European Journal of Archaeology
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# Is the Mesolithic-Neolithic Subsistence Dichotomy Real? New Stable Isotope Evidence from the Danube Gorges

Dusan Boric, Gisela Grupe, Joris Peters and Zivko Mikic

*European Journal of Archaeology* 2004 7: 221
DOI: 10.1177/1461957104056500

# IS THE MESOLITHIC–NEOLITHIC SUBSISTENCE DICHOTOMY REAL? NEW STABLE ISOTOPE EVIDENCE FROM THE DANUBE GORGES

Dušan Borić
*University of Cambridge, UK*
Gisela Grupe and Joris Peters
*Ludwig-Maximilians-University, Munich, Germany*
Živko Mikić
*University of Belgrade, Serbia and Montenegro*

*Abstract*: The article presents new results of stable isotope analyses made on animal and human bones from the Mesolithic–early Neolithic sites of Lepenski Vir and Vlasac in the Danube Gorges of the Balkans. It reconstructs the food web for the region during these periods on the basis of stable isotope analyses of mammal and fish species found at Vlasac. These results are compared to measurements made on human burials from the two sites. In the light of these new results, the article also discusses interpretations provided by previous isotopic studies of this material. It concludes that great care is required in the interpretation of stable isotope results due to inherent methodological complexities of this type of analysis, and suggests that it is also necessary to integrate stable isotope results with information based on the examination of faunal remains and the archaeological context of analysed burials when making inferences about palaeodietary patterns.

*Keywords*: Danube Gorges, early Neolithic, Lepenski Vir, Mesolithic, palaeodiet, stable isotopes, sturgeon, Vlasac

## INTRODUCTION

Questions about the type of subsistence have been of central importance in studies of Mesolithic–Neolithic transformations. Stable isotope analyses, supplementing faunal and palaeobotanical analyses, are becoming a routine way to characterize the subsistence of past communities on the basis of preserved human remains at archaeological sites. Yet interpreting stable isotope results is not always a straightforward business and this article re-examines the case of the Danube Gorges (or the Iron Gates) Mesolithic–Neolithic sites.

*European Journal of Archaeology* Vol. 7(3): 221–248

ISSN 1461–9571 DOI:10.1177/1461957104056500

Almost 40 years after the discovery of the celebrated type-site of Lepenski Vir (Srejović 1969, 1972), the archaeological record of Mesolithic–Neolithic transformations in the Danube Gorges region (Fig. 1) still remains one of the most important case studies for this time period in European prehistory. A series of settlements along the narrows of the Danube River on the Serbian–Romanian border provides a rich settlement and intramural mortuary dataset due to extensively excavated sites (Borić 1999, 2002a, 2002b; Borić and Stefanović 2004; Radovanović 1996; Roksandić 1999, 2000). The sequences indicate largely unbroken continuities of occupation on the Danube banks during the Mesolithic and early Neolithic periods – c. 10,000–5500 cal BC – (Borić and Miracle 2004). This regional group is characterized by specific features of material culture, such as trapezoidal buildings, examples of boulder art as well as specific mortuary rites. The early Neolithic pottery of the Starčevo-Körös-Criş type appears here around 6300 cal BC, similar to the starting date of the early Neolithic in the wider region of the north-central Balkans (Whittle et al. 2002). The combination of steep-sided mountains and the fast-paced river fostered an extraordinarily rich and diverse environment along the 130 km of the Danube Gorges with abundant subsistence resources, such as freshwater as well as migratory (anadromous sturgeon) fish of the Danube, and game, such as red deer, aurochs and wild boar, hunted in the forests of the hinterland areas. The mortuary record of this region, dated to the Mesolithic and early Neolithic periods, provides more than 500 burials from 11 sites.

In the Danube Gorges, stable isotope studies of human burials have indicated a change from a largely aquatic diet in the Mesolithic to a more terrestrial diet in the early Neolithic (Bonsall et al. 1997, 2000; see also Cook et al. 2002; Grupe et al. 2003). Due to a substantial intake of freshwater fish, an aquatic reservoir effect was noted when dating human burials; the consumption of aquatic resources that come from a reservoir that has different $^{14}C$ levels from the atmosphere resulted in radiocarbon measurements of humans (and dogs) that are 'too old' by approximately 200 to 500 radiocarbon years and require correction (Bonsall et al. 1997, 2000; see also Borić and Miracle 2004; Cook et al. 2002).

The question of subsistence change that occurred in the course of Mesolithic–Neolithic transformations in various other parts of Europe as reflected in stable isotope data has recently been discussed while different interpretations have been offered (e.g. Hedges 2004; Lidén et al. 2004; Milner et al. 2004; Richards 2003; Richards et al. 2003; Schulting and Richards 2002). In a similar vein, the case of the Danube Gorges region requires an interpretive critical scrutiny of the assumed Mesolithic–Neolithic subsistence dichotomy.

Here we present the results of our analyses that continue work conducted by previous researchers by enlarging the sample of isotopically analysed human skeletons from the sites of Lepenski Vir and Vlasac, and, in addition, by measuring stable isotopes on a wide range of animal species from Vlasac and Padina (Fig. 1).[1] Conclusions made by previous researchers with regard to stable isotope analyses on the Danube Gorges material, claiming 'fundamental changes in diet' (Bonsall et al. 2000:126) at the start of the early Neolithic, will be examined carefully in the

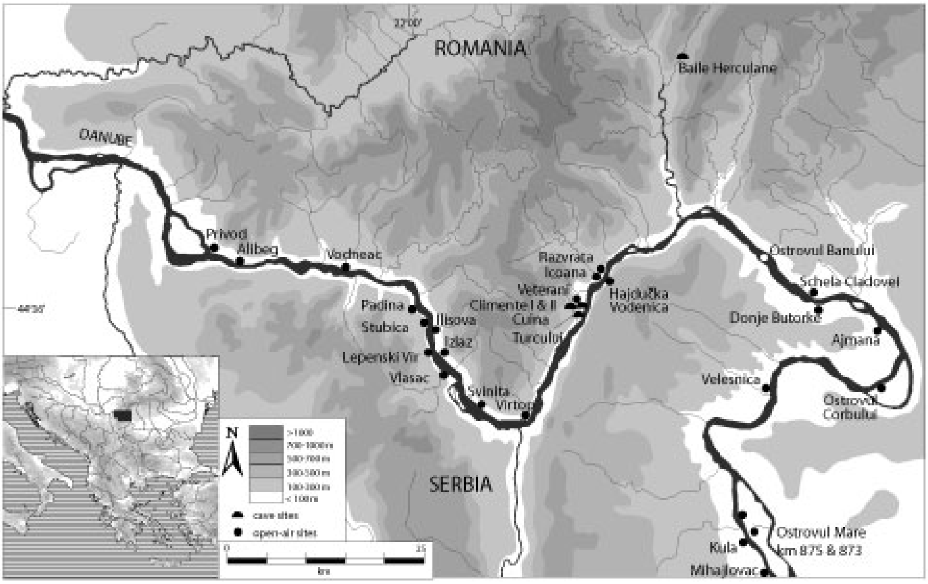

**Figure 1.** *Map of the Danube Gorges with principal sites discussed in the text.*

light of our reconstruction of the food web, re-examination of faunal remains from the two sites, and the archaeological context and radiocarbon dating of analysed burials.

First, we focus on methodological questions with regard to two main issues: (a) consumption of which animal species might have caused higher isotopic values, indicating a higher trophic level (i.e. a higher position in the food chain) for analysed humans from this region? and (b) are the available faunal data complementary with data obtained by stable isotope analyses? Second, we suggest a 'realistic' pattern of dietary changes over time and point out the necessity for contextually engaged discussions of stable isotope results.

## MATERIAL AND METHODS

We analysed 97 human bones from Vlasac (*N*=51) and Lepenski Vir (*N*=46) (Table 2) and 43 faunal samples (Table 1) representing the following species: lynx *Lynx lynx* (1), pine marten *Martes martes* (4), brown bear *Ursus arctos* (1), dog *Canis familiaris* (13), wolf *Canis lupus* (3), roe deer *Capreolus capreolus* (1), red deer *Cervus elaphus* (4), wild boar *Sus scrofa* fer. (2), carp *Cyprinus carpio* (6), catfish *Siluris glanis* (3), beluga *Huso huso* (1), sturgeon Acipenseridae, *Acipenser sturio* or *stellatus* (3) and zander *Sander lucioperca* (1). All faunal samples except for one red deer bone, which came from the site of Padina, and two modern fish (catfish and zander) bones, are from the same site – Vlasac (see Fig. 1). Human bone samples had all been analysed and published previously in a preliminary form (Grupe et al. 2003), except for burial 7/II-b from Lepenski Vir. In this way, we increased the sample of

*Table 1. Stable isotope values for archaeological (Vlasac and Padina) and modern (Golubac) vertebrate bones from the Danube Gorges, including indicators for the state of gelatine preservation (gelatine yield, %C, %N, molar C/N-ratio).*

