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Pigs and humans in Early Neolithic Southeastern Europe: new zooarchaeological and stable isotopic data from late 7th to early 6th millennium BC Džuljunica-Smărdeš, Bulgaria

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ABSTRACT – *The Bulgarian site at Džuljunica-Smărdeš, dating to 6205–5529 cal BC, is one of the oldest Neolithic sites in Europe. Both domestic cattle and caprines are present in the zooarchaeological assemblage, but suids, in contrast, are extremely rare. It is not known if the earliest Neolithic people in Europe reared domestic pigs, practised some form of pig management, or only hunted wild boar. This research investigates human-pig relationships, using biometry, kill-off patterns and isotopic dietary analysis. With this integrated methodological approach, it might be possible to characterise human-pig relationships in this pivotal Early Neolithic site with greater accuracy. Understanding this relationship at this site contributes to the broader debate on how Neolithisation and domesticates spread through Europe, and which bio-cultural mechanisms were responsible for differential patterns of animal exploitation.*

KEY WORDS – *Neolithic; Bulgaria; zooarchaeology; pig domestication; stable isotopic analysis*

Prašiči in ljudje v času zgodnjega neolitka v jugovzhodni Evropi: novi arheozoološki podatki in analize stabilnih izotopov iz najdišča Džuljunica-Smărdeš v Bolgariji v času poznega 7. do zgodnjega 6. tisočletja pr.n.št.

IZVLEČEK – *Bolgarsko najdišče Džuljunica-Smărdeš, datirano v čas med 6205 in 5529 pr.n.št., je eno najstarejših neolitskih najdišč v Evropi. V arheozoološkem zbiru najdišča prevladuje govedo in drobnica, prašiči pa so zelo redki. Ni znano, ali so ljudje v Evropu v času neolitika že vzrejali prašiče, se ukvarjali s kakšno obliko upravljanja s prašiči ali lovili le divje svinje. V članku raziskujemo odnos med ljudmi in prašiči s pomočjo biometrije, vzorcev starosti živali ob zakolu in analizo stabilnih izotopov. Z uporabo takšne integrirane metodologije lahko bolj natančno orišemo odnose med ljudmi in prašiči na tem ključnem zgodnje neolitskem najdišču. Razumevanje teh odnosov lahko prispeva k širši debati o načinu širjenja neolitizacije in domestikacije živali v Evropi in o tem, kateri biološko-kulturni mehanizmi so bili ključni za nastanek različnih vzorcev izkoriščanja živali.*

KLJUČNE BESEDE – *neolitik; Bolgarija; arheozoologija; udomačitev prašičev; analiza stabilnih izotopov*

Introduction

The Neolithic dispersed into Europe along two main routes, the southern Maritime Route and the northern Balkan Route (*Perlés 2005; Shennan 2018*). How animal husbandry spread in Europe is still subject to debate (*e.g., Reingruber* et al. *2017*). Recent meta-analyses show inter-regional variability in the relative abundance and composition of farm animals (sheep, goat, cattle and pigs) (*Arbuckle* et al. *2014; Ethier* et al. *2017; Ivanova* et al. *2018; Orton* et al. *2016*). Interpretations of this variability diverge along palaeoclimatic, geographic, and cultural lines. *Sus* (pig and/or boar) has assumed a special place in these interpretations, partly due to the challenges of understanding its domestication, as well as the chronological and regional patterns in its subsequent distribution. Current views hold that pigs were domesticated in Southwest Asia around 10 000 years ago; the domestic pig spread subsequently into Europe, where its maternal lineage was replaced fairly rapidly by the local pig lineage through interbreeding with local wild boar (*Sus scrofa*) (*Larson* et al. *2007; Ottoni* et al. *2013*). Although Early Neolithic layers in Bulgaria contain pig specimens carrying SW Asian and European maternal genes (mt-Y1 and mt-Y2 respectively) (*Geörg 2013*), the accompanying mechanisms of human-pig interactions in the Early Neolithic (late 7th millennium/early 6th millennium cal BC; in culture-historical terms pre-Karanova I and Karanova I) Bulgaria have not been scrutinised.

In this paper, we discuss the zooarchaeological and stable isotopic ($\delta^{13}C$ and $\delta^{15}N$) data from one of the earliest Neolithic pig assemblages north of the Balkan Mountains in Bulgaria, yielded during recent excavations in Džuljunica-Smărdeš (hereafter referred to as Džuljunica) (Fig. 1). We investigate the relative abundance, morphological characteristics, mortality patterns, and foraging ecology of pigs, and make inferences on the scale of human control over the pig population that the Džuljunica assemblage represents. We then compare our results with compatible data from Neolithic and Chalcolithic Turkey, Bulgaria, and Romania, and discuss the apparent trends in terms of the 'arrival of pigs' in Europe.

The site and its environment

Džuljunica is an Early Neolithic-Copper Age settlement located in eastern Bulgaria, north of the Balkan Mountains. The Neolithic settlement has been excavated by Nedko Elenski since 2005. Twenty-two test trenches have been excavated in the Neolithic
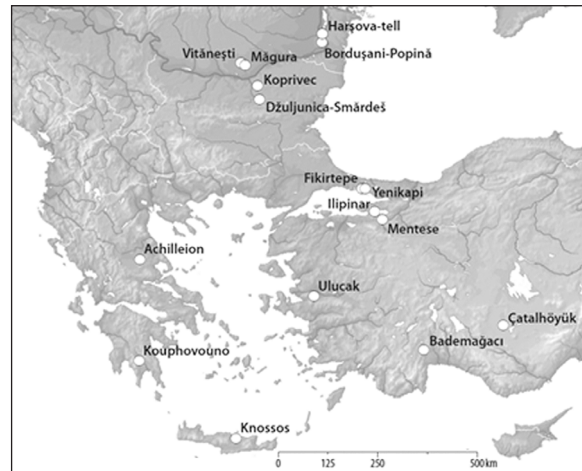

