Finally, models based on a polynomial regression (following Pike-Tay et al., 2000 and Fernandez & Legendre, 2003) did not yield better results.

This approach includes both sheep and goat dP4 (for the reasons expounded in subsection 4.1.5), which may hamper correlation. However, the same process based on sheep dP4 only does not provide a better correlation (only the mean absolute error is slightly better; Table 5). The variability in dP4 crown height relative to age is definitely too high.

Figure 6 compares the age estimates based on modern data sets with the age estimates calculated from the theoretical formulae proposed by Klein et al. (1983; the formulae are in Table 5). The linear formula provides very low coefficients of determination ($R^2 = -2.391$ or -0.349 , for sheep) and high mean absolute errors (Table 5). Quadratically-derived age estimates (QCHM) match our data better, but the coefficients of determination remain very low ($R^2 = 0.179$ or 0.213 , for sheep; Table 5). Figure 6B indicates that the QCHM, when compared to age estimates based on modern data sets, underage young individuals (65 per cent of global underestimation; Table 5). Gifford-Gonzalez (1991: Figure 4.10.) observed the same tendencies in bison molars. This suggests that the QCHM is not appropriate for sheep/goat dP4.

In conclusion, based on age estimates from modern data sets, no strong correlation exists between crown height and age in sheep/goat dP4, and the relationship is likely to be curvilinear, rather than linear. A large sample of specimens of known age, including a substantial number of unworn and heavily worn dP4, would be necessary to definitively assess this relationship, and determine whether dP4 crown height can be used to estimate age accurately in sheep/goats (with refined QCHM or other nonlinear formulae).

5.3. Fishing seasons

Almost all the known fish species from prehistoric sites in south-eastern Romania have been identified at Hârşova tell and Borduşani-Popină (Table 6; Bălăşescu et al., 2005). The latter contains fewer species but this may result from sample size as the fish assemblage is much smaller than at Hârşova tell (Table 6).

Fishing activities were possible all year round in the Danube River, but given that most fish are not active during the cold season (winter stasis) and are thus less visible, this is clearly

not the most favourable period. Table 6 shows the spawning periods for 19 fish taxa. Spawning occurs mainly between March and June and the peak is clearly in April-May. This period coincides with the spring-early summer floods, which start in March and culminate in June in this part of the Danube River (Zăvoianu, 1969a). Many species (such as cyprinids, which represent more than half of the fish remains; Table 6) take advantage of flooded areas to reproduce. As adult fish are less vigilant and more easily visible during the reproduction period (most cyprinids are in shoals for reproduction and they seek out shallow waters), spring-early summer was clearly a profitable and favourable period for fishing. The presence of shad could provide strong evidence of spring fishing as this anadromous species is only present in the Danube River between March and June (Ciolac, 2004), but the sparse remains identified at Hârşova tell (Table 6) render this proposition somewhat tenuous.

The water level recedes during summer and early autumn (the Danube River reaches its lowest level in September-October; Zăvoianu, 1969b), creating residual pools in the floodplains where some fish, especially young specimens born during spring, can be trapped and then easily gathered/fished. Summer-early autumn was thus another period conducive to fishing activities.

The next step is to examine whether size distributions and skeletochronology results provide evidence that fishing activities primarily occurred during these periods. Size distributions for the common carp (Figure 7; Table 7) show distinct strategies according to the site. At Borduşani-Popină, 62 per cent of the individuals are under the limit proposed for sexually mature animals (about 300 mm; Ciolac, 2004) whereas 90 per cent are above this limit at Hârşova tell (a Chi-square test confirms that size distribution is dependent of the site: $\chi^2=192.9$; $df=10$; $p= 4.897E-36$). The first distribution is similar to a catastrophic profile in which small individuals represent the majority of the dead fish (see the example of lake poisoning in Bartosiewicz, 2007: Figure 20.4). Given that the common carp spawns in flooded areas in May-June, this size distribution is likely to result from fishing/gathering activities in residual pools formed during summer-early autumn. These natural traps are common in the vicinity of the Borduşani-Popină site. At Hârşova tell, size distribution suggests distinct practices. Small fish were caught but the fishing of large individuals, i.e. adults, was the norm. It is possible that the Hârşova inhabitants fished mainly during the spawning period, when adult fish are less vigilant and easily visible. Fishing/gathering also took place after the spawning period, during summer-early autumn, given the presence of small (young) and medium-sized individuals. Even if some fishing/gathering activities took place during times when fish of all sizes were readily available, this selection of large individuals is not unexpected since carp 'is a typical fish of shallow waters, where even its large specimens may be easily caught' (Bartosiewicz, 2007: 387).

For pikeperch (Figure 7; Table 7), large individuals dominate at both sites (the lower limit proposed for sexually mature fish is about 250 mm and the range is between 250 and 400 mm; Bănărascu, 1964). The high proportion of individuals over 400 mm (67 per cent at Hârșova tell; Table 7) could indicate that fishing activities took place during the spawning period, from March to May. Adult males are particularly vulnerable during that time as they guard eggs until they hatch. At Hârșova tell, the clear presence of medium-sized individuals (200-350 mm) suggests that fishing could also have occurred during the second part of the warm period. Fish between 200 and 250 mm for instance (i.e. individuals in their second year of life) could have been trapped in residual pools or in small lakes which dry up during summer-early autumn and contain large quantities of small cyprinids, their favourite prey. They could then have been fished/gathered at the same time as carp, during summer-early autumn. Finally, unlike carp, small pikeperch (less than 150 mm, representing specimens under a year old) are absent (this is not due to differential collection as 4 mm sieves were used at both sites). This can be explained by the fact that unlike carp, pikeperch do not spawn in shallow waters, but in large lakes or quite deep branches of the Danube River that seldom dry up. Opportunities to catch young pikeperch are thus less widespread than for young carp. At Bordușani-Popină, this interpretation needs to be confirmed with a larger sample.

At Hârșova tell, the use of skeletochronology techniques, applied to common carp and pikeperch vertebrae (N=2162; see sections 3. and 4.2.), showed that fishing activities occurred throughout the year (Radu, 2000; Haită & Radu, 2003). However, winter was only identified for pikeperch, in one of the two studied assemblages and records a very low frequency (less than 4 per cent; Haită and Radu, 2003). Winter catching was thus rare. Although autumn and, to a lesser extent, spring fishing is apparent, at least half of the data indicate summer catching in both assemblages. Whatever the species, there thus appears to have been a main catching season. For both these species, the actual fishing/gathering seasons coincide with the most favourable and profitable fishing periods.

6. Discussion

At Hârșova tell, we demonstrated that the most favourable and profitable periods for fishing for two fish species (from spring to early autumn) were the actual fishing/gathering seasons. Pikeperch and the common carp are representative of the 19 taxa identified if we consider the spawning period, and they represent quite distinct behaviour. Therefore, results from

these two species can reasonably be extrapolated to the others. Although it is very likely that fish catching took place primarily from spring to early autumn, summer was probably not the main fishing season for all the fish species (it is possible that the proportion of summer to autumn or spring would be reversed for some species). Such evidence is not available at Borduşani-Popină but the size distribution for the common carp points to fishing/gathering activities during summer-early autumn. As fish species are the same as at Hârşova tell, it is probable that the inhabitants also took advantage of the period from spring to early autumn. However, the main fishing season could have varied.

Bivalves were also readily available sources of animal protein, considering the location of both tell sites. Bivalve remains are abundant at both sites, especially the painter's mussel and swollen river mussel (Bălăşescu et al., 2005; Radu, 2011). At Hârşova tell, for example, two stratigraphic units from the area of household refuse C521 (structure C521 represents 24.7 m² and 0.6 m in height and comprises more than 600 stratigraphic units) yielded about 500 kg of bivalve remains (Radu, 2011). Experiments conducted in the Danube River, close to the archaeological site of Hârşova tell, showed that such large amounts of bivalve could only be gathered during summer-early autumn, when the water level is low (Bălăşescu & Radu, 2004; Radu, 2011).

Conversely, we showed that sheep slaughtering seldom occurred during five months of the year, namely late spring-early autumn or summer-mid-autumn (according to the birth period). Most slaughtering (more than 80 per cent on average) occurred outside these five months, centred on an early or mid-winter peak. For both fish and sheep, several archaeological structures show the same tendencies, which suggests that these strategies were maintained for a number of years (or decades?). Thus, it is very likely that seasonal and complementary food supply strategies existed at Hârşova tell and Borduşani-Popină. Although sheep/goats were not the only mammals raised at these sites, and the situation was doubtlessly more complicated, they do represent the main domestic species at Hârşova tell (in relative frequencies, from NISP). For the time being, season of death distributions cannot be provided for domestic cattle and pig (see introduction).

For domestic species in the European Neolithic, few studies examine season/month of death distribution, partly for the reasons expounded in the introduction. A study based on a different method (dental growth mark analysis), conducted at an Early Neolithic site in Hungary, shows similar results (Pike-Tay et al., 2004). No deaths were identified from late spring to early autumn and the 23 specimens (with a predominance of sheep) were distributed from late autumn to spring. This corroborates the likelihood of the strategies observed at Hârşova tell and Borduşani-Popină. Fishing also played an economic role at this Hungarian site, like

at the Romanian tells, and pike size distribution points to late spring/early summer catching activities (Pike-Tay et al., 2004; Bartosiewicz, 2007).

Did the strategies observed at Hârșova tell and Bordușani-Popină directly result from wild resource availability (tell inhabitants would have taken advantage of the period when fishing and gathering activities were the most profitable, from spring to early autumn, and would have kept small livestock for the “bad” period) or did other factors come into play? Given the birth period, lamb slaughter as early as the summer would not have been profitable in terms of carcass weight. Waiting until late autumn would allow offspring to benefit from the abundant late spring-early summer food and from the new early autumn grass, and thus to obtain a higher meat yield. The succession of activities observed may result from the fact that the tell inhabitants maximised both wild resources and their flocks. The hypothesis that sheep herds were not kept at the sites during the warm period but were brought elsewhere, to more advantageous summer grazing grounds for instance, should also be considered. It is also possible that the cull of some of the oldest lambs was sometimes related to the availability of late winter/early spring feed. Indeed, this is a decisive period in herd management as grass growth can be delayed in case of prolonged winter conditions at a time when winter fodder stocks may be depleted. These propositions are not mutually exclusive.

