ANTHROPOLOGIE • LII/1 • pp. 73–89 • 2014

SÉBASTIEN VILLOTTE, SOFIJA STEFANOVIĆ, CHRISTOPHER J. KNÜSEL

EXTERNAL AUDITORY EXOSTOSES AND AQUATIC ACTIVITIES DURING THE MESOLITHIC AND THE NEOLITHIC IN EUROPE: RESULTS FROM A LARGE PREHISTORIC SAMPLE

ABSTRACT: External auditory exostosis (EAE) appears to be a faithful marker of water-related activities. The frequency of this condition has been calculated for 449 European Mesolithic and Neolithic individuals from several geographic regions. The condition is more frequent in females but not significantly so. Neolithic skeletons display significantly less EAE than Mesolithic ones. The very high frequency of EAE in Late Mesolithic samples is consistent with fishing subsistence activities, and the significant decrease in frequency in Neolithic populations provides further evidence (along with isotopic and other archaeological evidence) for a rapid abandonment of marine/freshwater resources after the transition.

KEY WORDS: Activity-related skeletal morphologies – Palaeopathology – Subsistence strategies – Palaeo-economy

INTRODUCTION

The use of aquatic resources is at the forefront of the discussions about the shift in diet with the onset of the Neolithic. Palaeo-dietary stable-isotope investigations on human bone from various locations such as Southern Scandinavia, the British Isles, Brittany, Portugal, and the Iron Gates region of the Danube River Valley tend to indicate a shift from Mesolithic diets dominated by marine or freshwater protein to Neolithic diets in which these sources are absent or rare (Bonsall *et al.* 1997, 2000, 2004, Lubell *et al.* 1994, Richards, Hedges 1999, Richards *et al.* 2003, Schulting 1998, Schulting, Richards 2001, Umbelino 2006). Other indicators, such as dental attrition and dental health (evaluated by caries rates) for instance, have been studied as well (Jackes *et al.* 1997, Lubell *et al.* 1994, Meiklejohn, Zvelebil 1991), but interestingly external auditory exostosis, an abnormal

Received 15 April 2013; accepted 9 July 2013.

bony growth within the external auditory meatus, has never been used to discuss this shift.

External auditory exostosis (EAE) is an asymptomatic bony growth caused by an irritation of the periosteum in the external meatus (Di Bartolomeo 1979). Several factors may play a role in stimulating such irritation, but repeated contact with water appears to be the main one. Indeed, many clinical studies, mainly of surfers, but also of sailors, kayakers, swimmers, water polo players, and divers, show that individuals habitually exposed to water, especially cold water, are substantially more predisposed to develop EAE (Adams 1951, Altuna Mariezkurrena *et al.* 2005, Chaplin, Stewart 1998, Cooper *et al.* 2010, Deleyiannis *et al.* 1996, Di Bartolomeo 1979, Filipo *et al.* 1982, Fowler, Osmun 1942, Harrison 1962, Hurst *et al.* 2004, Ito, Ikeda 1998, Karegeannes 1995, Kroon *et al.* 2002, Timofeev *et al.* 2004, Van Gilse 1938). A clear correlation between the time exposed and the prevalence and severity of EAE has been shown (Altuna Mariezkurrena *et al.* 2005, Chaplin, Stewart 1998, Cooper *et al.* 2010, Deleyiannis *et al.* 1996, Hurst *et al.* 2004, Ito, Ikeda 1998, Karegeannes 1995, Kroon *et al.* 2002, Van Gilse 1938). Clinical reports also suggest that ears exposed to a combination of water and cold air (wind chill) are more likely to develop EAE, and at a faster rate (Hurst *et al.* 2004, Ito, Ikeda 1998, Timofeev *et al.* 2004).

In human volunteers, it has been shown that water below body temperature produces a marked erythema related to an induced reflex vasodilation which, in turn, produces an increase in tension in the periosteum in the external canal (Harrison 1962). The colder the water, the longer vasodilation is sustained (Harrison 1962). It has also been shown that increasing the normal tension of the periosteum enhances bone formation (Amprino 1985, Glucksmann 1942). In guinea pigs, cold water also produces a marked erythema (Harrison 1962), and repeated irrigation of the ear canal eventually leads to new bone formation (Fowler, Osmun 1942, Harrison 1962).

This bulk of evidence from clinical and experimental studies led to what Kennedy (1986) called the "thermal aquatic hypothesis", which is the basis for many anthropological studies. EAE has been extensively studied in past populations (e.g. Ascenzi, Balistreri 1975, Crowe *et al.* 2010, Frayer 1988, Gregg, McGrew 1970, Hutchinson *et al.* 1997, Manzi *et al.* 1991, Okumura *et al.* 2007, Özbek 2012, Ponce *et al.* 2008, Standen *et al.* 1997, Velasco-Vazquez *et al.* 2000). Using published and unpublished sources, Kennedy (1986) examined the frequency of EAE by latitude to test the "thermal aquatic hypothesis". This analysis shows very high frequencies among communities who exploit either marine or fresh water resources between 30° and 45° latitude north and south of the equator, while EAE is absent or in very low frequency in the two other areas considered by Kennedy, defined as tropical/subtropical (0–30° north and south latitude) and polar/sub-polar (beyond 45° north latitude, as there were no available data for populations living beyond 45° south). According to the author, very low frequencies for populations living beyond 45° north latitude were expected, given the risk of lethal hypothermia in very cold water. This interpretation has been supported recently with the study of the southernmost archaeological populations from Tierra del Fuego, who also show very low frequencies of EAE (Ponce *et al.* 2008). Low frequencies for tropical/subtropical areas were also expected as the temperature of the waters of the tropics are above 19°C (Kennedy 1986). However, more recent studies have shown frequent EAE development in population samples living in areas between 0–30° north and south latitude, where cold streams lead to sea waters that are relatively cooler than expected according to latitude, or where the water is warmer but with relatively low atmospheric temperatures and strong wind chill (Okumura *et al.* 2007, Standen *et al.* 1997, Velasco-Vazquez *et al.* 2000).