| species | label/context | element | % gelatine | %C | %N | molar C/N | $\delta^{13}C$ | $\delta^{15}N$ |
|---|---|---|---|---|---|---|---|---|
| lynx *Lynx lynx* L. | sonda B | ulna | 0.69 | 45.3 | 15.08 | 3.51 | –21.4 | 10.64 |
| pine marten *Martes martes* | m9, sonda B | mandible | 0.68 | 34.89 | 11.63 | 3.5 | –20.16 | 10.14 |
| pine marten *Martes martes* | m1, sonda B | mandible | 0.88 | 35.51 | 12.39 | 3.32 | –19.38 | 9.12 |
| pine marten *Martes martes* | m7-12, sonda B | pelvis | 1.8 | 46.55 | 15.98 | 3.39 | –18.94 | 9.24 |
| pine marten *Martes martes* | m8, sonda B | mandible | 1.08 | 39.77 | 13.66 | 3.39 | –19.24 | 10.62 |
| brown bear *Ursus arctos* L. | m18?, sonda A | mandible | 0.28 | 30.97 | 10.84 | 3.34 | –20.54 | 8.22 |
| dog *Canis familiaris* L. | sonda B | tibia | 1.3 | 35.57 | 14.22 | 2.92 | –19.09 | 10.65 |
| dog *Canis familiaris* L. | sonda B | humerus | 2.14 | 43.36 | 15.06 | 3.36 | –19.5 | 10.21 |
| dog *Canis familiaris* L. | sonda A | radius | 0.45 | 29.87 | 10.55 | 3.3 | –19.56 | 10.97 |
| dog *Canis familiaris* L. | sonda B | mandible | 0.68 | 29.78 | 10.82 | 3.21 | –18.86 | 10.47 |
| dog *Canis familiaris* L. | 2 (45a) | os temp. | 2.69 | – | – | – | – | – |
| dog *Canis familiaris* L. | 3 (46a) | vertebra | 0.68 | – | – | – | – | – |
| dog *Canis familiaris* L. | 4 (8a) | mandible | 2.35 | 45.51 | 13.3 | 3.73 | –18.51 | 10.99 |
| dog *Canis familiaris* L. | 6 (m28-36) | humerus | 2.98 | 39.67 | 12.65 | 3.66 | –19.49 | 10.78 |
| dog *Canis familiaris* L. | 7 (43a) | tibia | 0.47 | 31.78 | 10.68 | 3.47 | –19.81 | 9.57 |
| dog *Canis familiaris* L. | 8 (50a) | pelvis | 0.43 | 31.33 | 12.92 | 2.83 | –20.29 | 10.98 |
| dog *Canis familiaris* L. | 10 (26a) | calcaneus | 2.73 | – | – | – | – | – |
| dog *Canis familiaris* L. | 1 (9) | humerus | 1.26 | 20.1 | 9.28 | 2.53 | –23.08 | 9.38 |
| dog *Canis familiaris* L. | 5 (35a) | mandible | 0.88 | 45.58 | 14.12 | 3.6 | –19.98 | 11.57 |
| wolf *Canis lupus* L. | sonda B | mandible | 1.31 | 49.09 | 16.86 | 3.43 | –19.68 | 11.87 |
| wolf *Canis lupus* L. | sonda B | metacarpus | 2.33 | 44.18 | 15.41 | 3.34 | –20.01 | 9.62 |
| wolf *Canis lupus* L. | sonda B | calcaneus | 1.33 | 51.17 | 17.67 | 3.38 | –20.1 | 10.1 |
| roe deer *Capreolus capreolus* L. | 12 (1200) | metatarsus | 2.46 | 39.62 | 13.19 | 3.51 | –21.59 | 6.06 |
| red deer *Cervus elaphus* L. | 13 (2026) | antler | 0.39 | 45.63 | 15.2 | 3.5 | –22.59 | 7.07 |
| red deer *Cervus elaphus* L. | 14 (1808) | antler | 2.19 | 68.59 | 22.03 | 3.63 | –21.58 | 6.76 |
| red deer *Cervus elaphus* L. | 16 (45a) | mandible | 0.68 | 34.57 | 12.76 | 3.16 | –22.35 | 6.89 |
| red deer *Cervus elaphus* L. | Padina 17 (OxA-9055: 8445±60 BP) | mandible | 0.46 | 40.55 | 14.67 | 3.22 | –21.84 | 4.55 |
| wild boar *Sus scrofa* fer. | sonda A | tibia | 1.1 | 43.75 | 15.17 | 3.27 | –20.32 | 7.06 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| wild boar *Sus scrofa* fer. | sonda A | scapula, juv. | 0.99 | 46.83 | 16.75 | 3.26 | –20.66 | 11.94 |
| carp *Cyprinus carpio* L. | 18 (P27) | mandible | 1.15 | 41.29 | 13.24 | 3.64 | –23.32 | 7.91 |
| carp *Cyprinus carpio* L. | P11, sonda B | vertebra | 1.34 | 47.12 | 16.36 | 3.34 | –20.34 | 6.59 |
| carp *Cyprinus carpio* L. | P12, sonda A | os phar. inf. | 0.34 | 29.08 | 12.74 | 2.66 | –21.19 | 6.3 |
| carp *Cyprinus carpio* L. | P25, sonda A | hyomandible | 0.35 | 23.67 | 8.49 | 3.26 | –23.68 | 9.8 |
| carp *Cyprinus carpio* L. | 27 (P28) | mandible | 0.35 | 29.47 | 9.91 | 3.47 | –20.69 | 6.44 |
| carp *Cyprinus carpio* L. | P10, sonda B | os phar. inf. | 0.17 | 20.01 | 7.02 | 3.32 | –20.84 | 7.12 |
| beluga *Huso huso* L. | 21 (54a) | dentale | 2.04 | 34.44 | 10.18 | 3.95 | –17.66 | 11.07 |
| Acipenseridae | P11, sonda B | ? | 2.27 | 44.35 | 15.82 | 3.27 | –19.21 | 10.07 |
| Acipenseridae | P10, sonda B | pectoral | 0.4 | 36.28 | 12.75 | 3.32 | –21.26 | 8.32 |
| Acipenseridae | P2, sonda B | ? | 1.12 | 42.01 | 14.31 | 3.42 | –19.4 | 8.78 |
| catfish *Silurus glanis* L. | 20 (P23) | vertebra | 0.29 | 23.28 | 6.75 | 4.02 | –20.2 | 9.3 |
| catfish *Silurus glanis* L. | 25 (P33) | vertebra | 0.92 | 24.84 | 7.81 | 3.71 | –20.87 | 10.63 |
| | | mean | 1.18 | 38.04 | 13.11 | 3.37 | | |
| | | sd | 0.81 | 9.84 | 3.18 | 0.3 | | |
| | | minimum | 0.17 | 20.01 | 6.75 | 2.53 | | |
| | | maximum | 2.98 | 68.59 | 22.03 | 4.02 | | |
| | | | | | | | | |
| zander *Sander lucioperca* L. | modern | | 3.68 | 41.93 | 13.31 | 3.68 | –23.46 | 12.2 |
| catfish *Silurus glanis* L. | modern | | 2.57 | 48.33 | 14.97 | 3.77 | –23.41 | 11.64 |

*Table 2. Stable isotope values for human individuals from Vlasac and Lepenski Vir, including available absolute dates (see Bonsall et al. 1996, 1997, 2000; Borić 2002b). The sex determination of Lepenski Vir neonates is based on DNA analyses (Čuljković et al. in press). We also indicate the state of gelatine preservation. Duplicate analyses by Bonsall et al. (1997, 2000) are indicated by asterisks.*

**Vlasac**

| no. | age | sex | original phasing$^{(a)}$ | dating$^{(b)}$ | % gelatine | %C | %N | molar C/N | $\delta^{13}$C | $\delta^{15}$N | $\delta^{13}$C* | $\delta^{15}$N* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4a | young adult | male | III?–group C | later | 3.52 | 46.63 | 15.51 | 3.51 | –19.19 | 15.07 | | |
| 4b | old adult | male | III?–group C | disarticulated | 3.99 | 48.33 | 16.33 | 3.45 | –19.13 | 15.05 | | |
| 5 | 13–16 y | nd | III?–group C | later | 3.43 | 47.36 | 15.2 | 3.63 | –20.26 | 14 | | |
| 6 | old adult | male | III?–group C | later | 3.14 | 41.07 | 16.54 | 2.9 | –19.71 | 15.15 | | |
| 7 | 15–16 y | nd | III?–group C | early | 2.72 | 40.16 | 13.94 | 3.36 | –20.34 | 12.19 | | |
| 11b | young adult | female | III?–group C | later | 3.54 | 48.32 | 16.27 | 3.46 | –20.01 | 14.51 | | |
| 16 | old adult | male | I?–group D | disarticulated | 3.46 | 42.19 | 14.17 | 3.47 | –20.04 | 12.26 | | |
| 17 | young adult | male | I?–group D | early | 3.94 | 39.62 | 17.75 | 2.6 | –20.31 | 13.79 | | |
| 18c | 9–10 y | nd | III?–group C | early | 1.91 | 33.87 | 11.47 | 3.44 | –21.03 | 12.86 | | |
| 23 | old adult | male | III–group B | later | 1.49 | 48.71 | 16.72 | 3.4 | –19.31 | 14.23 | –18.8 | 14.7 |
| 24 | young adult | female | III–group B | 6650–6100 cal BC | 3.17 | 42.91 | 17.8 | 2.8 | –18.73 | 14.39 | –18.2 | 14.7 |
| 27 | old adult | female | II–group A | later | 2.27 | 51.61 | 17.5 | 3.44 | –19.4 | 14.32 | –18.4 | 14.9 |
| 32 | old adult | female | I–group A | early | 1.32 | 45.89 | 15.94 | 3.36 | –20.22 | 13.22 | –19.5 | 14.0 |
| 36 | young adult | female | I–group A | disarticulated | 2.5 | 39.75 | 13.51 | 3.43 | –19.09 | 14.97 | | |
| 38 | old adult | female | I–group A | early | 1.56 | 36.83 | 14.91 | 2.88 | –18.81 | 15.31 | | |
| 44 | old adult | male | II–group B | later | 2.84 | 48.99 | 16.43 | 3.48 | –19.66 | 13.33 | –19.1 | 13.5 |
| 47 | young adult | female | I–group B | early | 2.05 | 45 | 14.96 | 3.51 | –19.26 | 15.03 | | |
| 48 | old adult | female | I–group B | early | 1.7 | 37.58 | 15.61 | 2.81 | –18.39 | 14.72 | | |
| 51 | 10–12 y | nd | I–group A | early | 0.56 | 28.51 | 9.15 | 3.63 | –21.93 | 9.87 | | |
| 53 | 8–9 y | nd | I–group A | early | 1.24 | 44.73 | 15.27 | 3.42 | –19.43 | 15.02 | | |
| 54 | old adult | male | I–group A | 7050–6350 cal BC | 0.37 | 31.53 | 12.32 | 2.99 | –20.04 | 14.22 | –19.1 | 14.9 |
| 55 | young adult | female | I–group B | early | 3.15 | 58.66 | 17.71 | 3.87 | –19.64 | 15.19 | | |
| 63 | old adult | male | I–group B | early | 1.39 | 44.84 | 17.56 | 2.98 | –19.26 | 14.26 | | |
| 65a | young adult | female | I–group B | disarticulated | 2.43 | 41.16 | 16.59 | 2.9 | –19.69 | 14.06 | | |
| 67 | young adult | female | I–group A | early | 1.64 | 45.78 | 18.13 | 2.95 | –18.69 | 13.83 | | |
| 69 | old adult | male | I?–group D | disarticulated | 1.58 | 37.59 | 15.83 | 2.77 | –19.42 | 14.41 | | |
| 71 | old adult | female | I?–group D | early | 1.38 | 37.15 | 12.01 | 3.59 | –19.6 | 14.25 | | |