Seasonal food supply strategies do not necessarily imply that fish and sheep meat consumption followed the same pattern. But it is difficult to demonstrate the existence of deferred consumption from archaeological data. Nonetheless, following the delicate excavation of an area of household refuse (C521) at Hârșova tell, deferred fish intake was proposed. This archaeological structure is the result of a succession of 118 stratigraphic sequences, the formation of which began during the warm season and ended during another warm season (Popovici et al., 2000; Tomescu et al., 2003). Skeletochronology analyses were applied on fish vertebrae from these sequences. The fact that spring, summer and fall seasons were identified in the same sequence several times along the stratigraphic profile may be evidence for deferred fish consumption (Radu, 2000, 2011). However, it is not possible to gauge whether or not this practice was frequent.

Lastly, our results back up the hypothesis of a permanent occupation at both sites. The succession of activities indicates that some inhabitants were present at the sites throughout the year. This corroborates findings from previous studies (Popovici et al., 2000, 2001; Marinescu-Bîlcu, 2001; Haită & Radu, 2003). However, given the high variability within the Gumelnița tell sites (e.g., Bréhard & Bălășescu, 2012), it would be unwise to extend this proposition of permanent occupation to other tell sites.

Previously observed similarities between the kill-off patterns established for sheep at four Gumelnița tell sites with distinct archaeological characteristics raised the question of a certain standardisation of husbandry practices during the Gumelnița period (Bréhard & Bălășescu, 2012). Besides this first common feature, Hârșova tell and Bordușani-Popină also show very similar month of death distributions for sheep and pig mortality profiles (Tresset, Bălășescu & Horard-Herbin in Frémondeau, 2012). Even though these sites display some common characteristics, such similarities in management strategies are unexpected given that sheep/goats and domestic pigs are not present in the same proportions at each site (at Hârșova tell, sheep/goats represent a quarter of the mammal remains compared to a sixth for pigs whereas these proportions are inverted at Bordușani-Popină). Moreover, although cattle management strategies do not show the same homogeneity, common characteristics can be observed between the two sites (Bréhard & Bălășescu, 2012). It is essential to analyse other Eneolithic sites in order to examine whether this homogeneity in the management of domestic herds is specific to these two large tell sites or if a certain standardisation of husbandry practices (affecting some or all domestic species?) during this period is possible. If confirmed, a standardisation of pastoral practices would contrast markedly with the diversity that characterises Late Eneolithic material culture in the East Balkans, but would be somewhat reminiscent of the similarities in settlement organisation that exist between tell sites, especially in north-eastern Bulgaria (Todorova, 1978; Bailey, 2000; Chapman et al., 2006; Ștefan, 2010).

7. Conclusions

Based on classical archaeozoological techniques (record of eruption and wear stages and identification to species-level of sheep/goat mandibles), the approach developed here (simulations with 1000 random runs) takes into account uncertainties specific to archaeological data (both the ranges of age-at-death estimates and the existence of different possibilities for the month of birth), in order to provide reliable month of death distributions for sheep/goats.

This study also provided the opportunity to test the use of dP4 crown height to estimate precise age-at-death for sheep/goats. Based on age estimates from modern data sets, we showed that no strong correlation exists between crown height and age in sheep/goat dP4, and that the relationship is likely to be curvilinear, rather than linear. A large sample of

specimens of known age is required to definitively assess this relationship, and determine whether dP4 crown height can be used to estimate age accurately in sheep/goats.

Regarding food (animal protein) supplies, we showed that the existence of seasonal and complementary strategies is very likely at Hârşova tell and Borduşani-Popină. The succession of activities observed may result from the fact that the tell inhabitants maximised both wild resources (they took advantage of the period when fishing and gathering activities were the most profitable, from spring to early autumn) and small livestock exploitation (obtaining a good meat yield from lambs born at the end of the winter and during spring may require waiting until the autumn to slaughter them). This could have coincided with resource availability since it is possible that, for grazing reasons, sheep herds were not kept at the sites during the warm period. The analysis of Eneolithic sites where fishing/gathering activities represent a lesser component of the diet should help to understand the factors influencing the food supply strategies developed by Eneolithic communities.

We also highlighted the homogeneity in the management of domestic herds between the two Eneolithic sites studied. Future research will establish whether this standardisation of husbandry practices is confirmed on a larger scale, by examining, for instance, if season of death distributions for sheep/goats vary according to the type of site (tell, flat settlement), site function or the chronological period (Neolithic, Eneolithic).

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TABLES with captions

Table 1. Radiocarbon dates for the Gumelnița occupation (phase A2) of Bordușani-Popină. They were calibrated using Calib Rev 6.0 (Stuiver and Reimer, 1993).

Lab no.	Date BP	2 σ calibrated age (cal BC)	Material (genus)	Context
Poz-51269	5445 \pm 35	4350-4242	<i>Quercus</i>	SL31
Poz-51284	5590 \pm 40	4494-4350	<i>Hordeum</i>	C394, SU7028

Table 2. Available samples and species-level identification for sheep/goat mandibles and lower teeth with broad age estimate at Hârșova tell and Bordușani-Popină (Gumelnița A2). See the text (4.1.) for explanation of the methodology. Ovis: *Ovis aries*. NISP: number of identified specimens. MNE: minimum number of elements.

Site	NISP	NISP species-level	% Ovis (NISP)	MNE	Complete hemimandibles of known-species with narrow age estimate
Hârșova tell	240	139	93.5	153	60
Bordușani-Popină	154	89	88.8	113	50

Table 3. Dental stage development for the sheep/goat hemimandibles from Hârșova tell (Hva) and Bordușani-Popină (Bord) selected for the study (Gumelnița A2). See the text (4.1.) for explanation of the methodology. The last six specimens are used only for examining the relationship between dP4 crown height and age. Ovis: *Ovis aries*; Capra: *Capra hircus*. WS: wear stage from Payne (1987); ES: eruption stage from Ewbank et al. (1964); Jones' stage: stage proposed by Jones (2006) for sheep, after Payne (1973).

#	Species	R/L	dP4		M1		M2		M3		Jones' stage (Ovis)	Estimated age range	dP4 measurements	
			WS	Age	ES	WS	Age	ES	WS	Age			ES	Age
Hva1	<i>Ovis</i>	L	0	0-1							A (0-1 m)	0-1		
Hva4	<i>Ovis</i>	L	4A	1-2	V						B (1-4 m)	1-2	12.5	
Hva5	<i>Ovis</i>	L	7L	1-4	V						B (1-4 m)	1-4	11.3	15.0
Hva10	<i>Ovis</i>	R	13L	3-9		2A	3-7				C1/2 (3-7 m)	3-7	9.3	15.0
Hva13	<i>Ovis</i>	R	13L	3-9		2A	3-7				C1/2 (3-7 m)	3-7	8.5	13.5
Hva13bis	<i>Ovis</i>	L	14L	6-21		2A	3-7				C1/2 (3-7 m)	3-7	8.6	14.0
Hva14	<i>Ovis</i>	R	14L	6-21		2A	3-7				C1/2 (3-7 m)	3-7	7.9	13.0
Hva16	<i>Ovis</i>	L	14L	6-21		3B	4-9				C3/4 (4-9 m)	4-9	9.2	12.4
Hva19bis	<i>Ovis</i>	L	14L	6-21		5A	6-10				C5 (6-10 m)	6-10	8.3	12.8
Hva21	<i>Ovis</i>	L	15K	9-21		5A	6-10				C5 (6-10 m)	6-10	5.8	9.1
Hva25	<i>Ovis</i>	R	15K	9-21		6A	8-11				C6+ (8-13 m)	8-11	6.9	10.0
Hva25bis	<i>Ovis</i>	L	14L	6-21		6A	8-11				C6+ (8-13 m)	8-11	7.5	12.5
Hva26	<i>Ovis</i>	L	14L	6-21		6A	8-11				C6+ (8-13 m)	8-11	7.8	11.0
Hva27	<i>Ovis</i>	L	15K	9-21		6A	8-11				C6+ (8-13 m)	9-11	7.4	10.6
Hva30	<i>Ovis</i>	L	16L	10-22		6A	8-11	V		≤11	C6+ (8-13 m)	8-11	6.8	10.2
Hva31	<i>Ovis</i>	L	16L	10-22		6A	8-11	V		≤11	C6+ (8-13 m)	8-11	5.9	9.8
Hva31bis	<i>Ovis</i>	R	16L	10-22		6A	8-11	V		≤11	C6+ (8-13 m)	8-11	6.3	10.2
Hva32	<i>Ovis</i>	L	16L	10-22		6A	8-11				C6+ (8-13 m)	8-11	6.8	10.0
Hva32bis	<i>Ovis</i>	R	15K	9-21		6A	8-11				C6+ (8-13 m)	8-11	8	12.6
Hva33	<i>Ovis</i>	L	16L	10-22		6A	8-11				C6+ (8-13 m)	8-11	6.6	11.0
Hva34bis	<i>Ovis</i>	R	14L	6-21		6A	8-11				C6+ (8-13 m)	8-11	7.1	10.5
Hva36bis	<i>Ovis</i>	R	16L	10-22		7A	8-13	V		≤11	C6+ (8-13 m)	8-11	5.7	8.0
Hva37	<i>Ovis</i>	L	15K	9-21		7A	8-13	V-E		≤11	C6+ (8-13 m)	8-11	6.5	10.1
Hva37bis	<i>Ovis</i>	R	15K	9-21		7A	8-13	E		8-13	C6+ (8-13 m)	8-13	7.5	10.5
Hva38	<i>Ovis</i>	L	16L	10-22		7A	8-13	V-E		≤11	C6+ (8-13 m)	8-11	6.5	8.4