While causes of EAE have been extensively discussed by biological anthropologists in the past (for review, see Kennedy 1986), more recently only a few authors have challenged the aquatic-related aetiology of EAE. Hutchinson and collaborators (1997) argue that *otitis externa*, which is due to a wide variety of chemical, biological, or other stimulating factors, could be a cause of EAE and that "cold water is not a sufficient exclusive etiology for external auditory exostoses given the wealth of clinical information regarding otitis externa" (Hutchinson *et al.* 1997: 421). However, one can read in Adams (1951: 425) the following observation: "Mr. R. R. Simpson said that he spent three years in Ceylon [warm water] during the war where he had records of over 6000 cases of *otitis externa*. Among the men there, who were accustomed to frequent bathing, *otitis externa* was extremely common and exostoses extremely rare." Moreover, it is generally admitted that *otitis externa* could be a result of accumulation of debris medial to the EAE (e.g. Altuna Mariezkurrena *et al.*, 2005; Cooper *et al.*, 2010), and thus not a cause of EAE. However, in a very small number of individuals, a bony lesion may be caused by chronic ear infection (Fowler, Osmun 1942), and inference to past activities should be avoided if only a few EAE are found (Kennedy 1986).

To summarise clinical and anthropological findings, repeated presence of water in the external auditory meatus may produce EAE. The colder the water, the more likely are EAE to develop. EAE can thus be a good marker of aquatic activity in the past, especially in temperate climates. Even if other causes may induce EAE, high frequencies of EAE in a sample is only seen when frequent contact with water occurs. Despite the numerous limitations in the discussion of EAE frequencies in skeletal collections when there is no ethnographic, iconographic, or textual data to corroborate the osteological findings, it is clear that frequencies of EAE can be considered as a proxy for water-related activities and thus a pertinent tool to discuss the shift in diet at the onset of Neolithic. The purpose of this article is to present the frequency of this condition for 449 European Mesolithic and Neolithic individuals from several geographic areas and to discuss prehistoric dietary behaviour and change during the Mesolithic-Neolithic transition.

MATERIALS AND METHODS

Skeletal material

External auditory exostoses are rare or absent in sub-adult groups (e.g. Crowe *et al.* 2010, Di Bartolomeo 1979, Özbek 2012, Standen *et al.* 1997, Van Gilse 1938), and for the purposes of this study, only skeletally mature individuals have been included in the present analysis.

Four hundred and forty-nine prehistoric individuals with at least one complete auricular meatus were examined (*Table 1, Figure 1*). The morphology and morphometry of the coxal bones was used for the assessment of sex, following Bruzek (2002) and Murail and collaborators (2005), completed with a secondary sex diagnosis based on discriminant function analysis (see Castex *et al.* 1993, Murail *et al.* 1999).

Costal Late Mesolithic individuals ($N = 16$) are from the sites of Téviec and Hoëdic (Brittany, France) (Péquart, Péquart 1934, Péquart *et al.* 1937, see also Schulting, Richards 2001 for new AMS dates, and

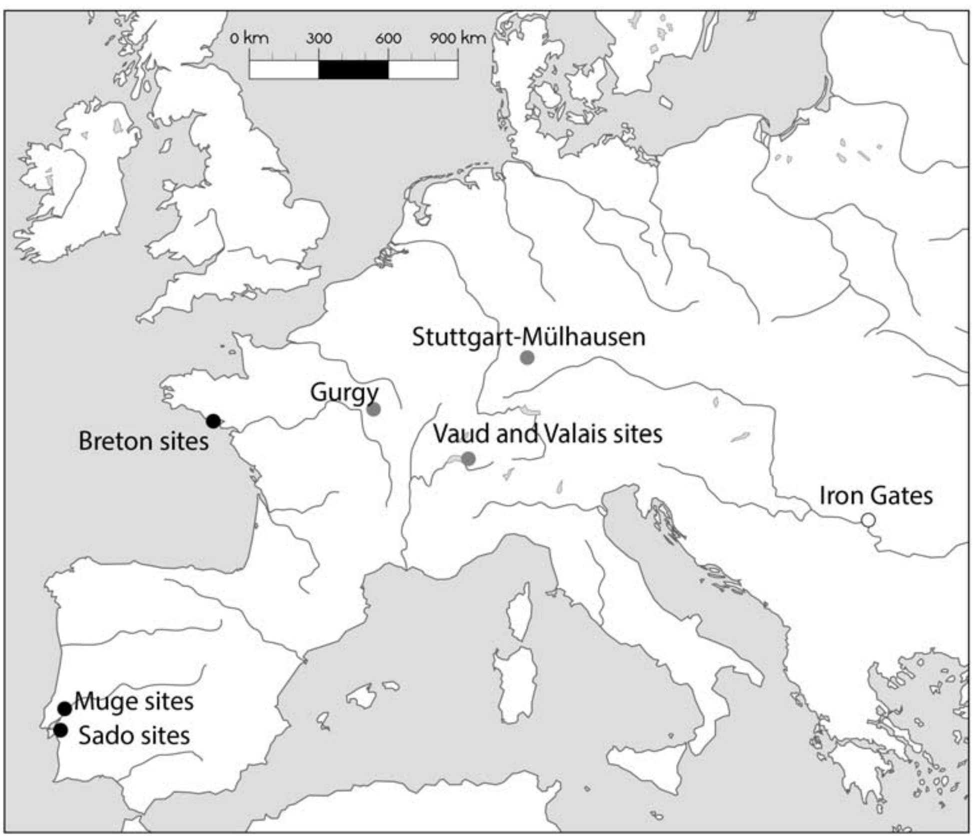

FIGURE 1. Location of the samples under study. Black dots, Mesolithic sites; grey dots, Neolithic sites; white dot, Mesolithic and Neolithic sites.

TABLE 1. Mesolithic and Neolithic collections examined.