|  |  |  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 72 | old adult | female | I–group A | 9750–8700 cal BC | 2.55 | 49.68 | 16.7 | 3.47 | –19.78 | 13.53 | –19.3 | 14.5 |
| 74 | old adult | female | I?–group D | early | 2.53 | 28.68 | 16.64 | 2.01 | –19.42 | 13.1 |  |  |
| 78 | old adult | male | I?–group C | early | 4.81 | 45.28 | 14.83 | 3.56 | –19.28 | 15.55 |  |  |
| 78a | old adult | male | I?–group C | early | 2.39 | 35.51 | 14.61 | 2.64 | –18.91 | 14.45 |  |  |
| 79 | young adult | female | II–group B | early | 1.5 | 36.26 | 15.96 | 2.83 | –18.56 | 14.84 | –18.7 | 15.1 |
| 80 | young adult | female | I?–group C | later | 2.39 | 38.62 | 15.5 | 2.91 | –19.51 | 13.14 |  |  |
| 80a | young adult | female | I?–group C | later | 1.76 | 36.52 | 12.04 | 3.54 | –19.45 | 14.81 |  |  |
| 81 | old adult | female | II–group B | later | 1.25 | 30.14 | 13.24 | 2.46 | –18.97 | 13.72 |  |  |
| 84M | adult | male | ? | ? | 1.38 | 44.02 | 16.2 | 3.17 | –19.37 | 14.98 |  |  |
| 6a | neonate | nd | III?–group C | early | 2.67 | 34.26 | 12 | 2.66 | –19.62 | 16.82 |  |  |
| 10 | neonate | nd | III?–group C | early | 3.68 | 43.49 | 15.34 | 3.33 | –20.34 | 14.91 |  |  |
| 12 | neonate | nd | III?–group C | ? | 4.47 | 44.77 | 15.48 | 3.37 | –19.48 | 18.31 |  |  |
| 12a | neonate | nd | III?–group C | later | 3.19 | 39.6 | 14.69 | 3.14 | –20.04 | 13.4 |  |  |
| 12b | neonate | nd | III?–group C | later | 3.35 | 43.18 | 14.89 | 3.38 | –19.66 | 17.3 |  |  |
| 21 | infant | nd | I–group B | early | 1.95 | 28.93 | 9.8 | 3.44 | –20.28 | 16.84 |  |  |
| 35a | neonate | nd | I–group A | early | 2.76 | 41.87 | 14.11 | 3.46 | –20.09 | 15.03 |  |  |
| 36 (1) | neonate | nd | I–group A | disarticulated | 1.45 | 40.03 | 13.62 | 3.43 | –19.35 | 16.45 |  |  |
| 42 | infant | nd | I–group B | later | 5 | 36.19 | 15.73 | 2.68 | –20.06 | 14.05 |  |  |
| 50a(1) | neonate | nd | I–group B | early | 2.59 | 42.72 | 14.76 | 3.38 | –20.8 | 15.21 |  |  |
| 58b | neonate | nd | II–group B | later | 1.87 | 39.8 | 13.04 | 3.56 | –20.47 | 13.67 |  |  |
| 59 | neonate | nd | I–group B | early | 1.53 | 42.75 | 14.98 | 3.33 | –20.64 | 14 |  |  |
| 61 | neonate | nd | I–group B | early | 3.33 | 42.29 | 14.04 | 3.51 | –20.15 | 14.84 |  |  |
| 62 | neonate | nd | I–group B | early | 2.82 | 40.29 | 13.41 | 3.5 | –20.1 | 15 |  |  |
| 66a | 6 y | nd | II–group B | disarticulated | 0.41 | 27.88 | 11.7 | 2.78 | –20.73 | 10.12 |  |  |

**Lepenski Vir**

| no. | age | sex | original phasing$^{(a)}$ | dating$^{(b)}$ | % gelatine | %C | %N | molar C/N | $\delta^{13}C$ | $\delta^{15}N$ | $\delta^{13}C^*$ | $\delta^{15}N^*$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7/I-a | old adult | male | LV Id | later | 0.46 | 21.1 | 7.43 | 3.31 | –19.7 | 11.49 |  | 15.8 |
| 7/II-b | old adult | female | LV Id | disarticulated | 0.45 | 22.75 | 9.59 | 3.26 | –19.75 | 15.12 |  | (?) |
| 11 | 14 y | nd | LV Ib-c | later | 1.47 | 42.69 | 14.98 | 3.33 | –18.76 | 15.15 |  |  |
| 14 | young adult | female | LV II | later | 0.17 | 26.28 | 10.53 | 2.91 | –21.38 | 9.35 | –18.6 | 15.1 |
| 17 | juvenile | female | LV II | later | 0.7 | 40.31 | 14.61 | 3.22 | –19.98 | 11.79 |  |  |
| 19 | old adult | female | LV IIIa | later | 3.65 | 42.53 | 16.95 | 2.93 | –18.95 | 15.52 | –18.8 | 14.8 |

*Table 2. continued*

**Lepenski Vir**

| no. | age | sex | original phasing(a) | dating(b) | % gelatine | %C | %N | molar C/N | δ13C | δ15N | δ13C* | δ15N* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 26 | young adult | male | LV I | later | 0.98 | 24.55 | 8.2 | 3.49 | –19.66 | 10.57 | –20.2 | 10.0 |
| 28 | senilis | male | LV II | later | 0.95 | 21.9 | 5.1 | 3.69 | –20.67 | 15.16 | –18.8 | 15.5 |
| 31/a | old adult | male | LV IIIb | 6220–5990 cal BC | 3.87 | 32.28 | 11.18 | 3.89 | –18.61 | 16.18 | –18.7 | 15.7 |
| 32/b | old adult | female | LV IIIb | 6080–5720 cal BC | 1.37 | 35.38 | 14.44 | 2.86 | –18.79 | 12.58 | –19.1 | 12.6 |
| 41 | young adult | female | ? | early | 3.35 | 45.89 | 17.95 | 2.98 | –18.78 | 14.41 | | |
| 42a | adult | male | LV II-III | later | 1.62 | 44.32 | 15.37 | 3.36 | –20.15 | 11.65 | | |
| 42b | old adult | female | LV IIIa | disarticulated | 2.29 | 41.88 | 16.36 | 2.99 | –18.26 | 15.24 | –19.0 | 12.8 |
| 45/b | old adult | male | LV I | later | 3.26 | 37.59 | 11.6 | 3.79 | –18.15 | 16.82 | –18.9 | 15.7 |
| 47 | old adult | female | LV Ic | early | 1.56 | 42.08 | 16.16 | 3.04 | –18.54 | 15.02 | –18.3 | 14.7 |
| 50 | old adult | male | LV I | early | 2.4 | 35.73 | 10.88 | 3.83 | –19.46 | 14.2 | –18.9 | 15.0 |
| 54/b | old adult | female | LV Ib | later | 1.64 | 37.61 | 14.74 | 2.98 | –19.78 | 10.38 | –19.9 | 11.2 |
| 54/c | old adult | female | LV Ib | later | 2.31 | 43.2 | 14.64 | 3.44 | –20.16 | 14.08 | –19.5 | 12.4 |
| 54/d | old adult | female | LV Ib | later | 0.51 | 29.24 | 10.75 | 3.17 | –19.93 | 13.41 | –18.0 | 15.3 |
| 54/e | young adult | female | LV Ib | later | 1.57 | 43.06 | 13.78 | 3.44 | –19.65 | 13.87 | –19.5 | 13.0 |
| 60 | young adult | male | LV Ic | early | 1.23 | 29.65 | 9.56 | 3.62 | –19.02 | 15.32 | –19.3 | 14.8 |
| 64 | old adult | male | LV I-II | later | 1.25 | 42.31 | 15.97 | 3.09 | –19.71 | 14.9 | –19.6 | 15.0 |
| 68 | senile | female | ? | early | 1.15 | 32.2 | 11.92 | 3.15 | –20.31 | 12.91 | | |
| 69 | old adult | male | Proto-LV | early | 0.56 | 32.43 | 11.76 | 3.22 | –19.4 | 14.44 | –19.2 | 14.8 |
| 70 | old adult | male | LV Ib-c | disarticulated | 1.18 | 44.83 | 16.18 | 3.23 | –18.51 | 15.97 | | |
| 72 | 2–4 y | nd | ? | disarticulated | 1.77 | 38.96 | 13.98 | 3.25 | –20.49 | 11.32 | | |
| 84 | 3–4 y | nd | ? | disarticulated | 2.38 | 39.65 | 14.3 | 3.24 | –18.81 | 13.2 | | |
| 89/b | 5 y | nd | ? | later | 2.16 | 46.19 | 16.26 | 3.32 | –19.25 | 15.25 | | |
| 90 | young adult | male | ? | early | 2.15 | 41.27 | 15.95 | 3.02 | –18.25 | 16.61 | | |
| 91 | young adult | female | ? | later | 0.18 | 22.23 | 8.31 | 3.12 | –20.42 | 12.98 | | |
| 93 | old adult | female | ? | later | 0.3 | 34.18 | 12.06 | 3.31 | –20.13 | 12.2 | | |
| 99 | 12–13 y | nd | LV Ia-e | disarticulated | 1.37 | 37.82 | 13.69 | 3.22 | –20.31 | 9.14 | | |
| 100 | 12–14 y | nd | LV Id-e | disarticulated | 0.64 | 37.34 | 14.56 | 2.99 | –20.43 | 9.79 | | |
| 104 | 15–17 y | nd | ? | later | 4.22 | 53.43 | 16.83 | 3.38 | –20.06 | 15.59 | | |
| 63 | neonate | female | LV Id-e | later | 1.93 | 45.01 | 15.58 | 3.37 | –19.27 | 15.49 | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 94 | neonate | male | LV Id-e | later | 0.35 | 34.79 | 13.03 | 3.12 | –19.38 | 15.16 |
| 101 | neonate | nd | LV Id-e | later | 1.4 | 37.11 | 13.28 | 3.26 | –19.37 | 15.25 |
| 103 | neonate | male | LV Ia-e | later | 1.88 | 57.14 | 19.24 | 3.47 | –18.84 | 17.66 |
| 107 | neonate | male | LV Ia-b | later | 2.65 | 49.1 | 17.14 | 3.34 | –18.41 | 16.79 |
| 109/a | neonate | female | LV Ia-b | later | 3.22 | 44.31 | 15.4 | 3.36 | –19.43 | 16.21 |
| 110 | neonate | female | LV Ia-b | later | 2.07 | 45.29 | 16.01 | 3.3 | –20.2 | 16.23 |
| 111 | neonate | female | LV Ia-b | later | 1.12 | 48.25 | 16.48 | 3.42 | –20.05 | 15.37 |
| 113 | neonate | female | LV Ia | later | 2.85 | 46.15 | 16.01 | 3.36 | –20.24 | 15.02 |
| 116 | neonate | female | LV Ia-b | later | 2.5 | 43.4 | 15.32 | 3.3 | –19.53 | 15.32 |
| 118 | neonate | female | LV Ia-c | later | 3.09 | 40.75 | 14.78 | 3.22 | –18.84 | 15.9 |
| 125 | neonate | male | LV Ib | later | 2.13 | 61.7 | 21.56 | 3.34 | –19.28 | 16.21 |
| 127 | neonate | female | LV Ib | later | 0.66 | 33.5 | 12.26 | 3.19 | –18.67 | 16.6 |