Hva38bis	Ovis	R	17L	11-27	7A	8-13	E	8-13		C6+ (8-13 m)	8-13	5.5	8.4
Hva39	Ovis	L	17L	11-27	7A	8-13	V-E	≤11		C6+ (8-13 m)	8-11	5.7	8.5
Hva40	Ovis	L	15K	9-21	7A	8-13				C6+ (8-13 m)	8-13	6.5	10.0
Hva40bis	Ovis	R	16L	10-22	7A	8-13	V-E	≤11		C6+ (8-13 m)	8-11	5.9	9.3
Hva41	Ovis	L	16L	10-22	7A	8-13	E?	8-13		C6+ (8-13 m)	8-13	5	8.8
Hva41bis	Ovis	R	17L	11-27	7A	8-13				C6+ (8-13 m)	8-13	5.7	9.6
Hva42	Ovis	L	15K	9-21	7A	8-13	V	≤11		C6+ (8-13 m)	8-11	5.4	9.0
Hva43	Ovis	L	16L	10-22	7A	8-13	V	≤11		C6+ (8-13 m)	8-11	6	9.2
Hva43bis	Ovis	R	17L	11-27	7A	8-13	V	≤11		C6+ (8-13 m)	8-11	5	7.3
Hva44	Ovis	L	16L	10-22	7A	8-13	V-E	≤11		C6+ (8-13 m)	8-11	6.7	9.3
Hva44bis	Ovis	R	17L	11-27	7A	8-13				C6+ (8-13 m)	8-13	5.4	8.0
Hva45	Ovis	L	16L	10-22	7A	8-13				C6+ (8-13 m)	8-13	6.4	10.4
Hva45bis	Ovis	R	16L	10-22	7A	8-13				C6+ (8-13 m)	8-13	6	9.0
Hva46	Ovis	L	16L	10-22	7A	8-13				C6+ (8-13 m)	8-13	5	8.3
Hva46bis	Ovis	R	16L	10-22	7A	8-13				C6+ (8-13 m)	8-13	5	8.6
Hva47bis	Ovis	R	15K	9-21	7A	8-13	V-E	≤11		C6+ (8-13 m)	8-11	7.4	10.3
Hva48bis	Ovis	R	16L	10-22	7A	8-13				C6+ (8-13 m)	8-13	7.2	10.5
Hva50bis	Ovis	R	14L	6-21	8A	11-27	E	8-13		C6+ (8-13 m)	8-13	6.8	10.1
Hva50	Ovis	L	15K	9-21	7A-8A	8-27	V	≤11		C6+ (8-13 m)	8-11	6.5	9.8
Hva51	Ovis	L	15K	9-21	8A	11-27	V	≤11		C6+ (8-13 m)	8-11	7.2	9.6
Hva52	Ovis	L	16L	10-22	8A	11-27	V-E	≤11		C6+ (8-13 m)	8-11	5.8	9.5
Hva52bis	Ovis	R	15K	9-21	8A	11-27	V-E	≤11		C6+ (8-13 m)	8-11	6.3	9.8
Hva53	Ovis	L	19M	11-30	8A	11-27	E	8-13		C6+ (8-13 m)	8-13	4	6.3
Hva54	Ovis	L	16L	10-22	8A	11-27	E-1/2	8-13		C6+ (8-13 m)	8-13	6.4	9.5
Hva55	Ovis	L	17L	11-27	8A	11-27	E	8-13		C6+ (8-13 m)	8-13	5.6	8.8
Hva56	Ovis	L	17L	11-27	8A	11-27	E-1/2	8-13		C6+ (8-13 m)	8-13	6	8.3
Hva57	Ovis	R	16L	10-22	9A	11-78	E-1/2	8-13		C6+ (8-13 m)	8-13	5.3	7.7
Hva58	Ovis	R	16L	10-22	9A	11-78		2A 10-14		D1/2 (10-14 m)	10-14	5.4	8.5
Hva59	Ovis	R	/	/	8B	11-27		2A 10-14		D1/2 (10-14 m)	10-14		
Hva59bis	Ovis	L	18L	11-30	9A	11-78		2A 10-14		D1/2 (10-14 m)	10-14	4.2	7.2

Continued

Table 3. *Continued*

#	Species	R/L	dP4		M1		M2		M3		Jones' stage (Ovis)	Estimated age range	dP4 measurements			
			WS	Age	ES	WS	Age	ES	WS	Age			ES	Age	aCH	pCH
Hva62	<i>Ovis</i>	R	18L	11-30		9A	11-78		2A	10-14		D1/2 (10-14 m)	10-14	3.9	6.0	
Hva75	<i>Ovis</i>	L	P4 early wear	≥22		9A	11-78		7A	14-42	E-U	18-27	(D6+ (14-27 m))	22-27		
Hva15	<i>Capra</i>	L	15K	3-20		4B	4.5-7.5						age class C	4.5-7.5	6.7	8.5
Hva17	<i>Capra</i>	R	15K	3-20		4A	4.5-7.5						age class C	4.5-7.5	6.8	9.0
Hva20	<i>Capra</i>	R	14L	3-10		5A	5-12						age class C	5-10	5.7	7.8
Bord4	<i>Ovis</i>	L	13L	3-9	E-U		2-5						B (1-4 m)	2-4	11.4	16.7
Bord5	<i>Ovis</i>	L	15K	9-21	U	2A	3-7						C1/2 (3-7 m)	3-7	8.9	12.4
Bord6	<i>Ovis</i>	L	15K	9-21	U	2A	3-7						C1/2 (3-7 m)	3-7	7.2	11.1
Bord6bis	<i>Ovis</i>	R	15K	9-21	U	2A	3-7						C1/2 (3-7 m)	3-7	8.8	12.7
Bord7	<i>Ovis</i>	L	16L	10-22	U+	2A	3-7						C1/2 (3-7 m)	3-7	7.5	11.3
Bord10	<i>Ovis</i>	R	15K	9-21		5A	6-10						C5 (6-10 m)	6-10	7.9	12
Bord10bis	<i>Ovis</i>	L				5A	6-10						C5 (6-10 m)	6-10		
Bord11	<i>Ovis</i>	R	15K	9-21		5A	6-10						C5 (6-10 m)	6-10	7.2	10.1
Bord12	<i>Ovis</i>	R	16L	10-22		5A+	6-10						C5 (6-10 m)	6-10	6.6	9.5
Bord13	<i>Ovis</i>	L	15K	9-21		6A	8-11	V		≤11			C6+ (8-13 m)	8-11	5.8	9.6
Bord14	<i>Ovis</i>	L	15K	9-21		6A	8-11	V		≤11			C6+ (8-13 m)	8-11	6.7	10.3
Bord15	<i>Ovis</i>	R	16L	10-22		7A	8-13	V		≤11			C6+ (8-13 m)	8-11	6	9.7
Bord15bis	<i>Ovis</i>	L	16L	10-22		7A	8-13	C-V		≤11			C6+ (8-13 m)	8-11	5.6	9
Bord16	<i>Ovis</i>	R	15K	9-21		7A	8-13	V		≤11			C6+ (8-13 m)	8-11	6.2	8.2
Bord17	<i>Ovis</i>	R	17L	11-27		7A	8-13	(V)		≤11			C6+ (8-13 m)	8-11	5.3	8.3
Bord17bis	<i>Ovis</i>	L	17L	11-27		8B	11-27	V		≤11			C6+ (8-13 m)	8-11	5.4	7.6
Bord18	<i>Ovis</i>	R	15K/16L	9-22		7A	8-13	V		≤11			C6+ (8-13 m)	8-11	6.1	9
Bord18bis	<i>Ovis</i>	L				7A	8-13	C/V		≤11			C6+ (8-13 m)	8-11		
Bord19	<i>Ovis</i>	R	16L/17L	10-27		6A	8-11	V		≤11			C6+ (8-13 m)	8-11	6.3	9.5
Bord19bis	<i>Ovis</i>	L	16L/17L	10-27		7A	8-13	E		8-13			C6+ (8-13 m)	8-13	5.4	7.6
Bord20	<i>Ovis</i>	R	17L	11-27		7A	8-13	E		8-13			C6+ (8-13 m)	8-13	4.8	8.7
Bord20bis	<i>Ovis</i>	L	14L/15K	6-21		7A	8-13						C6+ (8-13 m)	8-13	7	9.6
Bord21	<i>Ovis</i>	R	15K	9-21		7A	8-13						C6+ (8-13 m)	8-13	6.5	9.7
Bord21bis	<i>Ovis</i>	L	15K	9-21		7A	8-13						C6+ (8-13 m)	8-13	6.5	11.5