Fig. 1. Map of the sites mentioned in the text.

part of the settlement, revealing four layers, all of which have been radiocarbon dated (*Krauß* et al. *2014*) (Tab. 1). Today, the Yantra River, a tributary of the lower Danube flows 6.5km north of the site. However, some ancient watercourses suggest that the site may have been located closer to the Yantra (*Krauß* et al. *2014*). Oak is the most abundant wood species in the charcoal assemblage, but riparian species are frequent as well, indicating that the site was located at the border of riparian and oak forests (*Marinova, Ntinou 2017*).

It is clear that the inhabitants of Džuljunica were farmers, using pottery and relying on both domestic crops and animal husbandry (*Krauß* et al. *2014*). Charred seed assemblages are dominated by hulled barley. Einkorn, legumes, wild plum and hazel are also present (*Marinova, Krauß 2014*). Diachronic changes in cultivation, vegetation, and human-animal interactions at the site are subject to ongoing research.

Methods and material

So far, we have examined 6390 specimens in the hand-collected zooarchaeological assemblage of Džuljunica. In order to assess the frequency of interactions between humans and pigs, we calculated the

Layer	No. radiocarbon samples	Average range of cal BC age
I	12	6047–5930
II	7	6052–5880
III	1	6075–5920
IV	1	5670–5529

Tab. 1. The average of radiocarbon ages per layer (after **Marinova, Krauß 2014; Krauß** *et al.* **2014***).*

relative abundance of *Sus* in the assemblage. Since rough compatibility with regional and supra-regional datasets from the region is necessary to put our case study in regional context, we used the commonly applied NISP (= Number of Identified Specimens) counts to assess relative abundance.

To investigate size, as a proxy for the degree of interaction with humans and domestication status (*Albarella* et al. *2007; Evin* et al. *2015*), we used the Logarithmic Size Index (= LSI) method following Richard H. Meadow (*1999*). This is a logarithm of the ratio between a standard osteometric measurement and its counterpart in an animal (or animals) of known life history and size (*Meadow 1999*). This method makes it possible to compare different cranial and postcranial elements even if they are fragmented, thereby greatly increasing sample sizes. The standards for the LSI are those commonly used for assemblages of Neolithic Europe and the Near East, an Anatolian modern wild female boar for postcranial measurements (*Hongo, Meadow 2000*) and the mean of a modern Anatolian wild boar population described by Payne and Bull (*1988*) for the molars. Postcranial bones and teeth are analysed separately, since they can react differently, depending on environment, diet and management status (*Payne, Bull 1988*).

To understand kill-off patterns, we reconstructed mortality profiles based on the fusion of postcranial bones and dentition following Ximena Lemoine *et al.* (*2014*) and Melinda A. Zeder *et al.* (*2015*). To make inferences on suid diet and foraging environment, we used carbon and nitrogen stable isotopic analysis. We sampled all the suid specimens that were (logistically) available: a total of 20 specimens. Smaller samples were cut from the specimens, preserving diagnostic parts as much as possible. Most samples were taken from compact bone. Isotopic analysis was done at the University of Groningen CIO (= Centre for Isotope Research) lab, following their protocols (*Kuitems* et al. *2015*).

To avoid contamination, samples were first bathed in a HCL-solution for 20 minutes to two hours, then filtered through a 100μm filter, then rinsed with distilled water and soaked in NAOH solution to remove any humic acids, and then again filtered through a 50μm filter and rinsed with distilled water again. To remove any carbon which could have possibly reacted with the NAOH solution, the samples were rinsed with a HCL-solution once. After one more filtering and rinsing, boiled distilled water was added to the samples, and two drips of 46% HCL solution were poured in. All the samples were then put in an oven overnight. The solid material was filtered one final time over a 50μm filter, and the remaining liquid was put back into the oven for 18 hours. The solid collagen was sampled for analysis.

Some of the radiocarbon dating of the site was executed on animal bones. The $\delta^{13}C$ values have been published alongside the dates (*Krauß* et al. *2014*). The $\delta^{13}C$ values of the domestic specimens (cattle and sheep) will be used to compare with the suids. The $\delta^{15}N$ values are not available for comparison.

Results

Relative abundance
Suids make up a minor part of the zooarchaeological assemblage of Džuljunica (Tab. 2). However, their relative abundance increases slightly over time. Interestingly, the proportion of other species of large wild game (mainly cervids) seems to decrease simultaneously from Layer I to IV. Cattle become proportionally more abundant throughout the occupational layers.

Size
All postcranial measurements of Džuljunica suids are clearly larger than the modern Anatolian standard (Fig. 2). They are also larger than most suid assemblages from the 7th millennium BC Aegean, including Crete, but they compare well with the pre-6000 cal BC population from Çatalhöyük and the Marmara region (*e.g.*, Menteşe Basel, Fikirtepe (6800–6200 cal BC, unpublished data Çakırlar and Özdoğan), Ilıpınar X). In the later phases of Menteşe and Ilıpınar, suids are clearly smaller than those from Džuljunica.