(a) = excavator's original phasing of burials – for Vlasac: Srejović and Letica (1978); for Lepenski Vir: Srejović (1969, 1972).
(b) = a tentative dating of Vlasac burials into 'early' (c. 9000–7600 cal BC) and 'later' (c. 7600–6500 cal BC) and Lepenski Vir burials into 'early' (up to c. 6300 cal BC) and 'later' (after c. 6300 cal BC) provided on the basis of an extrapolation of stratigraphic observations, burial position and available radiometric evidence where applicable. Dating of disarticulated burials was not attempted (see text). Available radiometric dates for particular burials are calibrated at 2 s.d. (see Table 3 for details).
* = Stable isotopes reported by Bonsall et al. (1997, 2000).

previously analysed burials by 43 additional skeletons from Vlasac and 29 from Lepenski Vir. Bonsall et al.'s (1997) and our analyses overlap by eight measurements from Vlasac and by 18 from Lepenski Vir, and these overlaps are made in order to check for the consistency of sampling/labelling procedures as well as the inter-laboratory analytical rigour.[2]

Stable carbon and nitrogen isotope analyses provide information about an individual's protein intake. The stable carbon isotope value ($\delta^{13}C$) distinguishes between marine, terrestrial, and freshwater protein input to the diet. The stable nitrogen ($\delta^{15}N$) measures the level on which the protein is derived in the food chain. Here the analysed human samples come from bone. Due to constant remodelling of bone during an individual's lifetime, the obtained stable isotope signature reflects the diet primarily during the last 10 years of an adult individual's life (see some recent comments in Hedges 2004).

In our analyses, collagen was extracted according to Bocherens et al. (1997). The $\delta^{15}N$ and $\delta^{13}C$ of organic samples were detected online by a mass spectrometer type Thermo Finnigan Delta plus, coupled with a CHN-analyser Thermo Finnigan NA2500. Isotopic ratios are expressed in the conventional δ-notation referring to PDB- and AIR-standard. Measurement error never exceeded 0.15‰, and although this level of precision does not affect our palaeodietary inferences, the results are given to 2 decimal places in Tables 1 and 2. The percentage of carbon and nitrogen of the collagen extract, as well as molar C/N ratios were used for quality control. While a few specimens had C/N ratios outside of the recommended range (2.9–3.6) their respective δ values remain within the expected variability of measured isotopic ratios, and did not produce any outliers.

## RECONSTRUCTING THE FOOD WEB IN THE DANUBE GORGES

For the reconstruction of the food web in the Danube Gorges, a previous stable isotope project used three fish bones of unspecified species, one otter and three 'bovid (?)' bones from Lepenski Vir, and seven 'bovid (?)' bones from Schela Cladovei (Bonsall et al. 1997:7). By expanding the sample of analysed faunal remains we aim to represent more accurately the complexity of the food web in the course of the Mesolithic–Neolithic occupation of the region.

The larger faunal reference sample analysed here suggests that the vertebrate spectrum meets physiological expectations (Fig. 2): while the carnivorous wolfs, dogs, pine marten, and lynx are located on the top of the food chain, exhibiting highest $\delta^{15}N$ values, lowest values are measured in the exclusively herbivorous red deer and roe deer. The omnivorous brown bear and wild boar are located between carnivores and herbivores. The bone fragment of a juvenile wild pig belonged to a suckling piglet, and as such does not fall in the expected range for adult pigs.

Concerning dogs, the only domesticated species in the Mesolithic (Bökönyi 1975), it is noteworthy that the majority of dog specimens are indistinguishable from wolves isotopically, with the single exception of one dog, which resembles carp in terms of isotopic ratios. This exception may be a consequence of diachronic changes in the course of a long sequence of occupation at Vlasac, and it also

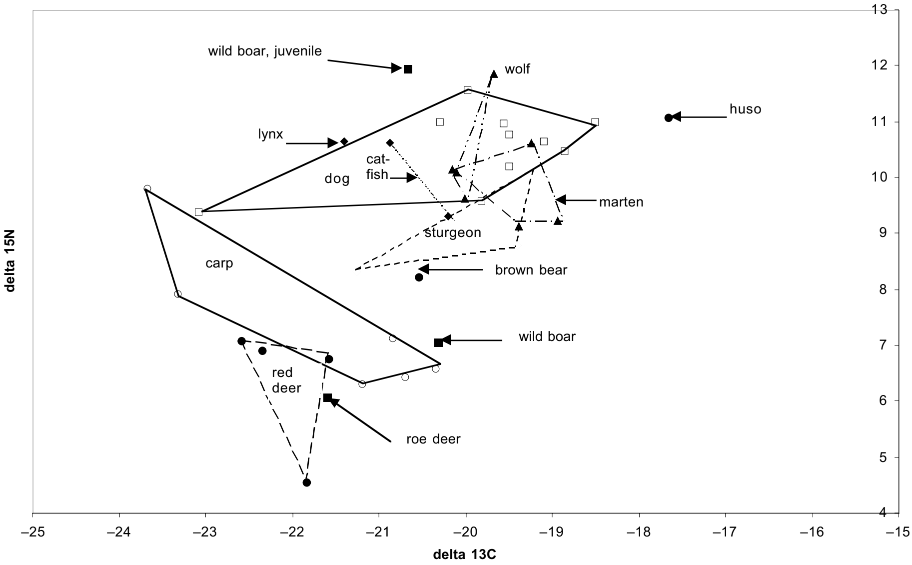

**Figure 2.** *Bivariate plot of δ¹³C and δ¹⁵N values of bone collagen from various animal species from Vlasac, with the addition of one red deer bone from Padina (see Table 1). Trophic levels are maintained both for the terrestrial and the aquatic food chain.*

indicates that individual differences in dietary behaviour may occur within the same species. Therefore, several individuals of one species should be analysed whenever possible. Yet, almost all the canid (*Canis familiaris* and *Canis lupus*) specimens that we analysed (16 specimens in all) are slightly enriched with $^{15}$N (i.e. between +9.38 and +11.87‰, with only two specimens with their δ$^{15}$N values just below +10‰; Table 1). It has previously been suggested on several occasions that one could use dog remains as proxies for human diets (Schulting and Richards 2002). For the Danube Gorges sites, however, this assumption has to be rejected since human values from both Vlasac and Lepenski Vir are clearly on the top of the food chain (see later in this article and see Table 2), exhibiting isotopic values more enriched with $^{15}$N than the dogs. On the basis of these findings, we could suggest that dogs from Vlasac most probably lived on leftovers of fish and game discarded by humans, while rather enriched δ$^{15}$N values exhibited by wolves require further attention, especially in the context of canid domestication. On the other hand, abundant presence of dog remains with butchery marks (see Borić 2002b; Borić and Dimitrijević in press; Clason 1980) may suggest that humans consumed dogs.

Expectations are also met with regard to the aquatic food chain, where the piscivorous catfish, beluga, and sturgeon are enriched with $^{15}$N over the detritivorous carp. The latter is also characterized by a tendency towards lower δ$^{13}$C values. The beluga δ$^{13}$C value of –17.66‰ may be indicative of the species' anadromous (migratory) behaviour, whereas smaller species of sturgeon might have been confined to the Danube eco-system only. As shown in Table 1, modern specimens of zander and catfish, caught at Golubac (the northern entrance to the Danube Gorges) in 2001, have much lower $\delta^{13}C$ values than the archaeological fish remains from Vlasac. This difference is most probably due to major changes in the riverine ecology over time. This example illustrates the limited relevance of modern animal specimens for the reconstruction of past food webs.

## PATTERNS OF STABLE ISOTOPE RESULTS

The bivariate plot of $\delta^{13}C$ and $\delta^{15}N$ values summarizes the analysed humans from Vlasac and Lepenski Vir, and analysed dog bones from Vlasac (Fig. 3). There are several major implications that one can draw from the observed patterning of this data set.