Bord22	<i>Ovis</i>	R	17L	11-27	7A	8-13					C6+ (8-13 m)	8-13	5.4	9	
Bord22bis	<i>Ovis</i>	L	16L	10-22	7A	8-13					C6+ (8-13 m)	8-13	5.8	8.1	
Bord23	<i>Ovis</i>	R	16L	10-22	7A	8-13					C6+ (8-13 m)	8-13	7	9.1	
Bord23bis	<i>Ovis</i>	L	17L	11-27	7A	8-13	E	8-13			C6+ (8-13 m)	8-13	6.3	8.6	
Bord24	<i>Ovis</i>	R	15K	9-21	7A	8-13					C6+ (8-13 m)	8-13			
Bord25	<i>Ovis</i>	R	16L	10-22	7A	8-13	E	8-13			C6+ (8-13 m)	8-13	7.5	11.8	
Bord26bis	<i>Ovis</i>	L	17L	11-27	8A	11-27	(E)	8-13			C6+ (8-13 m)	8-13	4.4	5.7	
Bord27	<i>Ovis</i>	R	16L	10-22	8A	11-27	V-E	≤11			C6+ (8-13 m)	8-11	8	12	
Bord27bis	<i>Ovis</i>	L	15K	9-21	8A	11-27	V-E	≤11			C6+ (8-13 m)	8-11	6.5	9.7	
Bord28	<i>Ovis</i>	R	16L	10-22	7A	8-13	E-	8-13			C6+ (8-13 m)	8-13	6.2	9.2	
Bord28bis	<i>Ovis</i>	L	17L	11-27	8A	11-27	E-	8-13			C6+ (8-13 m)	8-13	5.5	8.7	
Bord29	<i>Ovis</i>	R	17L	11-27	8A	11-27	E	8-13			C6+ (8-13 m)	8-13	6.1	9.8	
Bord29bis	<i>Ovis</i>	L	16L	10-22	8A	11-27	E	8-13			C6+ (8-13 m)	8-13	5.7	7.5	
Bord30	<i>Ovis</i>	R	17L	11-27	8A	11-27	V-E	≤11			C6+ (8-13 m)	8-11	6	10	
Bord30bis	<i>Ovis</i>	L	17L	11-27	8A	11-27	E	8-13			C6+ (8-13 m)	8-13	5.6	9	
Bord31	<i>Ovis</i>	R	16L/17L	10-27	8A-9A	11-66	E	8-13			C6+ (8-13 m)	8-13	6.1	8.1	
Bord31bis	<i>Ovis</i>	L	16L/17L	10-27	8A	11-27	E	8-13			C6+ (8-13 m)	8-13	5.8	8	
Bord32bis	<i>Ovis</i>	L	17L	11-27	9A	11-78	E	8-13			C6+ (8-13 m)	8-13	4.8	6.6	
Bord33bis	<i>Ovis</i>	L	17L	11-27	8A	11-27	≥E	8-13			C6+ (8-13 m)	8-13	5.3	8	
Bord39bis	<i>Ovis</i>	L	18L	11-30	9A	11-78	U	2A	10-14		D1/2 (10-14 m)	10-14	4		
Bord41	<i>Ovis</i>	R	22L	14-30	8A	11-27		2A	10-14		D1/2 (10-14 m)	10-14	3.6	5.5	
Bord41bis	<i>Ovis</i>	L	22L	14-30	8A	11-27		2A	10-14		D1/2 (10-14 m)	10-14	3.4	5.4	
Bord42	<i>Ovis</i>	R	16L/17L	10-27	9A	11-78		2A	10-14		D1/2 (10-14 m)	10-14	4.6	5.5	
Bord3	<i>Capra</i>	R	13L	2-7	E-	2.5-4.5					age class B	2.5-4.5	7.3	10.7	
Bord8	<i>Capra</i>	R	15K	3-20	U	4A	4.5-7.5				age class C	4.5-7.5	8	10.6	
Bord40	<i>Capra</i>	L	22L	12-25		9A	13-50	≤2A	10.5-18		age class D	13-18	2.4	4.8	
Hva18	<i>Capra</i>	R	15K	3-20	4A-5A	4.5-12					age class C	4.5-12	7.2	10.3	
Hva64bis	<i>Capra</i>	L	21M	12-25	9A	13-50		4A	12-20	C	≤29	age class D	13-20	4.8	5.5
Hva64	<i>Capra</i>	R	21M	12-25	9A	13-50		4A	12-20	≤C	≤29	age class D	13-20	4.8	5.3
Bord9	<i>Capra</i>	R	15K	3-20	5A	5-12					age class C	5-12	7.6	10	
Bord9bis	<i>Capra</i>	L	16L	3.5-20	5A	5-12					age class C	5-12	5.9	7.4	
Bord2	<i>Ovis</i>	R	10N	3-7							B/C1/2 (1-7 m)	1-7	11	15.5	

Table 4. Raw data for month of death distributions for sheep/goats from Hârşova tell and Borduşani-Popină. Values (average and standard deviation, 1σ) obtained after 1000 random runs for each of the hemimandibles (N=60 and N=50), for each hypothesis. See the text (4.1.) for explanation of the methodology. A: hypothesis A (birth period: February-March-April); B: hypothesis B (birth period: March-April-May).

Site	N	Hyp.	March	April	May	June	July	August	September	October	November	December	January	February
Hârşova	60	A	4.16 (± 1.89)	2.84 (± 1.45)	1.51 (± 1.11)	1.11 (± 0.98)	1.67 (± 1.13)	2.04 (± 1.22)	1.95 (± 1.22)	5.47 (± 2.22)	8.83 (± 2.66)	12.82 (± 3.07)	9.92 (± 2.85)	7.67 (± 2.54)
Borduşani	50	A	3.85 (± 1.71)	2.48 (± 1.48)	1.38 (± 1.10)	1.64 (± 1.10)	1.73 (± 1.16)	1.82 (± 1.21)	1.69 (± 1.20)	4.46 (± 1.94)	6.79 (± 2.42)	9.45 (± 2.69)	7.99 (± 2.51)	6.74 (± 2.40)
Hârşova	60	B	7.80 (± 2.43)	4.31 (± 1.86)	2.88 (± 1.54)	1.46 (± 1.10)	1.12 (± 0.94)	1.65 (± 1.16)	2.05 (± 1.25)	1.99 (± 1.27)	5.42 (± 2.10)	8.75 (± 2.75)	12.52 (± 2.95)	10.05 (± 2.78)
Borduşani	50	B	6.67 (± 2.34)	4.03 (± 1.87)	2.44 (± 1.48)	1.48 (± 1.06)	1.61 (± 1.12)	1.77 (± 1.18)	1.78 (± 1.25)	1.69 (± 1.22)	4.25 (± 1.92)	6.67 (± 2.36)	9.61 (± 2.75)	8.00 (± 2.53)

Table 5. Regression models and theoretical formulae used for examining the relationship between dP4 crown height and age estimate in sheep/goats. For each model, the values (for parameters, R^2 and mean absolute error) are the averages ($\pm 1\sigma$) after 1000 random runs. aCH: anterior crown height; pCH: posterior crown height; CHo: unworn crown height; AGEs: age at which the dP4 is shed; O: Ovis. See the text (4.1.5.) for explanation of the methodology.

Nonlinear regressions	Crown		Solver constraints	p	Intercept	CHo	CHmin	R^2	Mean absolute error (mths)	95% interval (mths)	Under-/over-estimation of age
	height	N									
Natural logarithm function	aCH	110	13.5≤CHo≤15; CHmin≥0	10.436 (±0.128)	/	15 (-0)	0 (+0)	0.412 (±0.063)	1.656 (±1.279)	-3.984-4.355	53%/47%
Age=-pLn((CH-CHmin)/(CHo-CHmin))	aCH	110	CH=0⇒Age=33; CHo≤15	11.614 (±0.200)	/	15 (-0)	-0.930 (±0.048)	0.442 (±0.058)	1.614 (±1.247)	-3.968-4.181	51%/49%
	aCH	110	CH=0⇒Age=25.5; CHo≤15	13.920 (±0.352)	/	15 (-0)	-2.860 (±0.158)	0.473 (±0.051)	1.565 (±1.220)	-3.925-4.008	50%/50%
	aCH	110	CH=0⇒22≤Age≤33; CHo≤15	17.536 (±0.746)	22 (+0)	14.980 (±0.089)	-5.978 (±0.429)	0.492 (±0.046)	1.530 (±1.205)	-3.889-3.900	49%/51%
	aCH	99 (O)	CH=0⇒Age=25.5; CHo≤15	14.048 (±0.366)	/	15 (-0)	-2.918 (±0.165)	0.457 (±0.067)	1.432 (±1.058)	-3.499-3.620	50%/50%
	pCH	108	16.7≤CHo≤18; CHmin≥0	13.426 (±0.172)	/	18 (-0)	0 (+0)	0.119 (±0.110)	1.994 (±1.456)	-4.357-5.328	61%/39%
	pCH	108	CH=16.7⇒2≤Age≤4	9.403 (±1.131)	/	29.314 (±3.065)	-2.062 (±0.521)	0.437 (±0.047)	1.566 (±1.210)	-3.960-3.956	51%/49%
Theoretical formulae											
(Klein et al. 1983; Klein & Cruz-Uribe 1983)	Crown		Solver constraints	AGEs	CHo	R^2	Mean absolute error (mths)	95% interval (mths)	Under-/over-estimation of age		
	height	N									
Linear formula	aCH	99 (O)	AGEs=25.5; 13.5≤CHo≤15	/	13.5 (+0)	-2.391 (±0.360)	3.980 (±1.978)	-8.023-0.123	2%/98%		
Age=AGEs-(AGEs/CHo)*CH	aCH	99 (O)	22≤AGEs≤33; 13.5≤CHo≤15	22 (+0)	13.5 (+0)	-0.349 (±0.164)	2.350 (±1.529)	-5.775-1.514	13%/87%		
Quadratic formula (QCHM)	aCH	99 (O)	AGEs=25.5; 13.5≤CHo≤15	/	15 (-0)	0.179 (±0.106)	1.758 (±1.302)	-3.277-4.872	65%/35%		
Age=AGEs((CH-CHo)/CHo) ²	aCH	99 (O)	22≤AGEs≤33; 13.5≤CHo≤15	26.724 (±0.336)	15 (-0)	0.213 (±0.107)	1.720 (±1.276)	-3.823-4.601	58%/42%		
Or Age=AGEs-2AGEs (CH/CHo)+AGEs(CH ² /CHo ²)											

Table 6. Spawning periods of the fish species identified at Hârșova tell and Borduşani-Popină. NISP: number of identified specimens. The last column indicates the requisite temperature for spawning. * identifies Cyprinids.

Taxa	Hârsova NISP	Bordusani NISP	Febr.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Temp. (°C)
Pike, <i>Esox lucius</i>	9001	698	■	■									6-8
Sturgeons, <i>Acipenseridae</i>	884	150		■	■	■	■			■	■	■	13
Orfe, <i>Leuciscus idus</i> *	78	2		■	■	■	■						7-8
Perch, <i>Perca fluviatilis</i>	1350	29		■	■	■	■						7-8
Asp, <i>Aspius aspius</i> *	102	13		■	■	■	■						6-10
Pikeperch, <i>Sander lucioperca</i>	9305	267		■	■	■	■						10
Ruffe, <i>Gymnocephalus (Acerina) sp.</i>	1447			■	■	■	■						12-18
Danube shad, <i>Alosa pontica</i>	2			■	■	■	■						9-13
Knife/Ziege, <i>Pelecus cultratus</i> *	166			■	■	■	■						12
Roach, <i>Rutilus rutilus</i> *	1680	11		■	■	■	■						12-14
Crucian carp, <i>Carassius carassius</i> *	2			■	■	■	■						16-20
Wels catfish, <i>Silurus glanis</i>	6888	1556		■	■	■	■						18-20
Bream, <i>Abramis brama</i> *	1868	32		■	■	■	■						18
Rudd, <i>Scardinius erythrophthalmus</i> *	421	1		■	■	■	■						18
Tench, <i>Tinca tinca</i> *	47	3		■	■	■	■						19-20
White bream, <i>Blicca bjoerkna</i> *	491	9		■	■	■	■						16-25
Common carp, <i>Cyprinus carpio</i> *	6448	1827		■	■	■	■						13-16
Bleak, <i>Alburnus alburnus</i> *	14			■	■	■	■	■					15-16
Cyprinids, <i>Cyprinidae</i>	77843	1542		■	■	■	■	■	■				/

Table 7. Raw data for size distributions for the common carp (*Cyprinus carpio*) and pikeperch (*Sander lucioperca*) from Hârşova tell and Borduşani-Popină. TL: total length. See the text (4.2.) for explanation of the methodology.