Country	Period	Collection	Females	Males	Undetermined sex	Total
France	Late Mesolithic	Hoëdic (Brittany)	3	2	4	9
		Téviec (Brittany)	2	2	3	7
	Middle Neolithic	Gurgy	14	25	9	48
Portugal	Late Mesolithic	Arapouco (Sado)	4	8	3	15
		Cabeço das Amoreiras (Sado)			1	1
		Cabeço do Pez (Sado)	2	2	6	10
		Romeiras (Sado)	1	2	3	6
		Várzea da Mó (Sado)			1	1
		Cabeço da Amoreira (Muge)	2	1	1	4
		Cabeço da Arruda (Muge)	15	5	4	24
		Moita do Sebastião (Muge)	10	7	27	44
Switzerland	Middle Neolithic	Barmaz I (Valais)	7	5		12
		Barmaz II (Valais)	7	5		12
		Chamblandes (Vaud)	11	8	10	29
		Corseaux (Vaud)	6	2	15	23
		Sion avenue Ritz (Valais)	3	3	2	8
		Sion chemin des Collines (Valais)	3	5		8
		Sion St Guerin (Valais)	1			1
		St Leonard 4 (Valais)	1			1
Germany	Early Neolithic	Stuttgart-Mülhausen	26	29	5	60
Serbia	Mesolithic and Neolithic	Kula (Iron Gates)		2	1	3
		Vlasac (Iron Gates)	20	9	26	55
		Hajdučka Vodenica (Iron Gates)		3	8	11
		Lepenski Vir (Iron Gates)	7	3	21	31
		Padina (Iron Gates)	7	3	11	21
	Early Neolithic	Ajmana (Iron Gates)	3	1	1	5
Total			155	132	162	449

Meiklejohn *et al.* 2010 for a review). One hundred and five individuals from the Portuguese Late Mesolithic shell middens located along the Muge and the Sado rivers were also included (for detailed presentation of the sites, see Cunha, Cardoso 2001, Cunha *et al.* 2002, Jackes, Meiklejohn 2004, 2008, Marchand 2001, 2005, Meiklejohn *et al.* 2009, Roche, Da Veiga Ferreira 1967). Sixty Early Neolithic (Linearbandkeramik) skeletons from Stuttgart-Mühlhausen (Germany), near the Neckar River (Biel 1982, Denaire 2009, Kurz 1991, 1992, 1993) were studied. Skeletons from the Middle Neolithic come from the French site of Gurgy (*N* = 48), near the Yonne River (c. 900 m) (Rottier *et al.* 2005), and from several Swiss sites (*N* = 94) near the Rhône River and/or Lake Geneva, from the cantons of Valais (Baudais *et al.* 1989, Honnegger, Desideri 2003), and Vaud (Baudais, Kramar 1990, Moinat 2007). One hundred and twenty-six skeletons from six sites located along the Iron Gates region of the Danube River Valley were also included (Bonsall *et al.* 2008a, Borić, Price 2013, Radovanović 1996). The archaeological record indicates several occupations during the Mesolithic and Early/Middle Neolithic periods in this area. The transition from the Mesolithic to the Neolithic (sometimes called the Mesolithic–Neolithic "Contact" period, e.g. Roksandić 1999) has been identified to have occurred around 6200 to 5900 cal BC in the Iron Gates region (Bonsall 2008, Borić, Miracle 2004, Borić, Price 2013). Skeletons from Ajmana appear securely dated to the Early Neolithic (Borić, Price 2013, Radosavljević-Krunić 1986, Stalio 1986). Human remains from Vlasac were originally associated with the chronological phases of the Mesolithic settlement (Srejović, Letica 1978), but recent excavations and new AMS dates have shown that the stratigraphic sequence is more complex than previously thought (Borić *et al.* 2008). It should be noted, however, that all the directly dated skeletons from Vlasac included in the present study are "Mesolithic" in date. Human remains from the Mesolithic and Early Neolithic sites of Kula, Padina, Lepenski Vir and Hajdučka Vodenica were also included (Bonsall *et al.* 2008b, Borić *et al.* 2004, Borić, Miracle 2004, Borić, Price 2013, Jovanović 2008, Sladić 1986, 2007).

The samples are located between 38° and 49° north latitude. A combination of cold water and/or relatively low atmospheric temperatures during winter, and possibly wind chill can thus be expected for the entire area under study.

Methods and statistical analysis

The presence and type of exostosis, side, extent of occlusion, number, and position were recorded. Examination was done with the naked eye and, when necessary, with the aid of a magnifying glass and a small lamp. The chosen scoring system of the extent of occlusion (Grade 0: no occlusion; Grade 1: occlusion of the meatus by up to one-third; Grade 2: one to two-thirds, Grade 3: more than two-thirds) has been previously applied by biological anthropologists (Crowe *et al.* 2010, Standen *et al.* 1997, Velasco-Vazquez *et al.* 2000), and by clinicians (e.g. Cooper *et al.* 2010, Hurst *et al.* 2004). Hurst and collaborators (2004: 350) noticed that early EAE (i.e. grade 1) are difficult to grade and considered that "any canal that had lost its circular pattern and exhibited an angle between the floor and the anterior wall […] was classified as grade 1." The same difficulty was encountered in the present study, but we did not follow this procedure; instead, a grade 1 was allotted when an osseous exostosis, even slight, was clearly distinguishable from the wall of the external auditory canal (*Figure 2*).

The differential diagnosis for EAE includes osteomata. The latter is a pedunculated, solitary and unilateral bone formation, while EAEs are sessile, and usually multiple and bilateral (Di Bartolomeo 1979, Filipo *et al.* 1982, White *et al.* 2012). No osteomata were identified in the prehistoric sample.

To assess differences between groups, Fisher's exact test (for 2×2 contingency tables), Chi-square (for larger than 2×2 tables), and Student's t-test (for means of isotopic values) were used. *P*-values presented are for two-tailed tests. A 5% threshold was taken as an acceptable Type 1 error rate. Normality of distributions was assessed using