First, in general, these results show that human subsistence must have relied heavily on freshwater fish[3] and was focused on large piscivorous species since their capture must have provided the population with large amounts of meat and fat (cf. Bonsall et al. 1997, 2000; Grupe et al. 2003). The results imply the intake of both freshwater fish and migratory sturgeon from the Black Sea, which was possibly a lake before 6700 BP (see Ryan et al. 1997). Here we may add that the consumption of fish roe (caviar) could have had a particular impact on the observed $^{15}N$ enrichment measured in humans due to the recycled nitrogen within a sturgeon's body, similar to a nursing signal of suckling mammals.[4] Although further research is needed, we hypothesize that this enrichment should also apply to fish eggs, which are likewise the product of a female's body. Dried

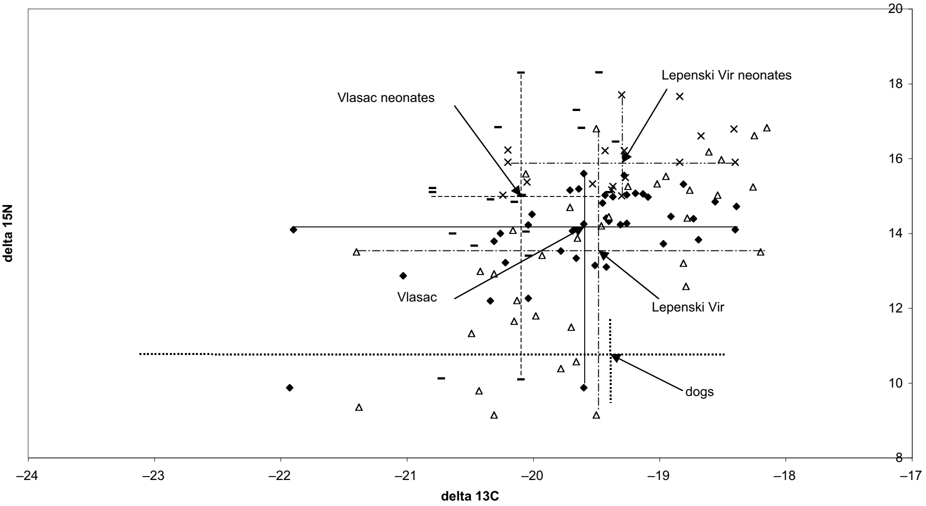

**Figure 3.** *Bivariate plot of $\delta^{13}C$ and $\delta^{15}N$ valules of bone collagen from human and dog bones from Vlasac and Lepenski Vir. Mean, minimum and maximum values for humans (separately for the neonates) are indicated. Black diamonds = Vlasac; dashes = Vlasac neonates; open triangles= Lepenski Vir; crosses= Lepenski Vir neonates.*

anadromous fish might also have been stored for the winter seasons. It is noteworthy that the consumption of fish is reflected isotopically in both Mesolithic and early Neolithic burials at Lepenski Vir, although with arguable changes in the Neolithic period (Bonsall et al. 1997, 2000). We shall return later to this last observation.

Second, our stable isotope results indicate differences between the two sites and different age groups. Out of 51 analysed burials from Vlasac, only five burials have $\delta^{15}N$ values below +13‰ (only burials 51 and 66a are significantly below), while out of 46 analysed burials from Lepenski Vir, 13 have $\delta^{15}N$ values below the +13‰ threshold (see Table 2). At the same time, these lower $\delta^{15}N$ values of some individuals from the two sites still indicate enrichment due to higher protein intake although one can suggest that they fed on a broader spectrum of dietary sources than those individuals with $\delta^{15}N$ values above +13‰. There are two main questions with regard to these results that we raise later: (1) do the differences in $\delta^{15}N$ values combined with the absolute dating of particular burials indicate diachronic dietary changes? and, (2) what dietary sources might have supplemented the consumption of fish for those individuals with $\delta^{15}N$ values below +13‰?

Third, on the basis of our isotopic analyses of archaeological fish specimens we are able to better understand the contribution of various fish species in patterning stable isotope results for humans. For instance, the 100 per cent consumption of an aquatic source such as carp, which according to our data could have ranged from +6.3–9.8‰ (Table 1), by applying +3.4‰ trophic level between this fish species and humans who consumed it (Minagawa and Wada 1984), would have produced a dietary spectrum between +9.7 and 13.2‰ in humans. However, this finding on its own does not prove that the humans in the Danube Gorges who isotopically fall into this range derived their protein intake only from carp (i.e. an aquatic source) over their lifetime. Since $\delta^{15}N$ values do not reflect the aquatic food sources only but the general contribution of protein in diet, the protein reflected in $\delta^{15}N$ values is a combination of several food sources. In addition, in the Danube Gorges, fish roe or even dogs might have added to the enriched $\delta^{15}N$ values. Similarly, abundant mammal remains at these sites indicate the subsistence importance of hunted game (see later). Yet, on the basis of previous isotopic analyses, Cook et al. (2002) estimate the contribution of aquatic sources to the diet in order to estimate the correction factor for the reservoir effect in absolute dating of burials. They take the highest $\delta^{15}N$ value of +17‰ measured for an adult individual from Lepenski Vir (burial 89a: Bonsall et al. 1997:table 5) as an end-point for 100 per cent aquatic diet, while an end-point of +8‰ is equated with 100 per cent terrestrial diet. Cook et al. (2002) suppose that the intake of aquatic food for five burials from Vlasac dated to the Mesolithic (Fig. 4), with high levels of $\delta^{15}N$, made up more than 70 per cent of their diet. With regard to our data, the highest measured $\delta^{15}N$ value of an adult from Vlasac is +15.55‰, and for an adult from Lepenski Vir +16.82‰ (see Table 2). However, we would disagree with the interpretation that sees the $\delta^{15}N$ value of +17‰ as an indication of an individual's 100 per cent intake of aquatic foods since this value may be derived from several protein-rich food sources and not only fish.

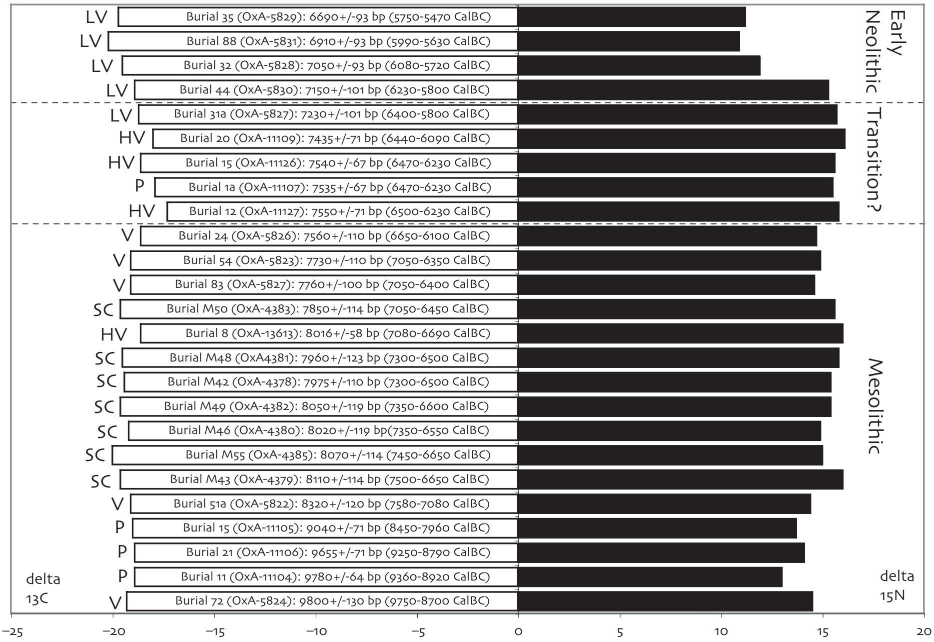

**Figure 4.** *$\delta^{13}$C and $\delta^{15}$N values for securely dated human individuals from sites in the Danube Gorges (Source: Table 3). LV = Lepenski Vir; HV = Hajdučka Vodenica; P = Padina; V = Vlasac; SC = Schela Cladovei.*

Pointing out the complexities of isotopic results puts into perspective a rather straightforward estimation of terrestrial versus aquatic contributions to an individual diet. Therefore, we raise the issue with regard to possible limits of using stable isotope data alone in providing very high-grained indications about palaeodiets (see Milner et al. 2004), and reject as misleading the possibility that dietary practices based on stable isotopes can be measured in percentages with the view of a fixed 100 per cent terrestrial as opposed to 100 per cent aquatic diet. This issue is further discussed by looking at faunal evidence from the two sites.

## FAUNAL REMAINS FROM VLASAC AND LEPENSKI VIR

Here we examine to what degree the information about palaeodiet based on stable isotopes is reflected in faunal data. At present, both Lepenski Vir and Vlasac have somewhat biased samples of preserved faunal remains. On one hand this situation is due to the rescue nature of excavations of the sites in the Danube Gorges in the 1960s and 1970s and hand-collecting of animal bones (without dry or wet sieving of the excavated sediments). On the other hand existing faunal assemblages from both sites are partial survivors of the originally collected faunal assemblages, since after their initial analyses (Bökönyi 1969, 1972, 1978) large portions of the two assemblages appear to have been discarded (see Borić 2001 for further discussion about biases of faunal samples from this region).[5]

Fortunately, small samples of faunal assemblages from both sites were preserved after their initial analyses and these bones provided the possibility for reanalysis and stable isotope measurements. In addition, some parts of the originally collected faunal assemblages have not been analysed previously. These unanalysed animal bones from Lepenski Vir mainly come from excavation units immediately on or beneath the limestone floors of Lepenski Vir trapezoidal buildings (Borić and Dimitrijević in press; Dimitrijević 2000 in press).

Based on the previously existing reports from Vlasac and Lepenski Vir (Bökönyi 1969, 1972, 1978), Bonsall et al. (2000:121) claim the absence of Acipenseridae from the faunal assemblages of these two sites (cf. Bartosiewicz et al. 2001:19). However, although at Lepenski Vir Bökönyi (1969:224–225, 1972) identified only catfish and carp, sturgeon remains are now positively identified in the preserved assemblage (Borić and Dimitrijević in press). Moreover, these faunal units relate to the occupation of trapezoidal buildings (i.e. to the period between 6400 and 5500 cal BC that is contemporaneous with the establishment of the first early Neolithic sites in the surrounding regions and the first appearance of early Neolithic pottery in the Danube Gorges: see Borić 1999, 2002a; Garašanin and Radovanović 2001; Whittle et al. 2002). Faunal remains in this case indicate that fish, including large specimens of sturgeon, were abundantly exploited during the early Neolithic phase of occupation at Lepenski Vir.[6] On the other hand, contrary to Bökönyi's report, analysed faunal units related to the occupation of the site during the early Neolithic show no evidence with regard to the presence of domestic animals (Borić and Dimitrijević in press; Dimitrijević 2000 in press). Both conclusions will be discussed later and compared with the previously offered interpretation of stable isotopes from the Danube Gorges, which maintains that the dietary changes at the beginning of the Neolithic were caused by 'a direct investment in agriculture' and the introduction of domestic animal husbandry and cultivation in this region (Bonsall et al. 2000:127).