Pikeperch TL (mm)	0-150	150-200	200-250	250-300	300-350	350-400	400-450	450-500	500-550	550-600	600-650	650-700	700-750	750-800	800-850	>850	N
Hârşova tell	0	2	16	28	37	26	32	41	37	39	31	18	10	6	2	4	329
Borduşani-P.	0	0	0	0	0	1	2	3	6	3	2	0	1	1	2	1	22

Common carp TL (mm)	0-100	100-200	200-300	300-400	400-500	500-600	600-700	700-800	800-900	900-1000	1000-1100	1100-1200	1200-1300	N
Hârşova tell	4	26	11	32	61	90	87	40	33	22	7	8	1	422
Borduşani-P.	9	30	50	15	3	7	10	4	8	3	5	0	0	144

Supplementary Material 1. Pairwise comparisons between estimated means obtained for month of death distributions for sheep/goats (raw data in Table 4) using paired *t*-test; p-value adjustment method: Bonferroni. A: hypothesis A; B: hypothesis B. Grey cells indicate no significant difference.

Hârsova-A	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan.
April	5.81E-50										
May	1.33E-180	2.04E-85									
June	3.75E-244	2.22E-141	1.05E-12								
July	4.58E-179	1.18E-73	0.089	1.25E-24							
August	1.46E-136	8.83E-36	8.96E-21	2.50E-57	3.03E-08						
September	5.67E-148	5.12E-44	7.45E-15	3.04E-49	0.000111	1					
October	3.92E-38	1.15E-143	1.13E-269	1.78E-304	7.14E-252	5.04E-214	2.38E-212				
November	6.74E-237	0	0	0	0	0	0	3.48E-126			
December	0	0	0	0	0	0	0	2.15E-316	2.16E-121		
January	2.96E-273	0	0	0	0	0	0	1.20E-184	6.89E-13	2.14E-68	
February	1.72E-154	5.09E-268	0	0	0	0	0	1.89E-74	7.29E-18	4.77E-181	3.86E-56

Bordusani-A	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan.
April	6.39E-61										
May	2.02E-193	1.50E-61									
June	5.66E-166	1.40E-38	6.46E-05								
July	4.50E-153	1.86E-30	9.32E-09	1							
August	3.77E-147	1.04E-22	2.88E-14	0.1271	1						
September	2.13E-159	9.50E-34	4.91E-07	1	1	1					
October	6.44E-11	7.52E-109	2.48E-236	1.14E-207	7.51E-189	2.98E-170	1.18E-186				
November	1.07E-139	3.43E-250	0	0	0	1.94e-313	3.18e-315	2.08E-85			
December	2.09E-295	0	0	0	0	0	0	1.79E-240	1.36E-75		
January	3.95E-211	7.97E-318	0	0	0	0	0	7.55E-158	1.96E-20	5.60E-25	
February	2.93E-126	1.99E-248	0	0	0	1.68e-316	0	1.11E-86	1	1.34E-81	7.12E-22

Supplementary Material 1. *Continued*

Hârsova-B	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
May	2.32E-52										
June	7.30E-210	5.52E-87									
July	4.83E-261	3.72E-141	4.52E-11								
August	3.89E-196	2.01E-76	0.0465	2.29E-21							
September	2.38E-155	5.52E-36	1.38E-22	2.49E-57	6.59E-09						
October	1.93E-150	7.12E-40	1.64E-19	1.23E-55	4.92E-07	1					
November	4.95E-30	3.16E-141	8.92E-287	4.82e-319	1.36E-259	2.47E-231	5.12E-219				
December	6.49E-215	0	0	0	0	0	0	9.07E-126			
January	0	0	0	0	0	0	0	9.40e-316	8.45E-111		
February	1.77E-289	0	0	0	0	0	0	2.80E-205	2.78E-18	1.15E-54	
March	4.01E-167	3.64E-282	0	0	0	0	0	2.28E-90	1.42E-11	3.41E-180	1.36E-57

Bordusani-B	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
May	3.60E-72										
June	4.28E-179	2.04E-52									
July	6.45E-177	2.62E-37	0.8000								
August	5.07E-157	8.36E-25	6.67E-06	0.3652							
September	5.15E-150	1.24E-23	1.32E-06	0.2597	1						
October	6.76E-160	7.45E-33	0.0042	1	1	1					
November	0.6573	1.06E-94	3.20E-210	1.02E-186	4.00E-170	4.48E-160	7.67E-166				
December	1.53E-115	7.25E-254	0	0	0	5.03e-312	3.91e-321	1.64E-96			
January	3.07E-271	0	0	0	0	0	0	1.74E-253	4.34E-91		
February	3.24E-188	3.28e-317	0	0	0	0	0	5.31E-172	1.70E-25	5.24E-29	
March	8.74E-112	3.94E-245	0	0	0	7.17e-320	0	7.85E-98	1	4.43E-92	4.87E-26

Figure captions

Figure 1. Location of the two Eneolithic sites included in the study.

Figure 2. Month of death distributions for sheep/goats from Hârşova tell and Borduşani-Popină. Values (average and standard deviation, 1σ) obtained after 1000 random runs for each of the hemimandibles (N=60 and N=50), for each hypothesis. A: hypothesis A (birth period: February-March-April); B: hypothesis B (birth period: March-April-May). Grey areas indicate summer and winter. Months overlapping the two groups identified (see the text) are underlined. See the text (4.1.) for explanation of the methodology and Table 4 for raw data.

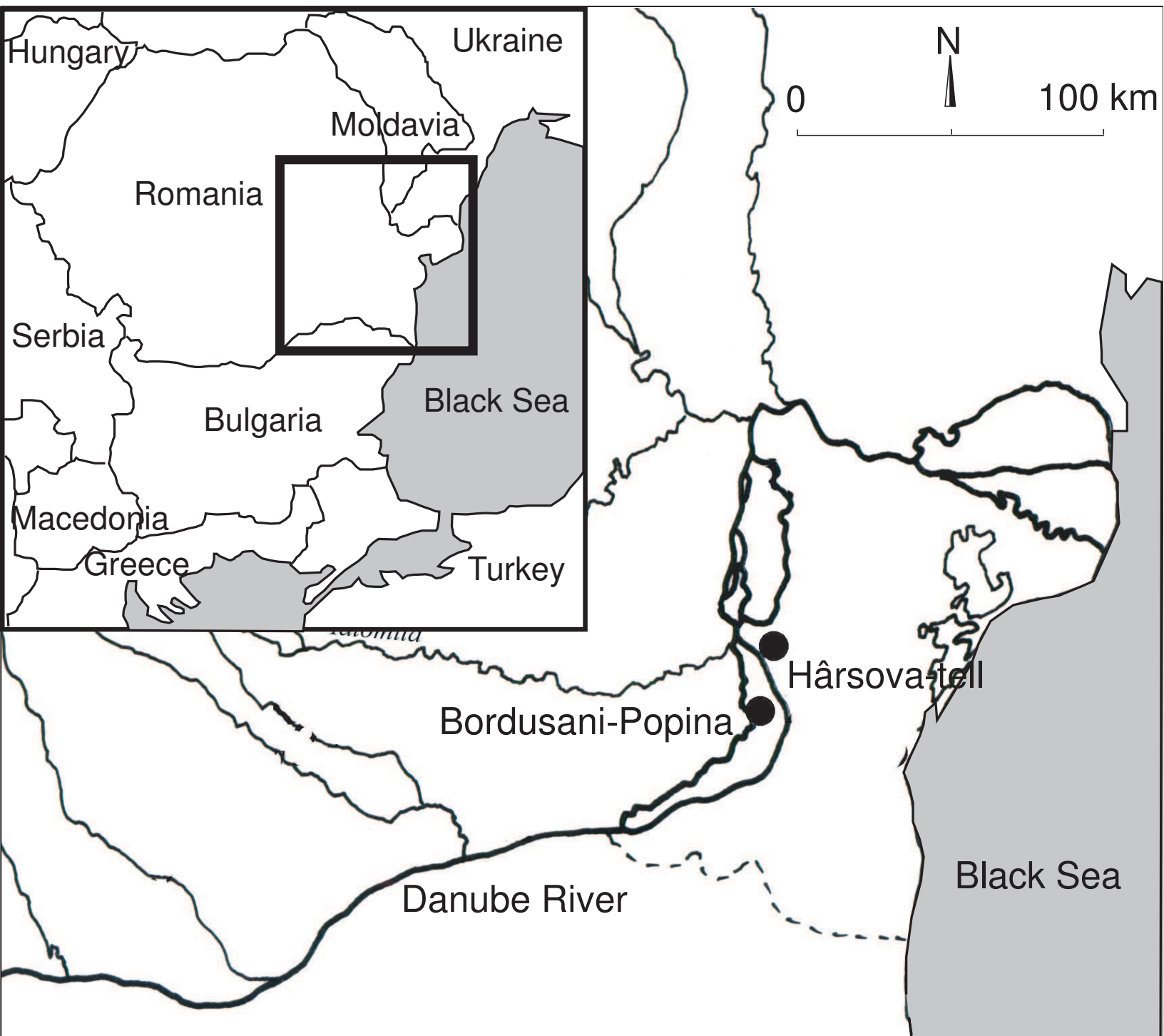
Figure 3. Month of death distributions for three archaeological structures/unit from Hârşova tell. Percentages are calculated from values obtained after 1000 random runs for each of the eleven hemimandibles, hypothesis B (birth period: March-April-May). The curve shows the percentages for the whole site. See the text (4.1.) for explanation of the methodology.