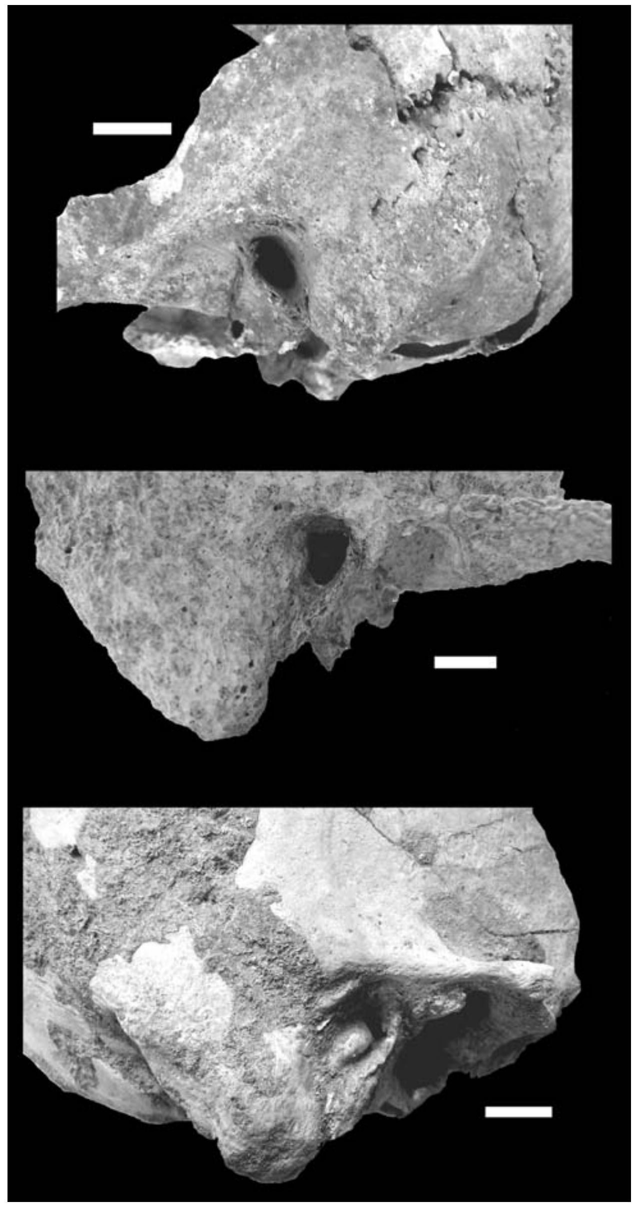

FIGURE 2. View of three external auditory canals. Top: Grade 0, "regular pattern". Centre: Grade 1, slight exostosis, clearly distinguishable from the wall of the external auditory canal. Bottom: Grade 2, well developed exostosis. Scale markers indicate 1 cm.

the Kolmogorov-Smirnov test. Data analyses were performed using STATISTICA 7.1 (StatSoft Inc., France).

RESULTS AND DISCUSSION

Crude frequencies by side and individual

No grade 3 (occlusion of the meatus by more than two-thirds) lesions were recorded in this sample. Grade 2 is uncommon in the prehistoric sample (2.6% for the right side; 1.1% for the left), and the majority was seen in the collections from the Iron Gates (*Table 2*). EAEs are less frequent for the left side (*Table 2*). As shown in *Table 3*, a difference of grade for the left and right side is seen in 6.6% (18/272) of the individuals with both ears scored.

Considering the lack of grade 3, and the low frequencies of grade 2, grades 1 and 2 were summed as

TABLE 2. Number of grades 0, 1, and 2, recorded for both sides and for each collection.

		Left side				Right side			
Period	Collection	G0	G1	G2	Total	G0	G1	G2	Total
Late Mesolithic	Hoëdic (Brittany)	7			7	9			9
	Téviec (Brittany)	4	3		7	4	3		7
	Arapouco (Sado)	11	1		12	12	1		13
	Cabeço das Amoreiras (Sado)	1			1				
	Cabeço do Pez (Sado)	5			5	6	1		7
	Romeiras (Sado)	3	1		4	3			3
	Várzea da Mó (Sado)	1			1				
	Cabeço da Amoreira (Muge)	3			3	1			1
	Cabeço da Arruda (Muge)	15	2		17	14	4	1	19
	Moita do Sebastião (Muge)	33	5		38	23	7		30
Early Neolithic	Stuttgart-Mülhausen	52	2		54	43	2		45
	Ajmana (Iron Gates)	5			5	3	1		4
Middle Neolithic	Gurgy	40			40	34	1		35
	Barmaz I (Valais)	11			11	8			8
	Barmaz II (Valais)	11			11	11			11
	Chamblandes (Vaud)	22			22	26			26
	Corseaux (Vaud)	23			23	21			21
	Sion avenue Ritz (Valais)	7			7	3			3
	Sion chemin des Collines (Valais)	7			7	6			6
	Sion St Guerin (Valais)	1			1	1			1
	St Leonard 4 (Valais)	1			1				
Mesolithic and Neolithic	Kula (Iron Gates)	2			2		1		1
	Vlasac (Iron Gates)	34	10	4	48	32	7	6	45
	Hajdučka Vodenica (Iron Gates)	7	2		9	7		1	8
	Lepenski Vir (Iron Gates)	21	4		25	19	4	1	24
	Padina (Iron Gates)	12	5		17	10	6		16
Total		339	35	4	378	296	38	9	343
Total (%)		89.7	9.3	1.1	100.0	86.3	11.1	2.6	100.0

TABLE 3. Number of individuals according to the grade for the left and the right ear. NR, not recordable.

Grades		Right side			
		G0	G1	G2	NR
Left side	G0	234	10	0	95
	G1	3	18	5	9
	G2	0	0	2	2
	NR	59	10	2	0

"presence of EAE". Taking into account the low number of individuals with differences in grades between the left and the right meatus, all individuals with at least one meatus with an EAE have been be considered as showing this feature. Some 13.6% of individuals in the sample (61/449) present an EAE (*Table 4*). There is clear heterogeneity in the distribution of EAE in the prehistoric sample, with marked differences between geographic areas, from 0% in the collections from Middle Neolithic Switzerland to 29.4% in the Iron Gates

TABLE 4. Frequencies of individuals with EAE by sex and geographic area.

Area	Period	Sex	*n* EAE / *N* total	% EAE
Brittany sites	Late Mesolithic	Females	0 / 5	
		Males	1 / 4	
		Undetermined	2 / 7	
		Total	3 / 16	18.8
Muge sites	Late Mesolithic	Females	7 / 27	
		Males	3 / 13	
		Undetermined	4 / 32	
		Total	14 / 72	19.4
Sado sites	Late Mesolithic	Females	0 / 7	
		Males	3 / 12	
		Undetermined	0 / 14	
		Total	3 / 33	9.1
Stuttgart-Mülhausen	Early Neolithic	Females	2 / 26	
		Males	1 / 29	
		Undetermined	0 / 5	
		Total	3 / 60	5.0
Vaud and Valais sites	Middle Neolithic	Females	0 / 39	
		Males	0 / 28	
		Undetermined	0 / 27	
		Total	0 / 94	0.0
Gurgy	Middle Neolithic	Females	0 / 14	
		Males	1 / 25	
		Undetermined	0 / 9	
		Total	1 / 48	2.1
Iron Gates	Mesolithic and Neolithic	Females	12 / 37	
		Males	4 / 21	
		Undetermined	21 / 68	
		Total	37 / 126	29.4
All areas		Females	21 / 155	13.5
		Males	13 / 132	9.8
		Undetermined	27 / 162	16.7
		Total	61 / 449	13.6