NISP	Total	Artiodactyls	Cattle	%Cattle	Sheep&goat	%Sheep&goat	Sus	%Sus	Deer	%Deer
Layer I	1138	497	156	**31.4**	278	**55.9**	6	**1.2**	57	**11.5**
Layer I-II	80	23	10	43.4	11	47.8	0	0.0	2	8.7
Layer II	3432	995	324	**32.6**	592	**59.5**	27	**2.7**	52	**5.2**
Layer III	128	44	11	25	29	65.9	0	0.0	4	9.1
Layer IV	1362	559	266	**47.5**	258	**46.2**	17	**3**	18	**3.2**
Total	6140	2118	767		1168		50		133	

Tab. 2. The absolute and % NISP of cattle, sheep, goat, suid, and large game of Džuljunica.
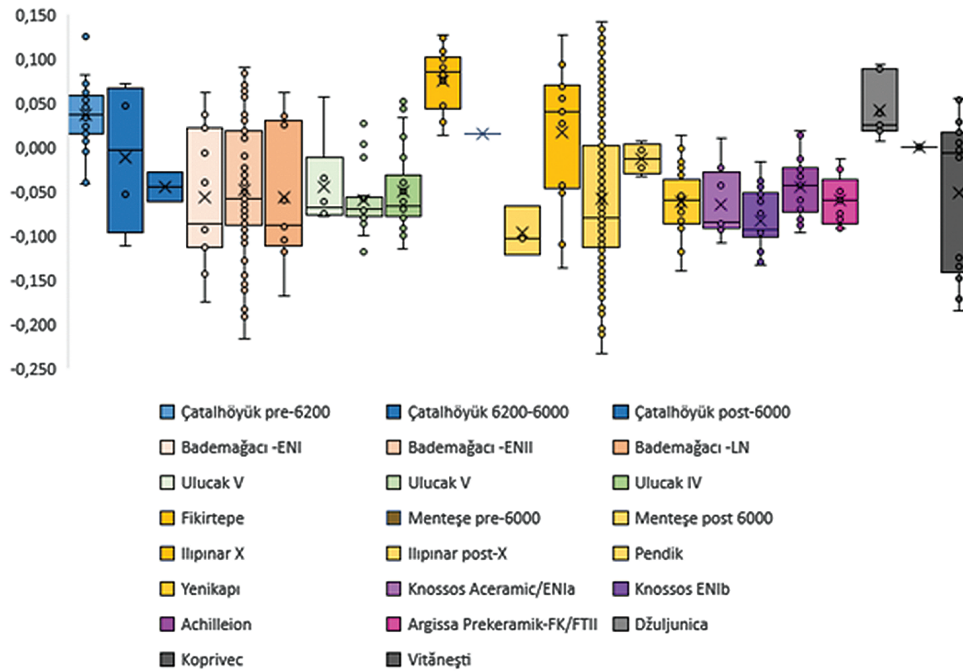
Fig. 2. Box-plot comparison of postcranial LSI's of suids from Neolithic Anatolia, Greece, Turkey, Bulgaria, and Chalcolithic Romania. Data from Arbuckle *et al.* 2014; Balasse 2016; Manhart 1998 *and this study. See Appendix for brief site descriptions.*

The overall large size and the skewed distribution of the postcranial index towards larger measurements at Džuljunica may indicate selection for males. At Fikirtepe, however, the specimens are even larger than at Džuljunica. The postcranial skeletons of the Džuljunica suids are also clearly larger than populations from later prehistoric sites in the Balkans. There is hardly any size overlap between Džuljunica and Chalcolithic (5th millennium BC) Vitănești in Romania, where both domesticated pigs and wild boar are thought to be present (*Balasse* et al. *2016*). Also, they are larger than the specimens from contemporary Greek Neolithic sites, in which most suids are thought to be domesticated.

The patterns for cranial (*i.e.* molar) measurements are slightly different than for the size index reconstructed from postcranial osteometry. The published data on cranial dimensions of the same period and region are limited. Džuljunica molars are smaller than the molars from Fikirtepe, for example. This is unexpected, because the postcranial bones from the specimens from Fikirtepe are not much larger than Džuljunica postcranial measurements. They overlap in

size with specimens from Bademağacı in southern Anatolia, which were interpreted as both wild and domestic (*De Cupere* et al. *2008*). The only measurement from Koprivec (Early Neolithic eastern Bulgaria) compares well with the molar measurements from Džuljunica.

Kill-off patterns

Fusion and dental ageing data suggest a wide range of age-at-death (Appendix Tabs. 2 and 3). Minor differences among occupational layers are present, but they are not significant. In Layer I, all specimens are adults. The specimens from Layer II are younger than the individuals in Layer I. Five specimens in Layer II
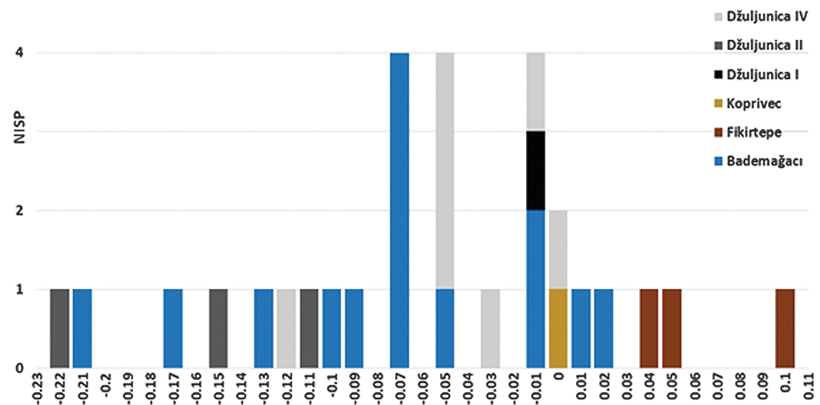

Fig. 3. LSI's based on the cranial measurement of the suids from Koprivec, Fikirtepe and Bademağacı compared to Džuljunica (data from Arbuckle *et al.* 2014; Manhart 1998 *and this study).*

represent individuals who died before 8 months of age. In the same layer, five other specimens are older than 24 months, two being older than 36 months and one even older than 96 months. In layer IV, no specimen younger than eight months was unearthed. The dental data show that the specimens were between 12–52 months when they died, one being between 18–30 months old. The fusion data from this layer also suggest that suids were slaughtered between 18 and 48 months.