Figure 4. Month of death distributions for goats from Hârşova tell and Borduşani-Popină. Percentages are calculated from values obtained after 1000 random runs for each of the six hemimandibles, hypothesis B (birth period: March-April-May). Hva: Hârşova tell; Bord: Borduşani-Popină. The curves show the percentages for the whole assemblages. See the text (4.1.) for explanation of the methodology.

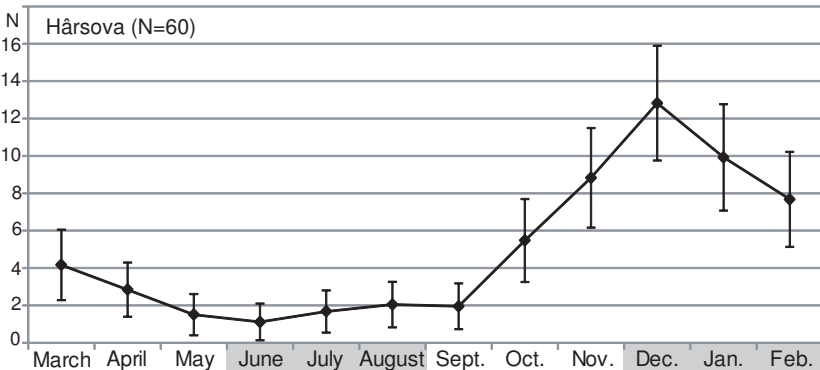
Figure 5. Sheep/goat dP4 crown heights (aCH) plotted against age estimates (data from Hârşova tell and Borduşani-Popină). Sheep: 99 hemimandibles (in black); goats: 11 hemimandibles (in grey). Fifteen supplementary hemimandibles of sheep are plotted (dotted lines) but they are not included in the calculations. B: same plot with fitting curves 1 and 3 (natural logarithm function; Table 5). See the text (4.1.5.) for explanation of the methodology and Table 3 for raw data.

Figure 6. Same plot than in Figure 5A, with age estimates based on the theoretical formulae from Klein et al. (1983). Linear and quadratic formulae are calculated for sheep (Table 5). The fitting curve (natural logarithm function) is calculated from sheep remains only (Table 5). All intercepts are at 25.5 months. See the text (4.1.5.) for explanation of the methodology.

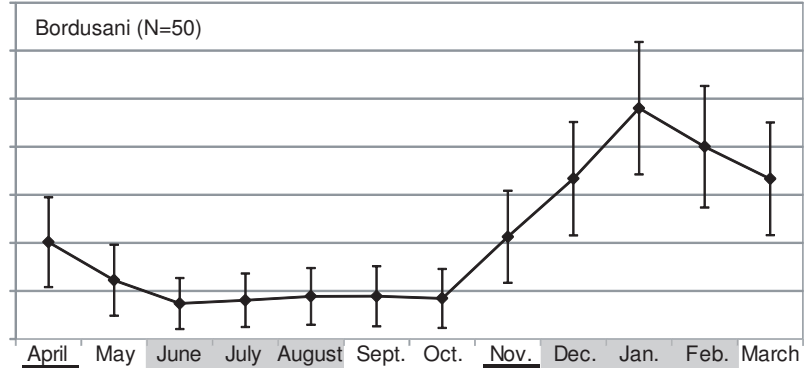
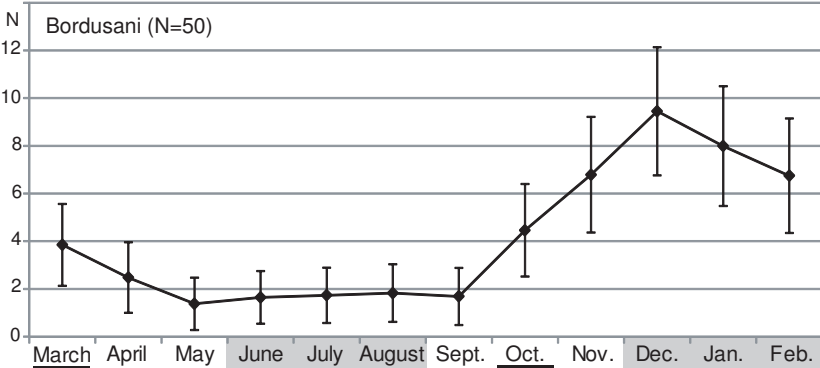
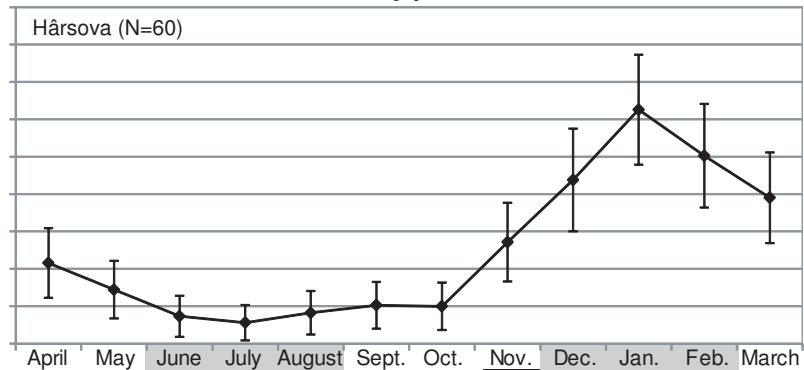
Figure 7. Size distributions for the common carp (*Cyprinus carpio*) and pikeperch (*Sander lucioperca*) from Hârşova tell and Borduşani-Popină. TL: total length. Arrows indicate averages. Grey areas indicate the limits for sexually mature fish (see the text). See the text (4.2.) for explanation of the methodology.