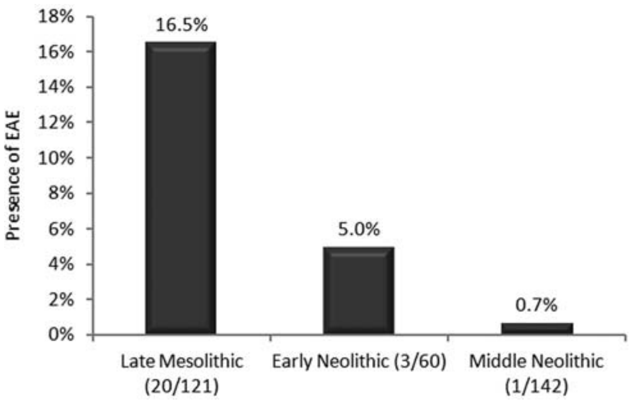

FIGURE 3. Frequencies of individuals with EAE (Iron Gates region not included). The number of subjects with EAE and the total number of individuals are indicated in parentheses (*n*/*N*).

sample. Females tend to exhibit more EAE than males (*Table 4*), but the difference is not significant (Fisher's exact test, $P = 0.364$).

If the skeletons from the Iron Gates region are not taken into account (see specific section below), a clear decrease in EAE frequency through time is seen (*Figure 3*). The difference between the Late Mesolithic sample and those from more recent periods is highly statistically significant (*Table 5*).

The Atlantic coast of Europe: Late Mesolithic costal and estuarine sites

Frequency of EAE in Portuguese and Breton samples is high (*Table 4*), indicating repeated contacts with cold water for the individuals from these sites. The frequencies in Brittany (18.8%) and Muge (19.4%) sites are virtually identical; there is less EAE at Sado (9.1%), but this is not statistically significant (chi-square = 1.82, $P = 0.402$). These frequencies are well below those recorded in surfers or kayakers nowadays (e.g. Altuna Mariezkurrena *et al.* 2005, Chaplin, Stewart 1998, Cooper *et al.* 2010), but in the range of variation of frequencies reported for prehistoric populations whose subsistence depended heavily on aquatic resources (e.g. Kennedy 1986, Okumura *et al.* 2007, Özbek 2012, Standen *et al.* 1997). Isotopic analyses as well as archeozoological evidence from Portuguese and Breton shell middens demonstrate the significant use of marine/estuarine resources by the site inhabitants (Da Veiga Ferreira 1968, Dupont *et al.* 2009, Jackes, Meiklejohn 2004, Lubell *et al.* 1994, Roche, Da Veiga Ferreira 1967, Schulting, Richards 2001, Umbelino 2006), and thus contact with cold water likely happened while gathering shellfish, fishing, or hunting marine mammals. There are no cases of EAE in females for Breton and Sado sites (*Table 4*), indicating a possible sexual division of labour regarding these activities, though there is no significant frequency difference between males and females. Interestingly, there are no cases of EAE at Hoëdic ($N = 9$), while three cases were recorded at Téviec ($N = 7$). This is in apparent contradiction with isotopic data from the two sites, with possibly a greater use of marine resources at Hoëdic compared to Téviec (Schulting, Richards 2001). However, given the very small sample size for these two sites, it seems difficult to draw any serious interpretation. On the contrary, the difference between Sado and Muge individuals is also seen in their isotopic values, with a proportion of 50% of marine food in the diet in the Muge shell middens, compared to around 30% in the Sado ones (Umbelino 2006), though isotopic data are still very scarce, especially for the Sado collections.

The study of EAE for the other Mesolithic skeletons from Breton sites and further studies of stable isotopes for other Mesolithic individuals from Portugal would permit direct comparison of isotopic values for individuals with and without EAE in the future (see below for the Iron Gates sites).

TABLE 5. Comparisons of frequencies of individuals with at least one EAE between chrono-cultural periods.

Comparison	Test	*P*-value
All periods	Chi-square (24.42)	< 0.001
All periods	Yates' chi-square (21.88)	< 0.001
Late Mesolithic vs. Early Neolithic	Fisher's exact	0.033
Late Mesolithic vs. Middle Neolithic	Fisher's exact	< 0.001
Early Neolithic vs. Middle Neolithic	Fisher's exact	0.079
Late Mesolithic vs. Early and Middle Neolithic	Fisher's exact	< 0.001

Neolithic sites from France, Switzerland, and Germany

The frequencies for French, Swiss, and German Neolithic sites are low (5% or below), and no cases of grade 2 (occlusion of the meatus by one to two-thirds) were recorded in these samples, indicating seldom, if any, unprotected contact with cold water. These few cases (four for 202 individuals) are rather inconspicuous and some of these may be related to chronic ear infection that in a very small number of individuals may cause a bony lesion (Fowler, Osmun 1942, Van Gilse 1938). These very low frequencies are similar to those reported in control groups in clinical studies, e.g. 0.0% in Karegeannes (1995) and 1.7% (all grade 1) in Cooper and collaborators (2010).

All cemeteries from which Neolithic skeletons were studied are near a river, or a body of water, such as Lake Geneva for sites from Switzerland. There is some evidence of fishing activities in Middle Neolithic sites from the Canton of Valais (Barmaz I, Barmaz II, and Saint-Léonard "sur le Grand Pré"), with some remains of trout, and the presence of some notched pebbles which were possibly used as weights for nets (Baudais *et al.* 1989, Chaix 1976). In Gurgy, shells of freshwater mussel (*Unio sp.*) were occasionally found as personal adornments in child burials (Rottier, personal communication). The absence of EAE does not exclude aquatic activities, even when the water is cold (which was likely the case for Lake Geneva, and the Neckar, the Rhône, and the Yonne rivers), if individuals had protected their ears (Okumura *et al.* 2007, Van Gilse 1938). However, based on the results from the present study and the scarce archaeological evidence for fishing, it seems very likely that aquatic activities did not represent an important part of the daily life of these Neolithic subjects. Stable isotope analysis of these samples would help to further refine this discussion.