As previously mentioned, a very limited sample of animal bones has been preserved from Vlasac[7], along with a larger assemblage of bone tools. In his report, Bökönyi (1978:table 1) notes only the presence of catfish, carp, and pike at Vlasac along with 8372 unidentified fish bones. Here, it seems that the absence of sturgeon is an artefact of Bökönyi's analytical procedure, particularly the lack of analytical focus on fish remains. The preserved assemblage of fish bones from Vlasac that we analysed amounts to a total of 1100 remains. There are 343 specimens of fish identified to the species or family level: wild carp *Cyprinus carpio* (n=258=75.1%), catfish *Siluris glanis* (n=40=11.7%), Salmonidae (n=7=2.0%), and Acipenseridae (n=38=11.1%). Due to the size of sturgeons (> 2.5 m) and catfish (1.5 m) compared to those of wild carps (0.4–0.5 m), these two taxa should have contributed 50 per cent of fish-related resources or more to the human diet, despite the lower specimen numbers.

## ABSOLUTE DATING AND PHASING OF ISOTOPICALLY ANALYSED BURIALS

The complex stratigraphic situation at sites in the Danube Gorges makes it difficult to phase human burials with certainty unless absolutely dated or stratigraphically connected with previously absolutely dated residual material found in association with architectural features. Hence an understanding of the complexity of burial rites is yet another element of a valid interpretation of isotopic results.

For example, it has not been possible to suggest even an approximate dating of a number of disarticulated burials (single bones or anatomical groups) found across the settlement deposits of the two sites discussed (Table 2).[8] Due to the need to reanalyse stratigraphic relations of burials and other features at Lepenski Vir (Borić 1999, 2002a, 2002b; Garašanin and Radovanović 2001; Radovanović 1996) and Vlasac (Borić 2002b; Radovanović 1996), we have had to revise or suspend the original excavator's phasing of burials from the two sites for the chronological ordering of our isotopic results. Moreover, although we have tentatively dated burials to 'early' and 'later' for the two sites respectively (Table 2), we also have refrained from drawing conclusions from the emerging patterns since at the moment this dating is based on rather speculative inferences, extrapolating the available radiometric dates, stratigraphic relations and burial positions.

In order to provide a realistic pattern of diachronic changes in stable isotope values for the Danube Gorges sites on the basis of the presently available data, we plotted only absolutely dated burials from the Mesolithic–early Neolithic sites (Table 3; Fig. 4), with 6300 cal BC as a cut-off date for an approximate start of the early Neolithic in the wider region of the north-central Balkans. The definition of the start of the early Neolithic is based here on the appearance of the early Neolithic pottery and other typically early Neolithic material paraphernalia (Borić 1999, 2002a; Whittle et al. 2002). Without the intention of drawing absolute and rigid boundaries by this type of labelling, these groupings of the dated human burials into 'Mesolithic', 'Transition?' and 'early Neolithic' as depicted in Figure 4 are intended as an heuristic visualization for the general timing of the Mesolithic–Neolithic transformation in the region.

Radiocarbon dates from Vlasac and Lepenski Vir suggested to Bonsall et al. (1997, 2000; Cook et al. 2002) that some variations in the intake of aquatic sources can be monitored over time. Three out of five absolutely dated burials from Lepenski Vir show the intake of lower trophic-level protein largely from terrestrial foods. This dietary shift from aquatic to more terrestrial food sources, admittedly still with 'a significant proportion of their dietary protein from riverine resources' (Bonsall et al. 1997:85) is dated to the period after c. 6000 cal BC, and according to their model, is related to the development of agriculture and 'the introduction of stock-raising and/or cultivation in the Iron Gates' (Bonsall et al. 1997:85, 2000:127). Since no major dietary shift is apparent among the Vlasac burials, which have Mesolithic dates (Fig. 4), Bonsall et al. (1997, 2000:128–130) suggest that stable isotope data from the Danube Gorges can be used as a dating proxy to distinguish Mesolithic and early Neolithic burials.

*Table 3. Stable isotope data for AMS-dated skeletons from the Danube Gorges. Dates corrected for the freshwater reservoir effect according to Method 2 as described by Cook et al. (2002:82). All dates calibrated with OxCal v. 3.9 (Bronk Ramsey 1995, 2001) using the INTCAL98 calibration curve (Stuiver et al. 1998).*

| site | burial no | lab ID | $\delta^{13}$C | $\delta^{15}$N | $^{14}$C age BP | corrected for FWR-effect | calibrated (2sd) |
|---|---|---|---|---|---|---|---|
| Vlasac (1) | 72 | OxA-5824 | –19.3 | 14.5 | 10240+/–120 | 9800+/–130 | 9750–8700 |
| | 51a | OxA-5822 | –19.1 | 14.4 | 8760+/–110 | 8320+/–120 | 7580–7080 |
| | 83 | OxA-5826 | –19.1 | 14.6 | 8200+/–90 | 7760+/–100 | 7050–6400 |
| | 54 | OxA-5823 | –19.1 | 14.9 | 8170+/–100 | 7730+/–110 | 7050–6350 |
| | 24 | OxA-5825 | –18.6 | 14.7 | 8000+/–100 | 7560+/–110 | 6650–6100 |
| Lepenski Vir (2) | 31a | OxA-5827 | –18.7 | 15.7 | 7770+/–90 | 7230+/–101 | 6400–5800 |
| | 44 | OxA-5830 | –18.9 | 15.3 | 7590+/–90 | 7150+/–101 | 6230–5800 |
| | 32 | Oxa-5828 | –19.5 | 11.9 | 7270+/–90 | 7050+/–93 | 6080–5720 |
| | 88 | OxA-5831 | –20.2 | 10.9 | 7130+/–90 | 6910+/–93 | 5990–5630 |
| | 35 | OxA-5829 | –19.7 | 11.2 | 6910+/–90 | 6690+/–93 | 5750–5470 |
| Padina (3) | 21 | OxA-11106 | –18.9 | 14.1 | 10095+/–55 | 9655+/–71 | 9250–8790 |
| | 11 | OxA-11104 | –18.9 | 13 | 10000+/–60 | 9780+/–64 | 9360–8920 |
| | 15 | OxA-11105 | –19 | 13.7 | 9480+/–55 | 9040+/–71 | 8450–7960 |
| | 1a | OxA-11107 | –17.9 | 15.5 | 7975+/–50 | 7535+/–67 | 6470–6230 |
| Hajdučka Vodenica (4) | 8 | OxA-13613 | –18.6 | 16 | 8456+/–37 | 8016+/–58 | 7080–6690 |
| | 12 | OxA-11127 | –17.3 | 15.8 | 7990+/–55 | 7550+/–71 | 6500–6230 |
| | 15 | OxA-11126 | –18.6 | 15.6 | 7980+/–50 | 7540+/–67 | 6470–6230 |
| | 20 | OxA-11109 | –18 | 16.1 | 7875+/–55 | 7435+/–71 | 6440–6090 |
| Schela Cladovei (5) | M43 | OxA-4379 | –19.6 | 16 | 8550+/–105 | 8110+/–114 | 7500–6650 |
| | M55 | OxA-4385 | –20 | 15 | 8510+/–105 | 8070+/–114 | 7450–6650 |
| | M49 | OxA-4382 | –19.6 | 15.4 | 8490+/–110 | 8050+/–119 | 7350–6600 |
| | M46 | OxA-4380 | –19.2 | 14.9 | 8460+/–110 | 8020+/–119 | 7350–6550 |
| | M42 | OxA-4378 | –19.4 | 15.4 | 8415+/–100 | 7975+/–110 | 7300–6500 |
| | M48 | OxA-4381 | –19.5 | 15.8 | 8400+/–115 | 7960+/–123 | 7300–6500 |
| | M50 | OxA-4383 | –19.6 | 15.6 | 8290+/–105 | 7850+/–114 | 7050–6450 |

(1) = Bonsall et al. (1997:table 3, 2000:table 3); Cook et al. (2002:table 4).
(2) = Bonsall et al. (1997:table 5, 2000:table 3); Cook et al. (2002:table 5).
(3) = Borić and Miracle (2004:table 5).
(4) = Borić and Miracle (2004:table 6). Note that OxA-13613 replaces previously published OxA-11128.
(5) = Bonsall et al. (1997:table 4, 2000:table 3); Cook et al. (2002).

While $\delta^{13}$C values do not differ significantly over time, three dated individuals from Lepenski Vir with the youngest dates do indeed exhibit lowest $\delta^{15}$N values (Fig. 4). However, no sharp dichotomy between Mesolithic and early Neolithic dietary behaviour has emerged. The isotopic data suggest to us a broadening of the dietary spectrum during the early Neolithic occupation of Lepenski Vir (i.e. only after 6000 cal BC), at least with regard to certain individuals. However, this conclusion is at the moment based primarily on stratigraphic dating of analysed burials as well as on these three dated burials to support the postulated change in the early Neolithic, and in order to accept or reject this assumption, we need more dates that would confirm this correlation between $\delta^{15}$N values significantly below +13‰ and post-6000 cal BC dating of human burials.

Furthermore, Bonsall et al. (2000:124; see Table 3) suggest distinguishing, on the basis of $\delta^{15}$N, three groups among analysed individuals from Lepenski Vir, which they assert have chronological significance: group 1 – mainly aquatic sources of protein (+14.4 – 17.0‰), dated to c. 6400–5800 cal BC (burials 31a and 44); an 'intermediate' group 2 (+11.8–+14.0‰) – similar proportions of aquatic and terrestrial protein, dated to c. 6080–5720 cal BC (burial 32); and, group 3 – mainly terrestrial sources of protein (+9.3–+11.2‰), dated to c. 5990–5470 cal BC. However, recently AMS-dated burials 11, 15, and 21 from Padina have respective $\delta^{15}$N values at +13‰, +13.7‰, and +14.1‰, and fall into this 'intermediate' range while actually dating to the early Mesolithic (the chronological range for all three burials is between 9360 and 7960 cal BC at 2 s.d.; Table 3). On the basis of these data, Bonsall et al.'s (2000:126–128) conclusion that the 'intermediate'/transitional Mesolithic-Neolithic group of burials, both isotopically and chronologically, fall between an aquatic/Mesolithic and terrestrial/early Neolithic diets has to be rejected. On the contrary, we conclude that fluctuations in the intake of aquatic sources in human diets are evident over the Mesolithic sequence too.

Even if one accepts stable isotopes as a dating proxy in distinguishing Mesolithic from a later phase early Neolithic burials, with a more crudely but realistically set threshold of the $\delta^{15}$N values at +13‰, the validity of any interpretation with regard to stable isotope results significantly relies on details of the archaeological context. Here, the question of contemporaneity of human remains found in the same context is of critical importance.