Stable isotope ratios

Seventeen samples yielded collagen. All collagen samples display reliable C:N ratios (following *Ambrose 1990; Brock* et al. *2010*). Collagen yielded between 0.8 and 9.7% of the sampled bone weight (Appendix Tab. 4). One sample yielded only 0.8% collagen and was therefore discarded, since reliable samples must contain at least 1.0% (*Brock* et al. *2010*). The reported $\delta^{13}C$ and $\delta^{15}N$ values are averaged values based on duplicate analysis, measured as permille (‰), and calibrated respectively to VPDB and AIR.

The $\delta^{13}C$ and $\delta^{15}N$ values show no clear clusters. The $\delta^{13}C$ values are expected in a terrestrial C3 environment (Fig. 4). The $\delta^{13}C$ values of Layer II range between –23.19‰ and –20.12‰, while specimens from Layer IV have a slightly wider range, between –24.37‰ and –19.50‰. The $\delta^{15}N$ values of Layer II range between 5.26‰ and 7.06‰, while the $\delta^{15}N$ values of Layer IV have a range between 5.35‰ and 10.42‰. None of these differences between the layers are statistically significant ((t-test) differences in $\delta^{13}C$ (t (14) = 0.23, p = 0.98)) and differences in $\delta^{15}N$ (t (14) = –1.310, p = –0.78).

Herbivores tend to have higher $\delta^{13}C$ values than carnivores and omnivores. In general, the $\delta^{13}C$ ratios of terrestrial herbivores in a C3 environment are expected to vary between –26 and –20‰, and carnivores in C3 environment between $\delta^{13}C$ –25 and –18‰ (*Lee-Thorp 2008*). The variation between the specimens can be either the effect of trophic level or caused by differences in plant consumption. In general, $\delta^{13}C$ values increase with 1–2‰ per trophic level. The $\delta^{13}C$ ratios of suids differ from the $\delta^{13}C$ values of the ruminants from the site. The $\delta^{13}C$ values of radiocarbon-dated sheep fall within the range of –20.44 and –19.59‰, and the $\delta^{13}C$ values of bovids within –20.46 and –19.26‰. These are clearly lower than those of the suids, and the difference between the ruminants and the suids is statically significant (t (19) = 4.05 p = 0.003). The samples dis-

playing the lowest $\delta^{13}C$ values possibly originate from suids that lived in dense forest or a riparian environment. Plants and trees in dense forests are more depleted in $\delta^{13}C$ than open grasslands, especially plants closer to the ground (*Drucker, Bocherens 2009*). It is possible that the lower $\delta^{13}C$ rates of the suids are the result of terrestrial diet. Another reason for lower $\delta^{13}C$ values could be the reliance on freshwater resources (*Balasse* et al. *2016*). In the botanical analysis, species expected in a riparian forest were indeed highly abundant.

$\delta^{15}N$ values are more reliable indicators for trophic levels than $\delta^{13}C$ values (*Lee-Thorp 2008*). The $\delta^{15}N$ values range within values to be expected for herbivores (5–7‰) (n = 14) and omnivores (7–9‰) (n = 2). The four suids which have $\delta^{13}C$ values within the range of the domesticated herbivores display low $\delta^{15}N$ values, which indicates that they were mainly herbivorous. The higher $\delta^{13}C$ level in these specimens cannot be the result of a higher trophic level. So, these higher $\delta^{13}C$ values are possibly the result of grazing in a more open landscape. One specimen displays a clearly higher $\delta^{15}N$ value, indicating a 'carnivorous' diet (9–11‰) (n = 1). The specimen is not a juvenile animal, so the high value cannot be due to the suckling effect (Appendix Tab. 5).

Interesting patterns arise when we compare our isotopic data to roughly contemporary neighbouring sites (Măgura, Borduşani-Popină, Harşova-tell and Vitănești) in the riparian forests of the Danube catchment in Neolithic and Chalcolithic Romania (*Balasse* et al. *2013; 2016; 2017*) and Kouphovouno, a Greek Middle/Late Neolithic site (*Vaiglova* et al. *2014*).
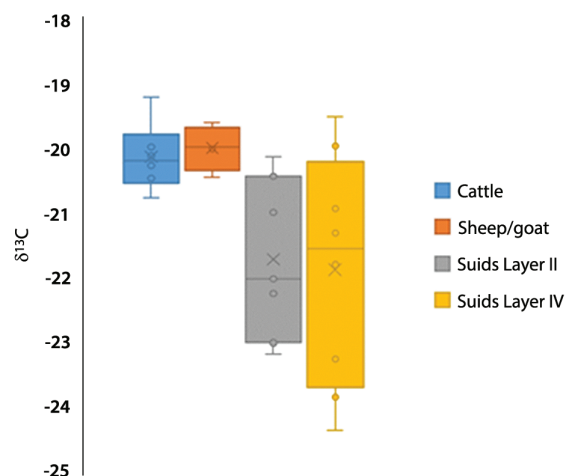