The Iron Gates

EAE are very frequent in the Iron Gates region (29.4%, *Table 4*), and individuals with exostoses are present in all sites (*Table 6*). Moreover, 10 of the 11 individuals with occlusion of at least one meatus by one to two-thirds (grade 2) come from the Iron Gates region. These results indicate that contact with cold water was frequent for the individuals of the Iron Gates. No clear sexual differences are seen, except for the site of Vlasac, where females display more EAE than males, though not statistically significantly so (Fisher's exact test, $P = 0.096$). This result is surprising, as in many prehistoric groups males display more EAE than females (e.g. Kennedy 1986, Okumura *et al.* 2007, Özbek 2012, Standen *et al.* 1997, Velasco-Vazquez *et al.* 2000).

The crucial role of fishing in the formation of the Danube Gorges settlements has been emphasised by many authors (Bartosiewicz, Bonsall 2004, Bartosiewicz *et al.* 2008, Bartosiewicz *et al.* 1995, 2001, Bökönyi 1978, Borić 2002, Dinu 2010, Jovanović 2008, Radovanović 1996, 2006), and it is tempting to associate the high frequency of EAE with this specific activity. The highest frequencies are seen in Padina and Vlasac (*Table 6*) with, respectively, 38.1% and 34.5% of the individuals with at least one meatus affected. The very high frequency of EAE in these two sites was previously reported by Roksandic (1999) (respectively, 52.6% and 36.9%) and by Frayer (1988) who reported 34.2% in Vlasac. Interestingly, Padina and Vlasac are considered to have been, at least during the Early Holocene, open-air camps focusing on fishing (Radovanović 2006). For instance, fish remains represent 60% of the vertebrate fauna discovered at Vlasac (Bökönyi 1978). Considering the scarcity of harpoons and hooks found in the prehistoric sites of the Iron Gates, scholars have considered many alternative fishing practices, among others the use of fences, nets,

TABLE 6. Frequencies of individuals with EAE from the Iron Gates region by sex and collection.

Collection	*n* EAE / *N* total					% in Roksandić (1999)
	Females	Males	Undetermined	Total	Total %	
Ajmana	0 / 3	0 / 1	1 / 1	1 / 5	20.0	/
Hajdučka Vodenica		1 / 3	1 / 8	2 / 11	18.2	23.1
Kula		0 / 2	1 / 1	1 / 3	33.3	/
Lepenski Vir	0 / 7	1 / 3	5 / 21	6 / 31	19.4	10.7
Padina	2 / 7	1 / 3	5 / 11	8 / 21	38.1	52.6
Vlasac	10 / 20	1 / 9	8 / 26	19 / 55	34.5	36.9

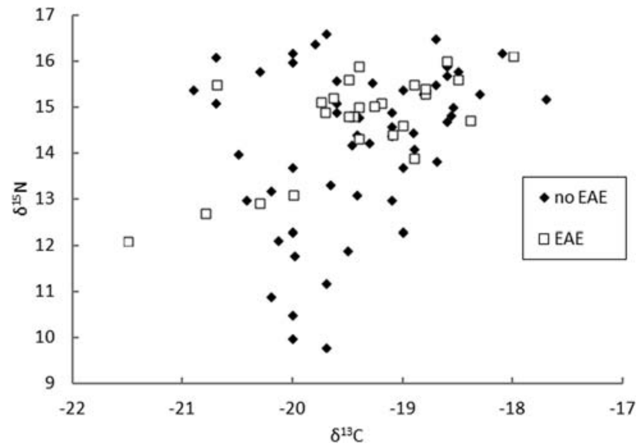

FIGURE 4. $\delta^{13}C$ and $\delta^{15}N$ values for individuals from the Iron Gates region with and without EAE.

baskets or other traps (e.g. Dinu 2010, Jovanović 2008), possibly combined with the use of stone clubs to stun large fish species (especially beluga sturgeon) (Živaljević 2012). All of these techniques may have implied the immersion of the head into the water or the possible entrance of drops into the ear canal.

Stable isotope values are available for 79 individuals of the studied sample from the Iron Gates region (data from Bonsall *et al.* 1997, 2008b, Borić *et al.* 2004, 2008, Borić, Price 2013, Nehlich *et al.* 2010). Values for individuals with and without EAE are presented in the *Figure 4* and summarised in *Table 7*. Values for both groups do not differ significantly (*Table 7*), but individuals with EAE tend to cluster at very high $\delta^{15}N$ values (indicating a very high proportion of fresh water fish in the diet) (*Figure 4*). If we postulate that EAE are related to fishing activities, it seems that there was no separation between individuals involved in these tasks and consumers of aquatic resources in the Iron Gates region.

Based on relative and absolute dating reported for the individuals of the Iron Gates (mainly from Table 1 of Supporting Information of Borić, Price 2013; but also Bonsall *et al.* 2008b, Borić *et al.* 2004, 2008, Nehlich *et al.* 2010, Sladić 2007, Stalio 1986), it has been possible to classify 84 individuals of the present study into four chronological groups: Early/Middle Mesolithic, Late Mesolithic, Mesolithic-Neolithic transition, and Early/Middle Neolithic (*Table 8*). There is a clear and regular decrease in EAE frequency through time (*Figure 5*), with a possible threshold at the beginning of the Mesolithic-

TABLE 7. Carbon and nitrogen isotopic analyses for all individuals from the Iron Gates region, for whom there was at least one complete meatus preserved.

		$\delta^{13}C$		$\delta^{15}N$	
	N	Mean	SD	Mean	SD
Iron Gates no EAE	53	−19.41	0.72	14.22	1.74
Iron Gates EAE	26	−19.40	0.79	14.75	1.04
Student's t-test		−0.04	$P = 0.969$	−1.43	$P = 0.156$

TABLE 8. Distribution of individuals from the Iron Gates region by chronological period.