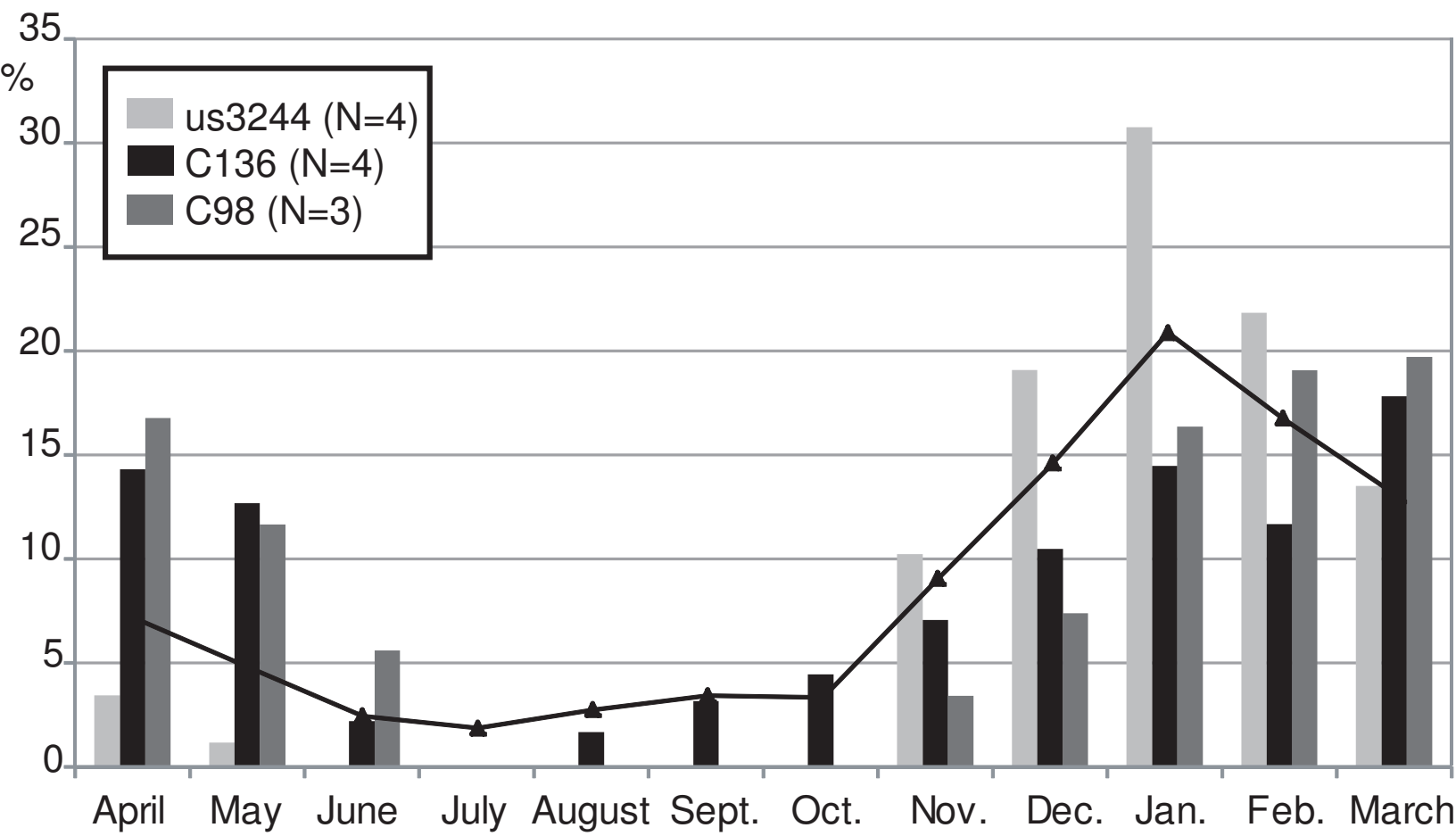


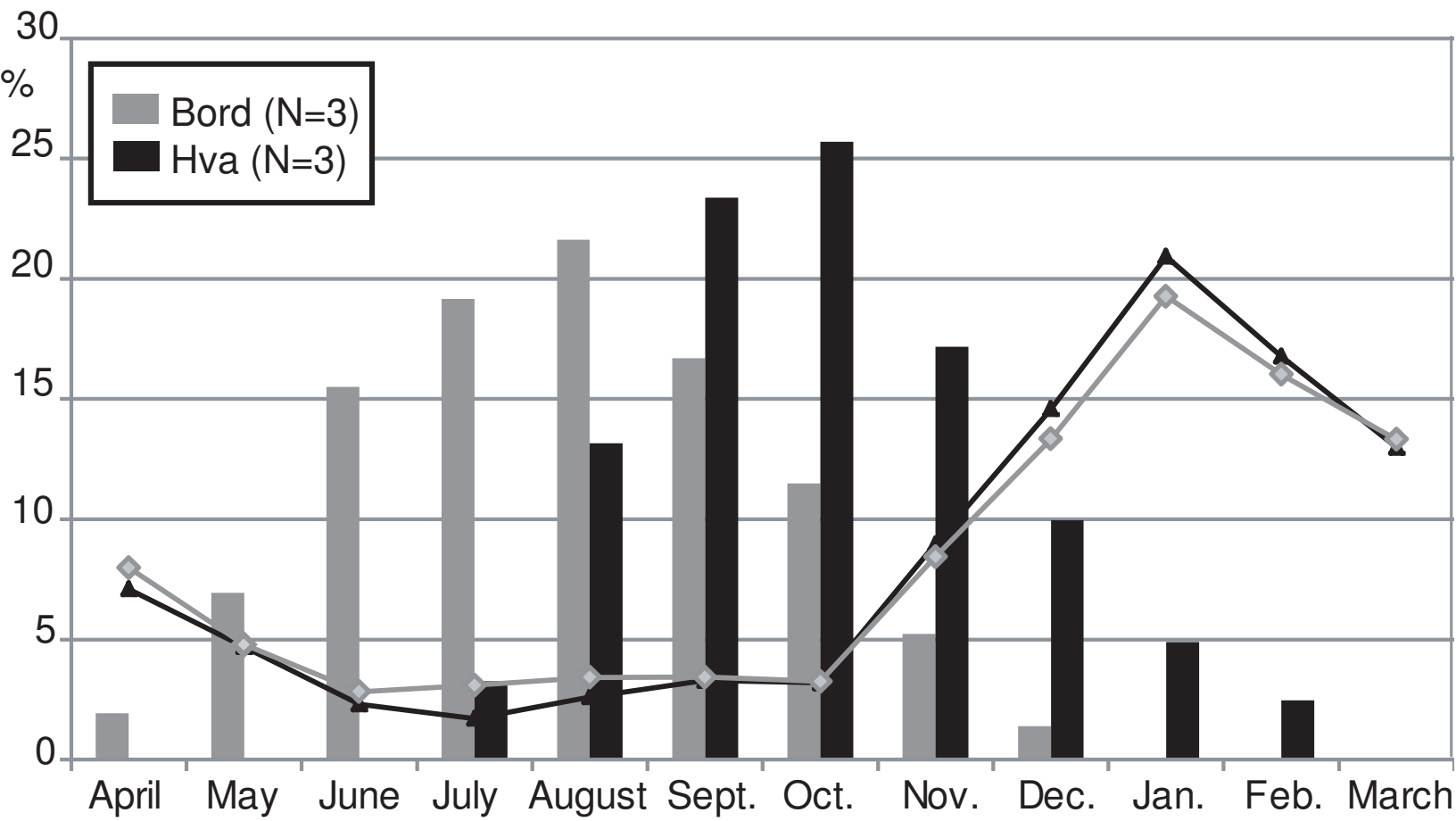
Hyp. A



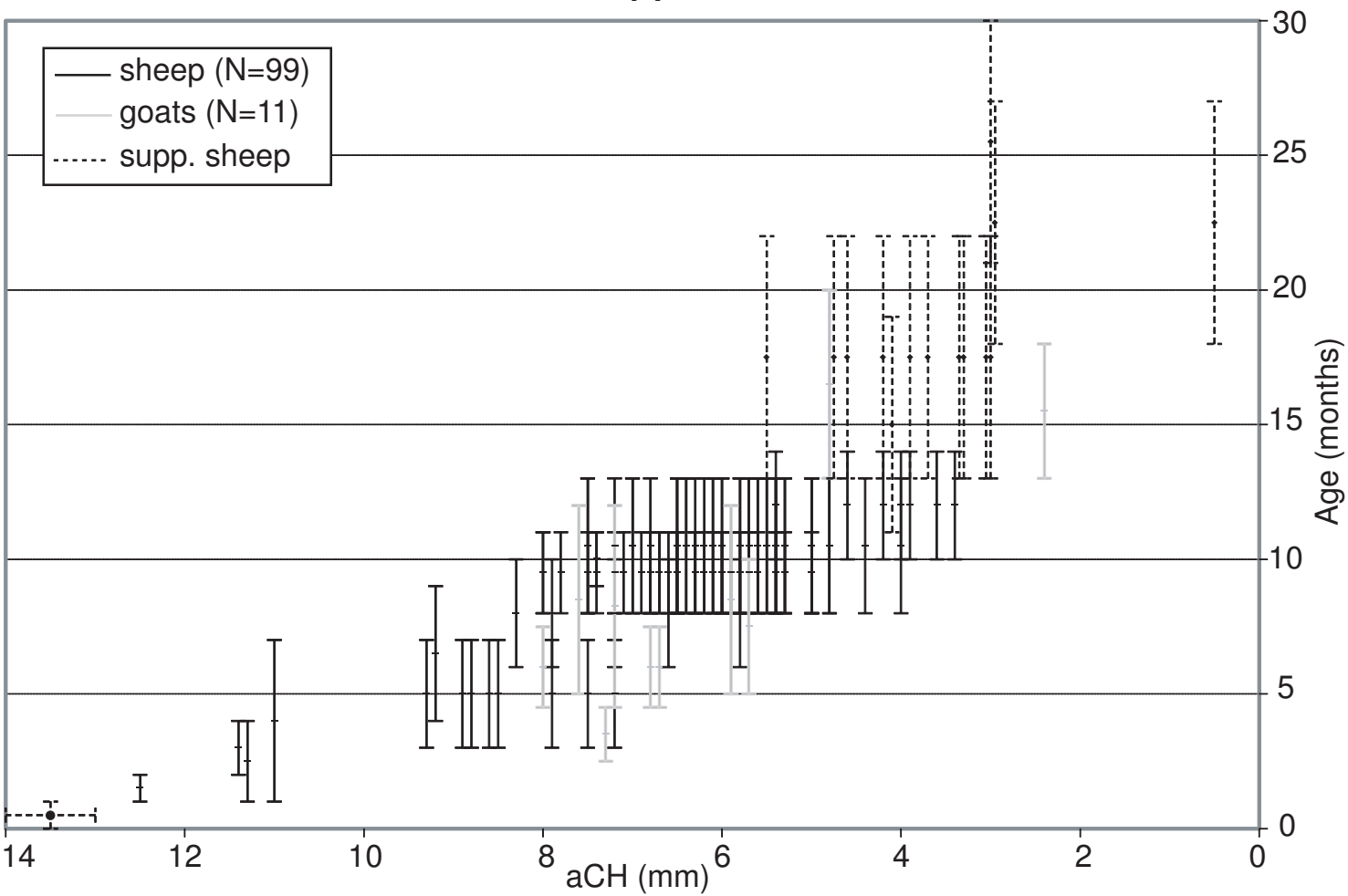
Hyp. B



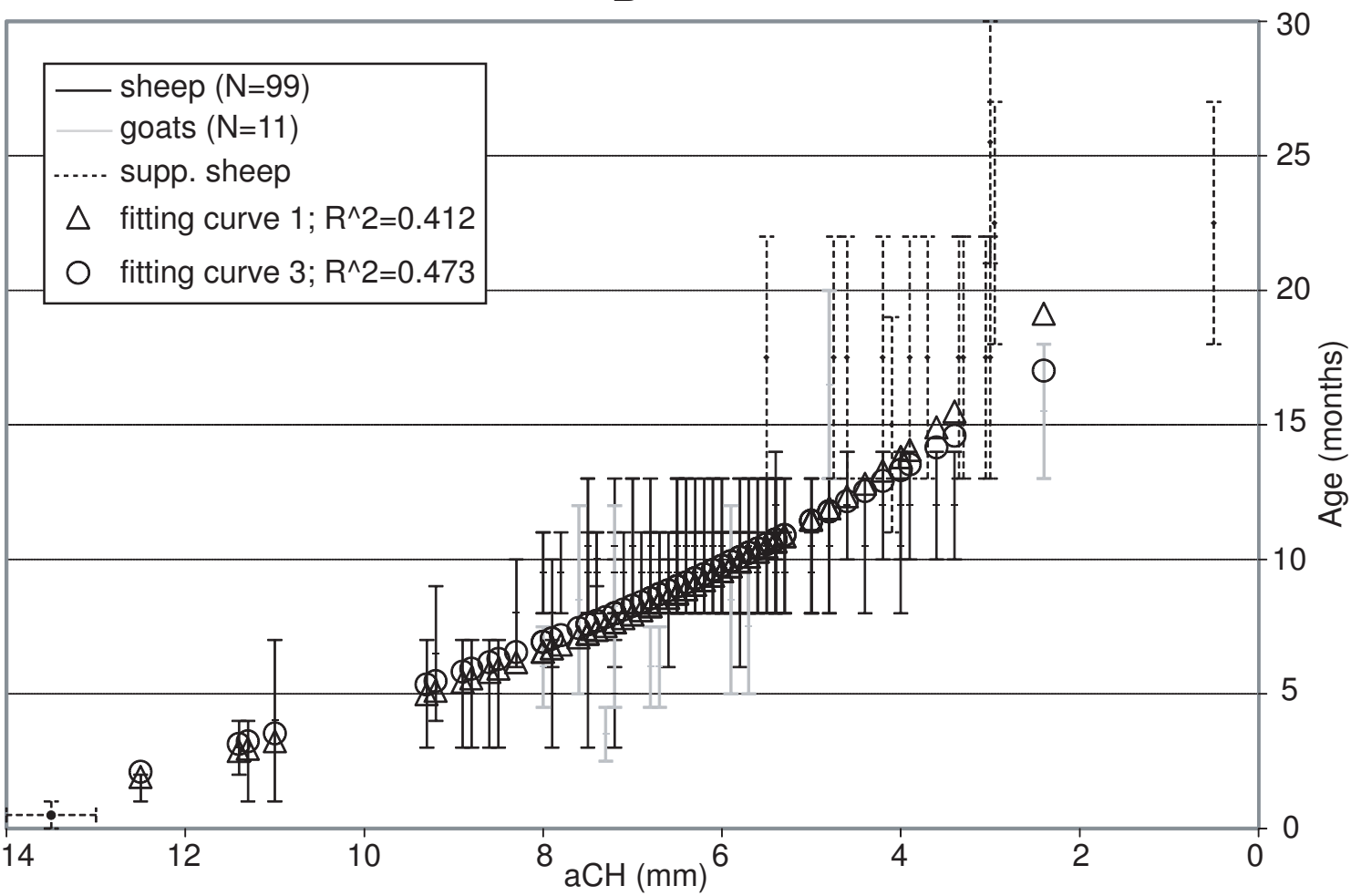


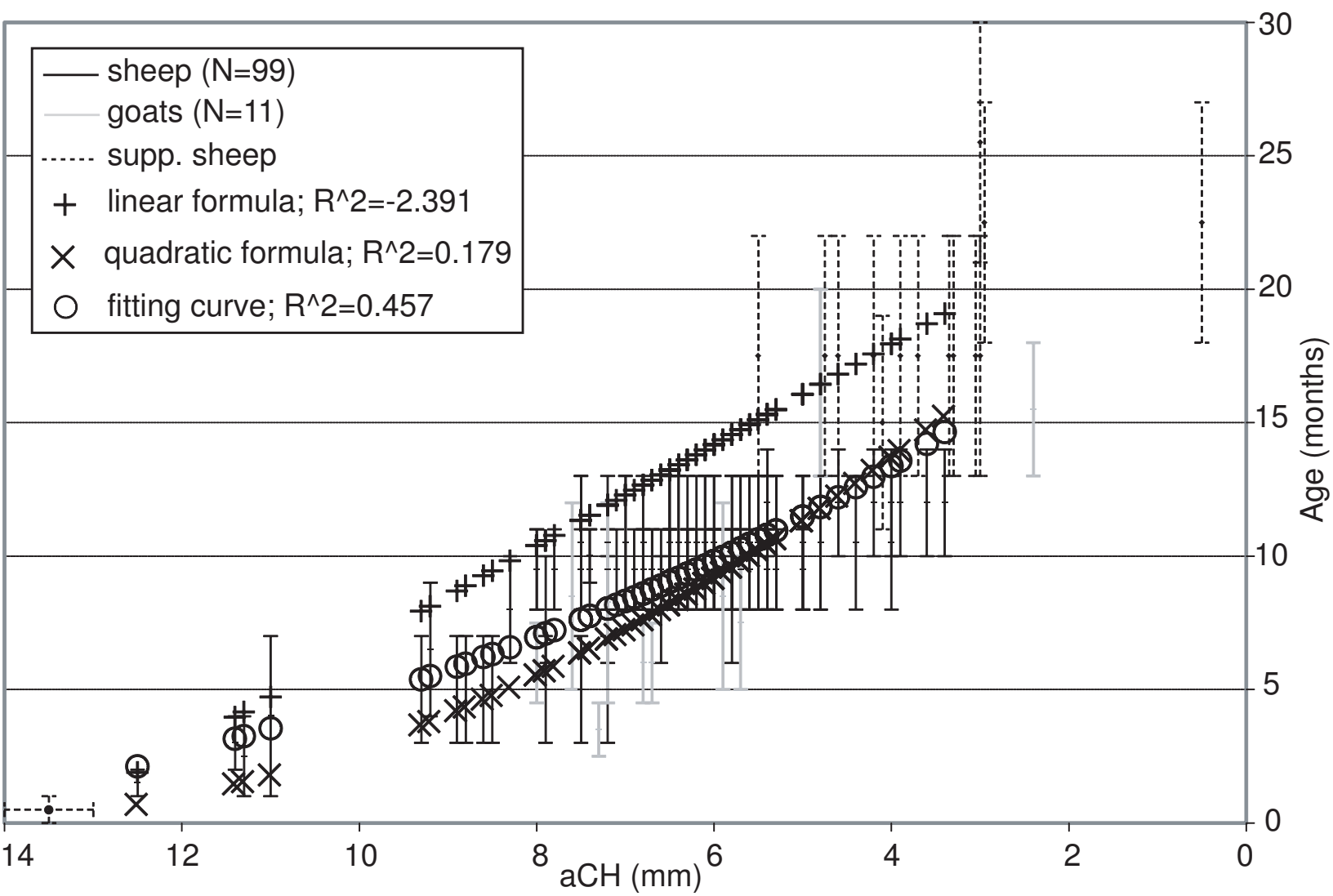


A

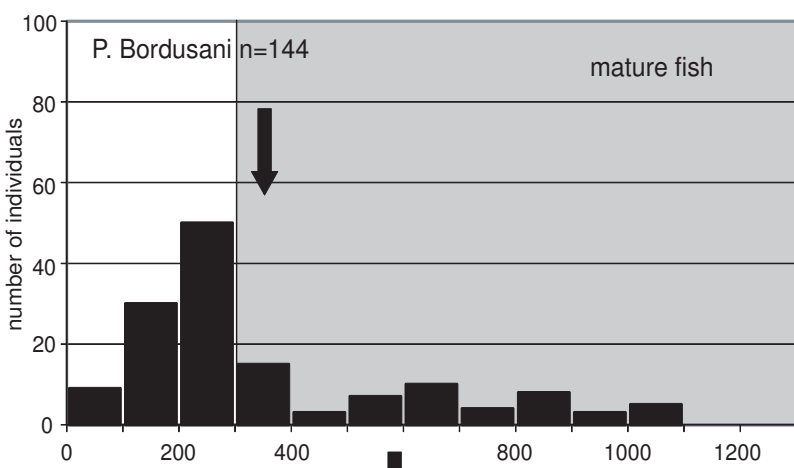


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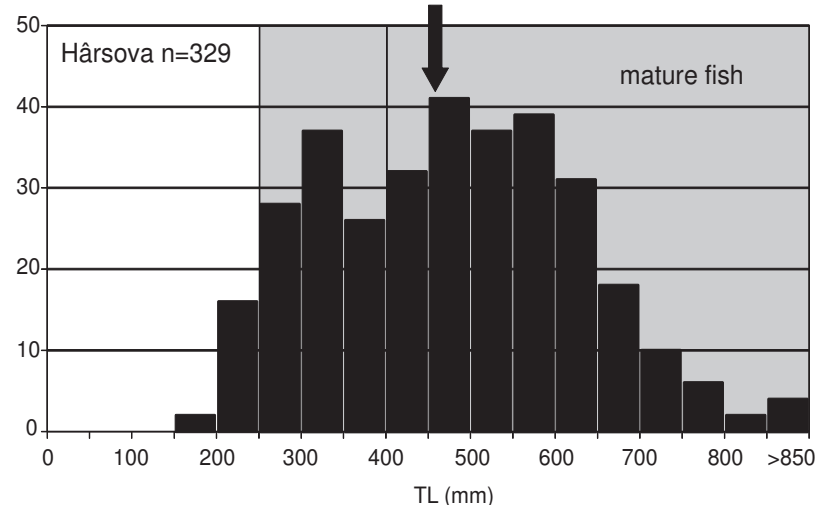
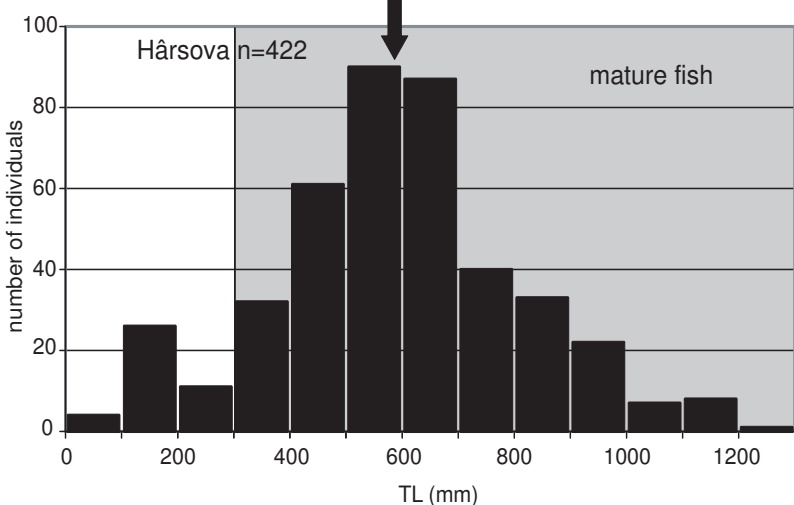
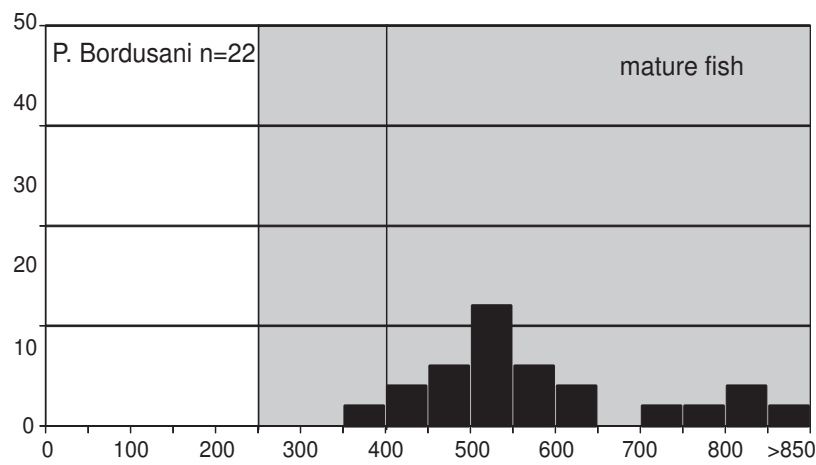




Common carp



Pikeperch



BIOGRAPHICAL NOTES

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Adrian Bălăşescu is a zooarchaeologist at the National Museum of Romanian History, Bucharest. He participated in various research teams at numerous archaeological excavations (in Romania, France and Armenia) being responsible mainly for the zooarchaeological investigation. His background is in Balkan prehistory and he also has research interests in Armenia Neolithic and Chalcolithic zooarchaeology.

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