Fig. 4. The $\delta^{13}C$ values of the different taxa (cattle, sheep and suid) from Džuljunica (data of Krauß et al. 2014 and this study).
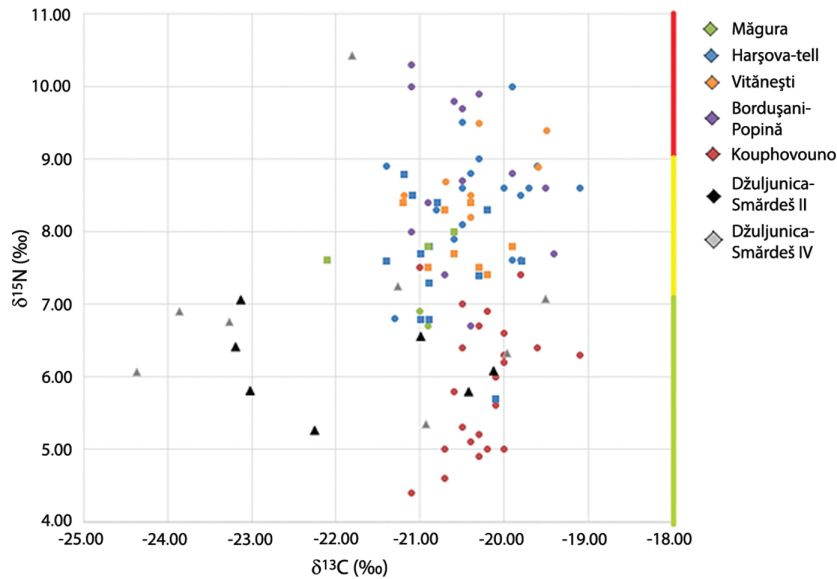
Fig. 5. δ15N and δ13C values compared. Circles (morphologically domestic suids, as identified by authors), squares (wild boar), triangles (Džuljunica specimens). The line on the right indicates the expected trophic level; green stands for herbivorous, yellow omnivorous, red carnivorous (data from Balasse et al. 2013; 2016; 2017 and this study – see Appendix Tab. 4).

The most striking observation is that the samples from the suids from Džuljunica have lower δ13C values than the suids of the compared sites (Fig. 5). However, not all specimens from Džuljunica have lower δ13C values than the compared sites; the highest δ13C values fall within the range of the δ13C values of the compared sites. The samples from suids from Măgura, the only other Early Neolithic site, also display lower δ13C values than the specimens from the other sites. No significant differences have been found between the δ13C values of the wild suids and the domestic suids from Borduşani-Popină, Harşova tell and Vitănești (*Balasse* et al. *2016; 2017*).

The sampled specimens of Borduşani-Popină, Harşova-tell and Vitănești have higher average δ15N values than the suids of Džuljunica. However, the highest δ15N value in the complete dataset derives from a specimen of Džuljunica. The δ15N values of morphological domestic suids of the latter three sites on average is significantly higher than the δ15N values of the wild boar. Neither the wild boar nor the morphologically domesticated specimens from Măgura show very elevated δ15N values compared to the Džuljunica specimens. The Kouphovouno specimens display even lower δ15N values than those of Džuljunica.

It has been argued that the wild boar from Borduşani-Popină, Harşova-tell, and Vitănești may have been foraging in open environments, as well as partly in the riparian forests (*Balasse* et al. *2016*). The fact that these suids would have been grazing in an open environment/within the settlement can explain the higher δ13C values in these suids. It is striking, however, that the morphologically wild specimens at this site also have higher carbon δ13C values than the Džuljunica specimens.

The domestic suids of Măgura are interpreted as extensively herded pigs, while the domestic suids of Borduşani-Popină, Harşova-tell and Vitănești may have been kept in the settlement and kept on a household scale (*Balasse* et al. *2013; 2016; 2017*). These elevated δ15N values of Borduşani-Popină, Harşova-tell, and Vitănești trophic have been interpreted as a greater consumption of human waste, such as remnants of hunted game or fish, domestic stock and dairy products or even human faeces (*Balasse* et al. *2016.33*). However, at all the Romanian sites, there is also a large overlap in the δ15N values between the morphologically wild and morphologically domesticated specimens, which is not to be neglected. The lower δ15N values of the specimens from Kouphovouno have been interpreted as a result of cereal waste foddering of the pigs (*Vaiglova* et al. *2014*).

No specimen identified as wild boar displays a δ15N value associated with a carnivorous diet. So, the Džuljunica specimen displaying δ15N value associated with a carnivorous diet is highly exceptional, not only for this site, but also for the region.

The isotopic values from all the other assemblages show smaller ranges in δ15N and δ13C both than the Džuljunica assemblage. Even if the isotopic values of the morphologically domestic and morphologically wild suids are considered together, the ranges are not as wide as in that from Džuljunica. This is surprising, since the sample size at Džuljunica is relatively small. In cases where suids are managed and/or domesticated, isotopic signals tend to become more uniform.

Discussion

The scarcity of suids in the zooarchaeological assemblage of Džuljunica is surprising when we consider the otherwise agricultural economy of the settlement and the reconstructed environment. Oak and riparian forests are excellent environments for suids, wild or domestic, under an extensive management regime. Hence, it is highly likely that wild boar was abundant around the site. Despite the suitability of the environmental setting in the Early Neolithic before 5900 BC of the northern Balkans, suid remains are rare at all archaeological sites, representing less than 5% of the total assemblage (based on NISP), and at some sites, suids do not even make up 1% of the assemblages (*Balasse* et al. *2013; Ethier* et al. *2017* and references therein; *Greenfield* et al. *2014*), in great contrast to Greece, the Struma Valley in southwestern Bulgaria, and in central western Anatolia (*Çakırlar 2013; De Cupere* et al. *2008; Ethier* et al. *2017; Perlés 2005*). In central and north western Anatolia, suids are also present in very small quantities at the earlier sites, but they become more frequent over time (*Arbuckle* et al. *2014; Çakırlar 2013*). In this cultural context, it is plausible to suggest that although agriculture and animal husbandry were present in eastern Bulgaria at the turn of the 7th millennium, this area contrasted with southwest Bulgaria in terms of interest in Suids.