Period	Ajmana	Hajdučka Vodenica	Kula	Lepenski Vir	Padina	Vlasac	Total
Early/Middle Mesolithic (ca. 9500–7400 cal. B.C.)				4	15	1	20
Late Mesolithic (ca. 7400–6200 cal BC)		5	1	1	1	36	44
Mesolithic-Neolithic transition (ca. 6200–5950 cal BC)				4	1		5
Early/Middle Neolithic (ca. 5950–5500 cal BC)	5	1		9			15

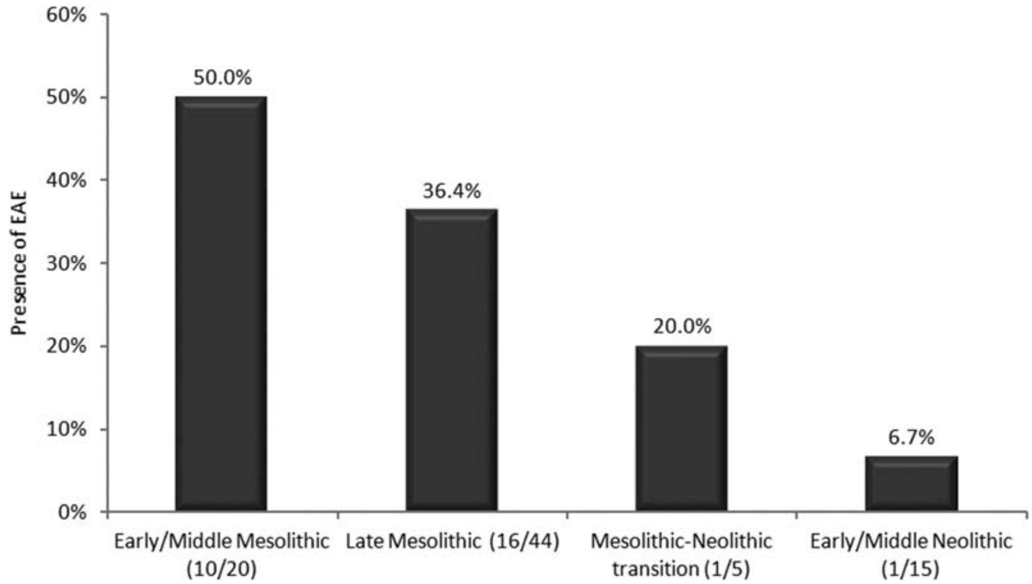

FIGURE 5. Frequencies of individuals from the Iron Gates region with EAE. The number of subjects with EAE and the total number of individuals are indicated in parentheses (*n*/*N*).

Neolithic transition (ca. 6200 cal BC) or at the end of this period (ca. 5950 cal BC) (*Table 9*). Isotopic studies clearly indicate a diachronic change in the intake of freshwater fish at the Iron Gates sites (Bonsall *et al.* 1997, 2000, 2004, Borić 2007, Borić *et al.* 2004), but there are some differences in the stable isotope patterns between sites, with an apparent dietary change after 6300 cal BC at Lepenski Vir while "dated burials from Padina, Hajdučka Vodenica and Vlasac show no dietary change in the period from around 6300 to 5900 cal BC" (Borić 2007: 34). Results of the present study indicate a significant decrease of EAE, implying less frequent contact with cold water, around this period (*Table 9*). If we postulate that the presence of EAE is related to fishing activities, our results are consistent with carbon and nitrogen stable isotope analyses and archaeozoological studies (e.g. Bartosiewicz *et al.* 2001), i.e. a decrease in the significance of fishing after 6200 cal BC, but – at least at the regional level – with a continuity in the exploitation of riverine resources during the Neolithic occupation of this area.

TABLE 9. Comparisons of frequencies of individuals from the Iron Gates region with at least one EAE by chrono-cultural period.

Comparison	Test	*P*–value
All periods	Chi-square (7.88)	0.049
All periods	Yates' chi-square (5.58)	0.134
Early/Middle Mesolithic vs. Late Mesolithic	Fisher's exact	0.411
Late Mesolithic vs. Mesolithic-Neolithic transition	Fisher's exact	0.646
Mesolithic-Neolithic transition vs. Early/Middle Neolithic	Fisher's exact	1.000
(E/M M) vs. (L M + M-N T + E/M N) [a]	Fisher's exact	0.100
(E/M M + L M) vs. (M-N T + E/M N) [a]	Fisher's exact	0.014
(E/M M + L M + M-N T) vs. (E/M N)[a]	Fisher's exact	0.016

[a] E/M M, Early/Middle Mesolithic; L M, Late Mesolithic; M-N T, Mesolithic-Neolithic transition; E/M N, Early/Middle Neolithic.

CONCLUSIONS: EXTERNAL AUDITORY EXOSTOSES, AND INSIGHTS INTO PREHISTORIC DIET AND SUBSISTENCE PRACTICES

In a prehistoric sample of 449 European individuals dating from the Mesolithic and the Neolithic, 61 individuals display at least one external auditory exostosis (EAE) for one meatus. Cases of EAE are frequent in the entire prehistoric sample, but they are not homogeneously distributed. At the European scale, a clear diachronic change is seen, with high frequencies during the Mesolithic (18.8% or more, with the exception of Sado sites with 9.1%) and low frequencies for the Neolithic (5.0% or below). At the regional scale a similar pattern is seen. In the Iron Gates region – as far as we know the only European location for which there is large series from both the Mesolithic and Neolithic periods – there is a clear decrease in the significance of fishing at the transition from the Mesolithic to the Neolithic.

These results are in apparent agreement with other analyses indicating a decrease in interest in aquatic resources during the Neolithic. However, the study of EAE has many potential pitfalls, as with virtually all activity-related skeletal morphologies (Dutour 1992, Jurmain 1999, Jurmain *et al.* 2012, Villotte 2008, Villotte, Perréard-Lopreno 2012), that one has to consider prior to discussion of differences in frequency between prehistoric groups.

Individual differential susceptibility to cold water contact was experimentally detected (Harrison, 1962) and is shown in many clinical surveys. Some individuals will not developed EAE, even if there are frequently engaged in aquatic activity. Conversely EAE will develop earlier and faster in some subjects who are more susceptible to the effects of cold. Comparison of frequencies between human groups may be blurred by genetic differences, but as shown by the comprehensive review done by Kennedy (1986), behavioural/environmental factors are overwhelmingly predominant in the appearance of EAE. Thus, even in the case of differing genetic backgrounds, we can postulate that the differences in frequency of EAE between Mesolithic and Neolithic groups are related to different behaviours.