Consider the case of burials 7/I-a and 7/II-b (Fig. 5). Although there is a good overall agreement between the isotopic values of those skeletons analysed in duplicates by the two research groups (see Table 2), in the case of burials 7/I-a and 7/II-b, major discrepancies occur in the results. Possibly this can be attributed to the mislabelling of burials during sampling. Bonsall et al. (2000:129) suggest that houses 21, 22, 29, and 30 at Lepenski Vir are Mesolithic, based on the palaeodietary signature of burial 7/I, an extended inhumation cut through the floor of the latest building at this location, house 21, that superimposed all previous buildings. This burial with a $\delta^{15}$N value of +15.8‰ as quoted by Bonsall et al. indicates to them a 'Mesolithic' dietary pattern and was referred to as burial '7/b or 7/I' (Bonsall et al. 2000). Such labelling is incorrect since this burial (extended articulation) was originally labelled '7/I or 7/a', while another separate skull from the same burial

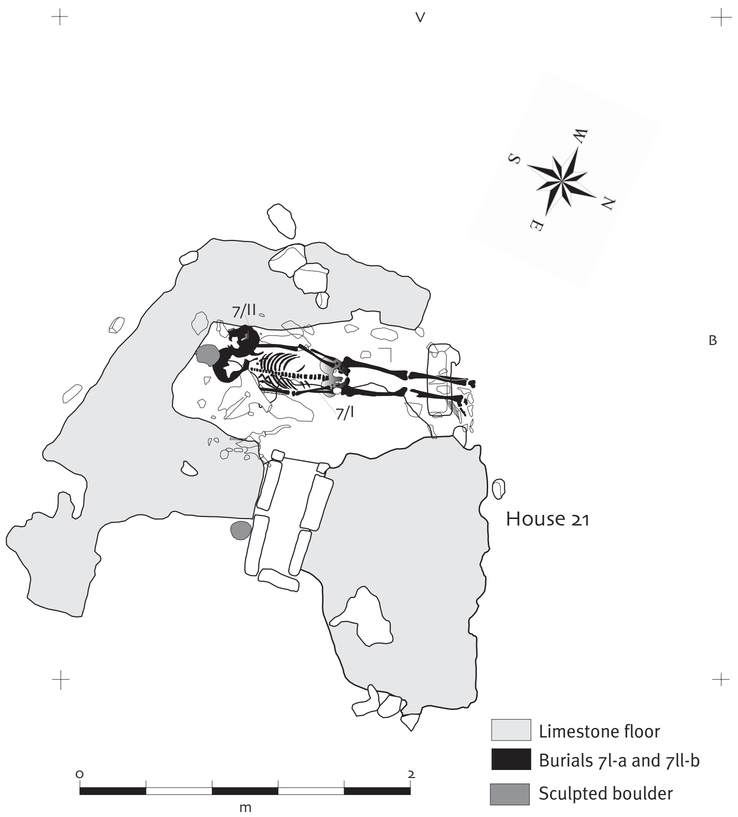

**Figure 5.** *House 21 and burials 7/I-a and 7/II-b, Lepenski Vir (after Stefanović and Borić in press:fig. 15).*

was labelled '7/II or 7/b' (see Radovanović 1996:fig.4.3). Thus, the sample used in this measurement might have come from the detached skull (burial 7/II, i.e. 7b) and not from the articulated extended inhumation (burial 7/I, i.e. 7a).

First, our measurements of the two skeletons (Table 2) suggest that mislabelling most likely took place. Second, by looking at the archaeological context of this burial and at morphological differences between the two skulls with regard to the pronouncedly different degrees of robustness, the possibility arises that there is a chronological difference between the two individuals. On the other hand, a population change might also have been marked by morphological differences (cf. Mikić 2003). The detached skull could be interpreted as being of some ancestral significance (possibly as a relic) and is likely to have been incorporated into this burial some time after this individual (7/II-b) deceased (cf. Borić 2003; Stefanović and Borić in press). Thus, this skull may indeed have a different dietary signature and, as such, would incorrectly point to the Mesolithic age of the building, which stratigraphically predates the interment of fully articulated inhumation burial 7/I-a.

On the one hand, our isotopic measurements for burial 7/I-a show an isotopic signature that indicates a mixed diet, less heavily based on riverine resources (Grupe et al. 2003), and which, according to the logic of Bonsall et al.'s (2000) dating proxy, is indicative of the chronological span of the early Neolithic period. Moreover, our $\delta^{15}N$ value measured for burial 7/II-b corresponds closely to the measurement made by Bonsall et al. (2000) when labelling the sample as '7/b or 7/I', referring to the extended inhumation (see Table 2). At the moment, we can only speculate that the abandonment of this building by interring burial 7/I-a can be associated after all with the early Neolithic phase at this site (i.e. the period after c. 6300 cal BC) on the basis of the burial's dietary signal. Only AMS dating of both individuals will clarify this particular point.

Another case concerning major discrepancies between Bonsall et al.'s (1997, 2000) and our results is the case of burials 42a (articulated inhumation) and 42b (disarticulated burial) from Lepenski Vir. We again are confronted with the same problem of mislabelling/error sampling, since it is possible that the much older disarticulated remains of burial 42b were deposited alongside the chronologically later inhumation burial 42a. There are only two other cases of larger discrepancies between the duplicated measurements – burials 14 and 54c from Lepenski Vir (see Table 2). There is no obvious explanation of these differences, and it would be worth re-measuring these two burials in the future.

## DISCUSSION

Our isotopic study of burials from Lepenski Vir and Vlasac and, also, various animal species from Vlasac and Padina, confirms previous indications that large carnivorous species of fish such as catfish or various species of sturgeon, the remains of which are abundantly present at the discussed archaeological sites during the Mesolithic and early Neolithic phases of occupation, were probably providing a significant $^{15}N$ enrichment to human diets. However, a part of this enrichment might have in particular come from the currently unknown effect that fish roe (i.e. some sort of caviar) could have and, also, through the possible consumption of dogs, which are themselves enriched by $^{15}N$ due to the intake of fish leftovers. It follows that, although fish sources in the Danube Gorges had a significant impact on the diet of the sites' inhabitants, we need a more complex understanding than a simple dichotomous distinction between terrestrial versus aquatic diets.

With regard to diachronic changes in diet, lower $\delta^{15}N$ values ($< +13$‰), compatible with the dog bones' isotopic signatures, show up especially well at Lepenski Vir. Here, three dated burials with such values belong to the period after c. 6000 cal BC, while all dated burials from other sites with $\delta^{15}N$ values $\geq +13$‰ date to the period before c. 6000 cal BC. However, before one can start using stable isotope data as means of distinguishing Mesolithic versus early Neolithic burials in this region, a robust series of absolute dates should be available accompanying stable isotope measurements, and as such the suggested dating proxy must remain tentative at present. Moreover, it seems that dietary changes, whether applicable to the whole or only parts of the population, were not extreme or sudden. Currently, they are evident only after c. 6000 cal BC, while early Neolithic pottery appears in the Danube Gorges already around 6300 cal BC. Also, two burials from Lepenski Vir – burials 31a and 44 – date in the range 6400–5800 and 6230–5800 cal BC at 2 s.d. respectively, overlapping with the early Neolithic sequence (i.e. the period after c. 6300 cal BC), but have undoubtedly 'Mesolithic' dietary signatures: $\delta^{15}N > +15‰$ (see Fig. 4).

Faunal remains provide additional information in balancing out our views of dietary habits based on the stable isotope results. While Bonsall et al. (2000:127) relate changes in dietary habits after c. 6000 cal BC to 'a direct investment in agriculture', on the basis of faunal remains from Vlasac, Lepenski Vir, and Padina, it seems unlikely that agricultural practices and farming ever played an important part in the subsistence base of the early Neolithic inhabitants of the Upper Gorge of the Danube (see Fig. 1). The situation might have been different at Schela Cladovei during the early Neolithic phase of occupation at this site (see Bartosiewicz et al. 2001), since it is situated in a different environment, more suitable for early farming. Thus, the adoption of the 'Neolithic package' was not likely to have been wholesale in the region, which supports some of the previously suggested scenarios for the Neolithization of the region envisioning a mosaic of processes of transformation (e.g. Borić 1999; Tringham 2000; Whittle et al. 2002).

An increasing reliance on, for instance, hunted game as a source of terrestrial protein or perhaps food taboos toward certain fish species (cf. Radovanović 1997; see also Richards 2003; Thomas 2003) could be considered as viable interpretations for the observed pattern of using a broader spectrum of resources during the early Neolithic phase at Lepenski Vir. That fish played a significant, although possibly varying, role in the subsistence during the early Neolithic occupation of Lepenski Vir is clear, both from stable isotopes and the presence of a large number of fish bones (including migratory Acipenseridae) found in contexts related to the occupation of trapezoidal buildings at Lepenski Vir, and in the same context of similar structures also found at the neighbouring and contemporaneous site of Padina. Conversely, contexts dated to the Mesolithic period at Padina indicate that terrestrial food sources such as game played a significant role along with the importance of fish during the Mesolithic (Borić 2002b:appendix 3). Thus, a contextualization of the isotopic palaeodietary patterns is best accomplished by a complementary consideration of faunal remains and their archaeological context.

## CONCLUSION

We conclude that the assumption about a Mesolithic–Neolithic subsistence dichotomy – from largely fish-based subsistence in the Mesolithic to a diet significantly altered by the introduction of agricultural products in the early Neolithic – is overly simplistic and not supported by the existing evidence in the Danube Gorges on the basis of our extended isotopic study of human burials from Vlasac and Lepenski Vir. In this article, we have also aimed for a better integration of isotopic results and archaeological evidence, hoping to provide a more nuanced perception of Mesolithic–Neolithic transformations in the studied region. Obtaining more absolutely dated burials to monitor diachronic dietary changes still remains a priority to confirm our results but the dietary shift seen here does not appear to be fundamental or sudden. Furthermore, a possibly increasing reliance upon terrestrial food sources after 6000 cal BC does not seem to be related to the introduction of agriculture in the Upper Gorges sites, since the existing faunal evidence does not support such a model. Also, any subsistence changes lagged behind the appearance of early Neolithic pottery in the region for at least several centuries. A simple question of 'who is who?' among the buried individuals at the discussed sites in chronological and population terms still remains, and disentangling methodological and chronological aspects of this case study continues through ongoing research efforts.