The post-cranial size of the Džuljunica specimens does not indicate that the pigs were managed, domesticated or heavily exploited. However, body size is not immediately affected at the beginning of the domestication process (*Zeder 2012*). Therefore, it could still be possible that the suids at the site were herded without any traceable influence on their appearance. On the other hand, domestication and management are not the only factors that influence body size (*Albarella* et al. *2007*). A relation between environment and suids has been attested; suids in arid areas with high temperatures tend to be smaller (*Albarella* et al. *2009; Davis 1981*). The discrepancy between large post-cranial size and smaller molar size (which is also apparent in neighbouring Koprivec) is more difficult to explain. Cranial features are expected to decrease in size at an earlier stage of the domestication process than the post-cranial body features (*Zeder 2012*). Smaller molar size in large-bodied suids in this part of Bulgaria at the end of the 7th -beginning of the 6th millennium could represent a population in the process of domestication or two co-existing populations, but it could also be a phenotypic trait prevalent in this region.

The limited ageing data are widely distributed. Starting with Layer II, kill-off patterns suggest the infrequent exploitation of suids, and that individuals of different ages were targeted mostly at random. The absence of infant and juvenile (<8 months) individuals suggests that littering and nursing was undertaken outside the settlement. In general, and especially in Layer I in which all suid specimens represent adult individuals, nothing in the ageing data indicates intensive exploitation, in agreement with the infrequency of suids in the settlement.

The δ^{15}N and δ^{13}C ratios suggest that the majority of specimens from Džuljunica were not foddered with domestic waste, as would be expected in a domestic relationship with humans. In addition, the ratios are quite dispersed. The dispersed pattern in Džuljunica indicates that the suids relied on a wide range of different food sources. So, it is clear that most suids were, if at all, only loosely managed by humans, and that humans probably had no influence on the suids' diet. It is still possible that the inhabitants controlled the diet only of some of the suids, and that other samples were hunted wild boar. If these suids were managed, humans managed them extensively in the riparian forest or in a closed forest, where pigs ate mainly plant foods and molluscs.

None of the specimens identified as wild boar at the other sites had δ^{15}N values which are associated with a mostly carnivorous diet. An unmanaged suid with such a high δ^{15}N ratio is an exception. It could have been that this specimen mainly relied on freshwater fish, which often have higher elevated δ^{15}N values (*Lee-Thorp 2008*). Although there is not much evidence at Džuljunica of fish exploitation, this is likely an artefact of hand-collection mode of excavation. Therefore, it is not possible to determine whether the suids which show an isotopic signal which may indicate a foraging in a freshwater environment could have also been foddered with the remains of freshwater resources by humans instead. δ^{13}C values from wild terrestrial animals and human remains are necessary to test this hypothesis.

To sum up, the combined results of our zooarchaeological and stable isotopic analyses suggest that humans and suids were not in a close relationship in Džuljunica. There is nothing to suggest they were an important part of the food economy. There are very few suids; they are large bodied, and they seem to have foraged in the surrounding forested landscape.

It has been argued that the earliest Neolithic people in the Balkans had to adapt considerably to the new environmental conditions (*Ethier* et al. *2017*). In contrast with Greece, Anatolia and the southern Balkans, the northern Balkans are often subject to frosty winters with heavy snow. It has been suggested that transhumance practises must have been adopted in this region to cope with stronger seasonal fluctuations (*Greenfield* et al. *2014*). Seasonally relocating is considered untypical for domestic pigs and seen as an explanation for the general lack of suids in the archaeological record of the northern Balkans in the Early Neolithic (*Ethier* et al. *2017*). However, while pig transhumance may not be practised often anymore, it was surely practised in the recent past (*Albarella* et al. *2011*).

Moreover, the reconstructed vegetation for Neolithic Džuljunica, riparian and oak forests in a well-watered landscape, indicates a perfect environment for suids, wild or managed, and the small assemblage from the site indicates that they were in the surrounding landscape. Such a discrepancy between the suitability of the environment and the role of suids in Neolithic cultures has been observed elsewhere. Suids are very scarce and morphologically wild in the earliest Neolithic layers of some sites in Central Anatolia and the Marmara region (*Arbuckle* et al. *2014*), where the environmental conditions are completely different from in eastern Bulgaria, but nevertheless suitable for suids as well. The northern Balkans is not the only region along the path of Neolithisation during the late 7th millennium without suids (*Arbuckle* et al. *2014; Evin* et al. *2015*).

All this leads us to suggest that the absence of suids may be part of a cultural trend reflecting deliberate choice in some Early Neolithic cultures, including the northern Balkans. This does not mean, however, that suids were not important in their value system.

Conclusions

Our analysis shows that humans only peripherally interacted with suids in Early Neolithic Džuljunica, despite the indications that the environmental conditions would allow a closer relationship. Regions where interactions with suids were limited in the early phases of farming during Neolithisation are along the so-called Continental Route (Central Anatolia, via the Marmara Region, the eastern and northern Balkans), whereas more intensive management of domestic pigs is observed along the Maritime Route. Our analysis does not suggest a domestic partnership between humans and suids in the northern Balkans, but this suggestion should be investigated with further research, including palaeogenomics, GMM, and other stable isotopes. Whether the 7th millennium BC suids along the Continental Route are domestic at all is an important question, because this has potential implications for the subsequent genetic history of the domestic pig originating from Southwest Asia, which later disappears through inter-breeding with local European wild boar (*Larson* et al. *2007*).

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Appendix

Tab. 1. The postcranial and cranial measurements of the suids of Džuljunica.

Faunal ID	Layer	Element	Measurement	Value (mm)
27–617	I	Radius	Bp	36.3
11–162	I	Ulna	Bfp	26.4
119–2670	II	Metacarpus III	Bd	23.4
111–2380	II	Metacarpus IV	Bp	20.1
48–2059	II	Radius	Bp	34.8
95–3149	II	Tibia	Bd	36.6
63–1157	IV	Radius	Bp	42.4
19–343	I	Maxilla	Breadth M1	15.7
48–2060	II	Maxilla	Breadth dP4	9.3
			Length dP4	13.5
			Length M2	15.3
57–1078	IV	Maxilla	Breadth M1	14.1
			Length M1	19.8
			Breadth M2	17.8
			Length M2	25.2
117–2620	IV	Maxilla	Breadth M1	12.2
			Length M1	18.2
52–1027	IV	Mandibula	Length M1	19.2

Tab. 2. The fusion stages of the postcranial elements of the suids of Džuljunica.

Element	Unfused	Fused	Fusing
Layer I			
Radius proximal		1	
Layer II			
Pelvis	1		
Scapula		1	
Radius proximal	1		
Humerus distal	1		
Tibia distal	1	2	
Metacarpus		2	
Radius and Ulna		1	
Layer IV			
Radius proximal		3	
2 Phalanx		1	
Tibia proximal	1		

Tab. 3. The dental wear of the suids of Džuljunica following Lemoine et al. 2014.

specimen	Layer	element	dc	dp2	dp3	dp4	I1	I2	I3	C /P1	P2	P3	P4	M1	M2	M3
Dz-19-343	I	Maxilla with teeth											10–12	13–16		
Dz-37-884	II	Maxilla with teeth					6	2								
Dz-39-898	II	Mandibula with teeth					10									
Dz-43-959	II	Maxilla with teeth						2								
Dz-48-2060	II	Maxilla with teeth	8	10 –12	10–12	18										10
Dz-117-2620	IV	Maxilla with teeth										7		11	10	
Dz-52-1027	IV	Mandibula with teeth											9			
Dz-57-1078	IV	Maxilla with teeth									10 –12	10		11	10	
Dz-72-1354	IV	Mandibula with teeth					10	10	10							

Tab. 4. The results of the isotopic analysis of suids of Džuljunica.

Sample	yield (%)	%C	%N	C/N	δ¹³C (‰)	δ¹⁵N (‰)
DZ-57-1078	4.7	8.8	3.2	3.3	−24.37	5.57
DZ-61-1116	7.8	12.3	4.5	3.2	−23.86	6.07
DZ-63-1156	6.1	8.8	3.2	3.2	−23.27	6.91
DZ-63-1157	2.9	28.4	10.1	3.3	−21.26	6.76
DZ-69-1254	2.9	41.3	15.1	3.2	−20.93	7.25
DZ-72-1354	1.1	27.7	10.6	3.1	−19.96	5.35
DZ-83-1761	0.8	36.4	13.9	3.1	−19.50	6.32
DZ-86-1828	4.8	15.1	5.5	3.2	−21.80	7.07
DZ-95-3149	3.3	20.5	7.4	3.2	−22.25	5.26
DZ-39-898						
DZ-48-2060	3.3	6.1	2.2	3.2	−22.02	5.74
DZ-37-884						
DZ-43-959	3.0	7.1	2.5	3.3	−23.02	5.81
DZ-117-2620	8.7	16.6	6.0	3.2	−21.31	10.42
DZ-119-2670	9.7	14.1	5.2	3.1	−20.42	5.79
DZ-39-902						
DZ-48-2059	7.8	7.3	2.6	3.3	−23.19	6.41
DZ-43-953	7.6	3.7	1.3	3.4	−23.13	7.06
DZ-47-2022	5.6	8.2	3.0	3.2	−20.99	6.55
DZ-111-2380	2.8	19.8	7.6	3.0	−20.12	6.08

Sp. number	Level	Element	Size (LSI/ comments)	Age (Lemoine *at al.* age in months/ comments)	Isotopic signal δ¹³C (‰)	δ¹⁵N (‰)
19–343	I	Maxilla with teeth	−0.01	52–96 months	not sampled	
DZ-27-617	I	Radius	0.03	>8 months	not sampled	
DZ-95-3149	II	Tibia	0.03	>24 months	not sampled	
DZ-39-898	II	Mandibula (male)	−	no Lemoine *et al.* stage, but clearly adult/ old	failed	
DZ-37-884	II	Maxilla with teeth	−	3–8 months	failed	
DZ-39-902	II	Radius	−	<7 months	failed	
DZ-43-953	II	Scapula	very large	−	bad quality collagen	
DZ-48-2060	II	Maxilla with teeth	−0.15, −0.21, −0.22	no Lemoine *et al.* stage, but juvenile	−22.02	5.74
DZ-43-959	II	Maxilla with teeth	−	3–8 months	−23.02	5.81
DZ-119-2670	II	Metacarpus III	0.09	>36 months	−20.42	5.79
DZ-48-2059	II	Radius and Ulna	0.01	>96 months	−23.19	6.41
DZ-47-2022	II	Tibia	0.04	>24 months	−20.99	6.55
DZ-111-2380	II	Metacarpus IV	0.02	−	−20.12	6.08
DZ-52-1027	IV	Mandibula with teeth		12–52 months	not sampled	
DZ-57-1078	IV	Maxilla with teeth	−0.05, −0.01, −0.05	18–30 months	−24.37	5.57
DZ-61-1116	IV	Tibia	−	<48 months	−23.86	6.07
DZ-63-1156	IV	Mandibula	−	−	−23.27	6.91
DZ-63-1157	IV	Radius	0.09	>8 months	−21.26	6.76
DZ-69-1254	IV	Mandibula	−	−	−20.93	7.25
DZ-72-1354	IV	Mandibula with teeth	−	no Lemoine *et al.* stage, but old	−19.96	5.35
DZ-83-1761	IV	Frontale	−	−	−19.50	6.32
DZ-86-1828	IV	Radius	−	>8 months	−21.80	7.07
DZ-117-2620	IV	Maxilla with teeth	−0.12, −0.05	18–30 months	−21.31	10.42