## ACKNOWLEDGEMENTS

This project was made possible through the collaboration of the Bavarian State Collection of Anthropology and Palaeoanatomy in Munich (Germany) and the Anthropological Collection of the Faculty of Philosophy, Belgrade University (Serbia). The Deutsche Forschungsgemeinschaft financially supported the project. We also acknowledge the financial support of the Humboldt Foundation through the Fritz Thyssen Programme for the scientific reconstruction of south-east Europe (V-Thyssen-SER/1094682 and V-8121/SER/1018576). We are most indebted to Dr U. Struck, GeoBio-Center of the University of Munich, for the mass spectrometry. We also thank Vesna Dimitrijević, Robert Hedges, Preston Miracle, Kirsten Olson, Doug Price, and Alasdair Whittle for their useful comments on previous drafts of the article.

## NOTES

1. This work is part of a long-term project of systematic, detailed, and coordinated study of human osteological material from the Danube Gorges. The results presented here represent the initial phase of a joint effort at obtaining various archaeometric (stable isotopes, AMS dating, cementum increment, DNA, strontium isotopes and so on) and morphological analyses on this material by a larger research group, in close co-operation with the Anthropological Collection of Belgrade University that curates this material.
2. In a more recent article, Bonsall et al. (2000:123–124) mention an enlarged sample of 46 skeletons from Lepenski Vir and Vlasac in comparison to their original data set, including both adults and infants/neonates. However, these results have not been published as a list of individual skeletons with their respective isotopic values, but only presented in their figs 4–7, and we are unable to comment on these results here.
3. An important reliance on fish can be additionally supported by studies of wear and dental disease (y'Edynak 1978, 1989; y'Edynak and Fleisch 1983), which indicate a very intensive pattern of wear on teeth in the analysed individuals. On the whole in the Danube Gorges, the pattern of tooth abrasion does not correspond with average wear stages in humans, indicating an intensive abrasion due to fish, possibly river sand (the main soil matrix across the sites, which can be included in the process of food preparation) and/or various occupational activities that might have utilized teeth.
4. The $^{15}N$ enrichment is especially evident in neonates/infants but as a consequence of breastfeeding (e.g. Dittmann and Grupe 2000).

5. In the case of Vlasac the original assemblage size amounted to over 29,000 animal bones. Existing faunal reports from these two sites provide only general information about species abundance: at Lepenski Vir by the main phases (Bökönyi 1969, 1972), while in the case of Vlasac the whole assemblage was lumped together and reported as one unit, with the publication of contexts for measurable bones only (Bökönyi 1978).

6. While the complete quantification of animal remains found on the floors of Lepenski Vir buildings is provided elsewhere (Boriç and Dimitrijeviç in press; Dimitrijeviç 2000, in press), it is necessary to point out that direct comparisons of fish vs. mammal contributions to the diet on the basis of faunal remains can be methodologically misleading due to varying fragmentation of fish and mammal bones. In addition, with regard to sturgeon, the absorption of bones in older individuals may misleadingly lead to underestimating its subsistence role (Brinkhuizen 1986).

7. The preserved sample of animal bones from this site is an arbitrarily selected assemblage of diagnostic and measurable bones of mammal species and lumped bones of various fish species that come from the excavation areas marked as 'Sonda A' and 'Sonda B', which were excavated at the start of works at Vlasac in 1970 (based on the 1970 field diary; for the list of preserved bones and their stratigraphic position see Boriç 2002b:appendix 4). It remains unclear under what conditions and for what reason these bones have been selected and preserved. Since these test pits went through the entirety of vertical stratigraphy at Vlasac, we still find the faunal assemblage collected in this area of the site as being a representative sample of the Mesolithic occupation at Vlasac.

8. Although in some instances these disarticulated skeletal elements were stratigraphically connected to architectural features (e.g. burial 7/II-b from Lepenski Vir, see later in the article), it is likely that this group of burials relates to specific mortuary rites and subsequent practices of manipulation and circulation of older burials' skeletal elements. Most of these burials are, thus, found in a secondary context.

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## BIOGRAPHICAL NOTES

Dušan Borić is a research associate at the Department of Archaeology, University of Cambridge, England, with special research interests in European and Near Eastern prehistory and with a current field project in the Danube Gorges region, Serbia.

*Address:* Department of Archaeology, University of Cambridge, Downing Street, Cambridge CB2 3DZ, UK. [email: db231@cam.ac.uk]

Gisela Grupe is Professor of Physical Anthropology and Environmental History at the Biological Faculty, Ludwig-Maximilians-University of Munich, Germany, and director of the Anthropological Department of the Bavarian State Collection of Anthropology and Palaeoanatomy in Munich. Special research interests are in the field of archaeometry.

*Address:* Staatssammlung für Anthropologie und Paläoanatomie, Karolinenplatz 2a, 80333 München, BRD. [email: ASM.Grupe@extern.lrz-muenchen.de]

Joris Peters is Professor of Palaeoanatomy and History of Veterinary Medicine at the Veterinary Faculty, Ludwig-Maximilians-University Munich, Germany, and director of the Palaeoanatomy Department of the Bavarian State Collection of Anthropology and Palaeoanatomy. His research focuses on the animal remains from early Neolithic to medieval sites in Europe, the Near East and Africa.

*Address*: Staatssammlung für Anthropologie und Paläoanatomie, Karolinenplatz 2a, 80333 München, BRD. [email: joris.peters@palaeo.vetmed.uni-muenchen.de]

Živko Mikić is Professor of Physical Anthropology at the Department of Archaeology, University of Belgrade, Serbia with special research interests in the study of human skeletal material from Serbia and Montenegro.

*Address*: Anthropological Collection, Department of Archaeology, University of Belgrade, Čika Ljubina 18–20, 11000 Beograd, Serbia and Montenegro. [email: zmikic@f.bg.ac.yu]

## ABSTRACTS

### La dichotomie de subsistance mésolithique-néolithique est-elle réelle? Nouveaux résultats d'études par les isotopes stables pour les gorges du Danube

*Dušan Borić, Gisela Grupe, Joris Peters et Živko Mikić*

Dans cet article sont présentés de nouveaux résultats d'analyses par isotopes stables faites sur des ossements humains et animals provenant des sites du Mésolithique et du Néolithique récent de Lepenski Vir et de Vlasac, dans les gorges du Danube sur les Balkans. À l'aide de l'étude isotopique de différentes espèces de mammifères et de poissons trouvés à Vlasac, on essaie de reconstruire le réseau alimentaire de la région durant ces périodes. Ces résultats sont ensuite comparés aux analyses faites sur des inhumations des deux sites. A la lumière de ces nouveaux résultats, cet article se penche aussi sur les interprétations des analyses isotopiques faites sur ce matériel antérieurement et conclut qu'à cause des complexités méthodologiques inhérentes à ce type d'analyses, les études isotopiques doivent être exécutées avec le plus grand soin. De même, il est nécessaire d'intégrer les résultats des études par isotopes stables aux informations extraites de l'étude des restes de faune et des contextes archéologiques des sépultures analysées, avant d'en déduire des modèles d'alimentation paléolithique.

*Mots clés*: Vlasac, Lepenski Vir, gorges du Danube, isotopes stables, paléoalimentation, Mésolithique, Néolithique ancien, esturgeon

### Ist die Dichotomie zwischen mesolithischer und neolithischer Subsistenz real? Neue Ergebnisse vom "Eisernen Tor" anhand von Isotopenanalysen

*Dušan Borić, Gisela Grupe, Joris Peters und Živko Mikić*

In diesem Beitrag präsentieren wir die neuesten Ergebnisse von Analysen stabiler Isotope von mesolithischen und frühneolithischen tierischen und menschlichen Skelettfunden der Fundorte Lepenski Vir und Vlasac aus der Donauschlucht "Eisernes Tor" auf dem Balkan.

Ein Nahrungsnetzwerk für diese Zeitstufen konnte anhand der Isotopenanalysen der Säugetier- und Fischknochen von Vlasac rekonstruiert und mit den Ergebnissen der menschlichen Überreste beider Fundorte in Bezug gesetzt werden. Die neuen Erkenntnisse dieser Studie werden mit den Ergebnissen früherer Isotopenstudien an Material beider Fundorte diskutiert. Eine sorgfältige Interpretation der Isotopendaten ist aufgrund von inhärenten methodischen Komplexitäten dieser Forschungsmethode erforderlich. Weiterhin ist es relevant, dass die zur Verfügung stehenden Isotopendaten im Kontext des Faunenspektrums und der archäologischen Fundsituation vor Ort abgeglichen werden, um stichhaltige Schlussfolgerungen über frühe Ernährungsmuster zu gewinnen.

*Schlüsselbegriffe*: Vlasac, Lepenski Vir, Eisernes Tor, stabile Isotope, frühe Ernährung, Mesolithikum, Frühneolithikum, Störe

## Da li je mezolitsko-neolitska razlika u ishrani stvarna? Nove analize stabilnih izotopa sa Đerdapa

*Dušan Borić, Gisela Grupe, Joris Peters and Živko Mikić*

Ovaj rad predstavlja nove nalaze u analizi stabilnih izotopa na životinjskim i ljudskim kostima sa mezolitsko-ranoneolitskih lokaliteta Lepenski Vir i Vlasac u Đerdapu. Na osnovu analiza stabilnih izotopa na različitim sisarskim i ribljim vrstama sa Vlasca bilo je moguće rekonstruisati lanac ishrane u datom regionu tokom ovih perioda. Ovi rezultati uporedjeni su sa merenjima stabilnih izotopa na ljudskim ostacima sa dva pomenuta lokaliteta. U svetlu novih analiza, rad razmatra prethodno ponudjene interpretacije analiza ovog materijala. Zaključak upozorava da je neophodan veći oprez u razumevanju rezultata stabilnih izotopa zbog svojstvene metodološke složenosti ovakvih analiza. Takodje je potrebno da informacije koje su dobijene na osnovu analiza stabilnih izotopa u rekonstrukciji paleo-ishrane budu integrisane sa podacima o ishrani koji su zasnovani na analizi faunističkih ostataka i arheološkom kontekstu analiziranih ljudskih ostataka.

*Ključne reči*: Đerdap, rani neolit, Lepenski Vir, mezolit, paleo-ishrana, stabilni izotopi, jesetra/moruna, Vlasac