Tab. 5. The ageing, size and isotopic data of the suids of Džuljunica combined.

Site descriptions

Achilleion is a tell site only consisting of Neolithic layers, dating from 6500 to 5500 BC. Domestic mammals make up more than 90% of the zooarchaeological assemblage in all phases. Caprines make up the majority of the domestic species, but cattle and domestic pig become more frequent over time (*Gimbutas 1974*).

Bademağacı is an Early Neolithic mound site in Western Turkey dating. The mound consists of five early Neolithic levels dating from 6700–6200 BC. Cattle, sheep, goat and pig were all present from the earliest layers of the site onwards (*De Cupere* et al. *2008*).

Borduşani-Popină is a Gumelniţa tell site in southeastern Romania dating to the second half of the fifth millennium BC. The site was located on an island in the Danube. Pulses and wheats were both cultivated. The inhabitants relied on aquatic resources and domestic mammals. Pigs are the most represented domestic mammal based on NISP (*Balasse* et al. *2017*).

Çatalhöyük is an early Neolithic site in South-eastern Anatolia, occupied between 7300–6200 BC. Domestic caprines are the most represented domestic mammals. All aurochs in the earliest layers of Çatalhöyük are morphologically wild and no evidence indicates that they were herded. From *c.* 6500–6400 BC smaller individuals start to appear. Domestic suids are absent (*Russell 2013*).

Fikirtepe is a Neolithic site in North-western Turkey from 6500–6000 BC. It is not known whether the site was seasonally occupied or was inhabited year-round. The inhabitants relied on both animal husbandry and aquatic resources. Domestic pigs are absent in the earliest layers but introduced in later phases (*Çakırlar 2013*).

Harşova-tell is a tell site in Southeastern Romania, situated between a riparian forest and an oak forest. Diverse hulled wheats were cultivated, but wild fruits were consumed too. The inhabitants heavily relied on aquatic resources and domestic mammals. Caprines are the most common domestic mammal, followed by pigs (*Balasse* et al. *2017*).

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Ilıpinar is an early Neolithic site located in North-western Turkey, dating to *c*. 6000–5400 BC. Domestic caprines are the most abundant domesticates in all layers, sheep dominating goat. Suids are very rare in the layers, but suid percentages in the assemblage increases over time, while the average size of the pigs clearly decreases (*Çakırlar 2013*).

Knossos was inhabited since 7000 BC and the Neolithic phase lasted for about 1500 years. Caprines are the most common domestic species in the earliest phases, but cattle becomes more important over time. Pigs also became more abundant over time (*Isaakidou 2008*).

Koprivec is an Early Neolithic site in Bulgaria dating 6100–5900 BC. 2005 animal remains have been found, mostly of domestic specimens. Cattle is the most abundant species, followed by caprines. Suids however, are very rare and make up less than 1% of the total assemblage (*Manhart 1998*).

Kouphovouno is a Middle/Late Neolithic site in Southern Greece dating to *c*. 5800–5000 BC. The botanical assemblage consists of domestic species of cereals and pulses. The faunal assemblage is dominated by domestic animals such as cattle, sheep, goats, pigs and dogs, but wild animals were found as well (*Vaiglova* et al. *2014*).

Măgura is a Neolithic site probably belonging to the initial neolithisation of Romania. Animal remains have been found dating as far back as the early sixth millennium BC. Caprines are the most represented domestic mammal. Botanical studies suggest people cultivated cereals too (*Balasse* et al. *2013*).

Menteşe is an Early Neolithic site situated in Northwestern Turkey and inhabited from 6500 until 5500 BC. Cattle and caprines are very abundant, while domestic pig is absent in the earliest phases. In later phase, domestic pig seems to be introduced (*Çakırlar 2013*).

Ulucak is an Early Neolithic site in Western Turkey inhabited from 7000 until 5700 BC. Caprines make up the majority of the zooarchaeological assemblage, but cattle and pig are both kept from the earliest layer onwards (*Çakırlar 2012*).

Vităneşti is located on the floodplain of the river Teleorman surrounded by marshlands, dating to the fifth millennium BC. A high number of domesticated taxa are represented in the zooarchaeological remains, but wild taxa (68% based on NISP), mainly large and very large mammals, predominate the assemblage (*Balasse* et al. *2016*).

Yenikapi is a Neolithic site in Western Anatolia, from *c*. 6000–5500 BC. The site consisted of a small year-round inhabited village. Domestic mammals make up the majority of the zooarchaeological assemblage, but due to sampling strategies it is unknown in what quantities the inhabitants relied on aquatic resources. Domestic pigs are absent from the earliest layers, but were introduced later (*Çakırlar 2013*).

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