The rate of inter-observer error for the qualitative method used is very likely high (see Gregg, McGrew 1970, and also *Table 6*, but see Crowe *et al.* 2010). We did not calculate inter- and intra-observer error for the present study. Skeletal collections were analysed by the same observer, with sometimes a delay of several months between study visits. Some differences between collections may be related to differences in the assessment of the presence of EAE, especially in cases of early EAE (i.e. grade 1). However, the general trend observed (i.e. a decrease of frequency through time) is also seen for the collections of the Iron Gates region, studied at the same time, and without any *a priori* knowledge of the chronology of the subjects. Thus, it seems unlikely that a significant part of the differences seen between Mesolithic and Neolithic groups is related to methodological issues.

EAE is a progressive pathological condition. Exostoses may appear in susceptible individuals after one to three years of regular contact with water (Adams 1951, Van Gilse 1938), but 5–10 years of exposure seems the most common time necessary to develop a lesion (Altuna Mariezkurrena *et al.* 2005, Chaplin, Stewart 1998, Cooper *et al.* 2010, Deleyiannis *et al.* 1996, Di Bartolomeo 1979). As noted by Crowe and collaborators (2010), some younger individuals involved in aquatic activities can be assumed to have died before they were old enough to develop it. We did not attempt to control for age-at-death in the present study due the number of individuals for which it had not been possible to assess it, or for which the assessment provided a very broad age range. We assume that even if differences in frequency can be related to different demographic profiles, this cannot be the only explanation for the clear differences seen between Mesolithic and Neolithic groups.

Water and atmospheric temperatures may have been different between regions or changed throughout time. Due to the great diversity of areas and to the rather long period considered here, a control for environmental factors would have been open to question and even impossible for some regions. However, the sites under study are all located between 38° and 49° north latitude, and water and atmospheric temperatures in these areas were likely low, at least during a great part of the year. Thus, we can postulate that if contact with water was frequent enough, all individuals included in the analysis would have been susceptible to EAE.

Finally, other factors could explain, in part, the differences seen between samples. For instance, a selection of buried people based on specific activities practiced during life (e.g. in Neolithic groups a selection of individuals who were not involved in water-related activities) may have existed. However, it seems unlikely that such a very specific behaviour was present in so many different areas and widely dispersed groups.

Interpretation of high frequencies of EAE is often straightforward and related to subsistence strategies (e.g.

Özbek 2012, Standen *et al.* 1997, Velasco-Vazquez *et al.* 2000). One should keep in mind that this marker indicates frequent contact with cold water but reveals nothing about the exact activity practiced: fishing, diving, but also bathing, for instance. In the present analysis, for all the collections for which a high frequency was recorded, archaeological and/or isotopes analyses indicate a significant reliance on aquatic resources. Thus, EAE seen in these groups is very likely related to subsistence activities in the first place, but one should not forget other possible cultural practices or rites. On the contrary, the absence of EAE does not exclude aquatic activities, for instance when individuals protect their ears (Okumura *et al.* 2007). However, in this study there is no indication of a great reliance on aquatic resources where only a few cases of EAE were recorded. For instance, even if remains of fish were found in Middle Neolithic sites from the Canton of Valais (Baudais et al. 1989, Chaix 1976), their proportion is nothing in comparison with the proportion recovered at sites like Vlasac (see Bökönyi 1978). Thus, it seems that a good correlation between the suspected diet of prehistoric individuals and frequencies of EAE exists.

Based on a broad range of studies, EAE appears to be a faithful marker of water-related activities. Some limitations in the interpretation and comparison of frequencies do exist, but when multiple and varied and independent indicators agree, one can posit an underlying relationship to explain such a correspondence. The significant decrease of frequency of EAE seen in this study enriches the debate on dietary changes surrounding aquatic resources during the Mesolithic-Neolithic transition. This debate is mainly based on isotopic values of Mesolithic and Neolithic individuals. For Northern Europe, while some authors have used these data to discuss cultural prohibition (e.g. Thomas 2003), Milner and colleagues have raised some concerns regarding the over-interpretation of isotopic values, even if they "agree that the available isotope record indicates a consistent tendency towards a more dominant terrestrial signal in the diets of Neolithic individuals compared to their Mesolithic predecessors." (Milner *et al.* 2004: 18). Our study provides further independent evidence for a relatively minor component of freshwater food resources during the Neolithic, at quite a large geographical scale. This decrease in interest in aquatic resources is also seen at the regional scale, in the Iron Gates region, supporting the impression of a general pattern all over Europe. Other regional studies where isotope data and EAE are analysed conjointly, taking into account palaeo-environmental reconstructions, would help to further understanding of the changes in behaviours, social structures and beliefs at the Mesolithic-Neolithic transition in Europe.

ACKNOWLEDGEMENTS

The skeletons included in this study are curated in the following institutions: Musée d'Archéologie Nationale (France), Institut de Paléontologie Humaine (France), Ostéotèque de Pessac (France), Museu Geológico (Portugal), Museu Nacional de Arqueologia (Portugal), Museu de História Natural (Portugal), Département d'anthropologie et d'écologie de l'université de Genève (Switzerland), National Museum (Serbia), Department of Archaeology of the University of Belgrade (Serbia), Institute of Anatomy (Serbia), and University of Tübingen (Germany). SV is grateful to the many curators and researchers who allowed access to the material. Thanks to them, staff members, and students for their helpful comments on the collections. Thanks to Clive Bonsall, Bruno Maureille, Stéphane Rottier, Rick Schulting, and many others for comments and opinions on past behaviours. We also thank Sacha Kacki, Aline Thomas, and the two reviewers for comments on an earlier version of this manuscript.

SV gratefully acknowledges the financial support of the Fondation Fyssen.

REFERENCES

ADAMS W. S., 1951: The ætetiology of swimmer's exostoses of the external auditory canals and of associated changes in hearing. *The Journal of Laryngology & Otology* 65: 424–425.

ALTUNA MARIEZKURRENA X., GÓMEZ SUÁREZ J., LUQUI ALBISUA I., VEA ORTE J. C., ALGABA GUIMERÁ J., 2005: Prevalence of exostoses among surfers of the Basque Coast. *Acta Otorrinolaringológica Española* 55: 364–368.

AMPRINO R., 1985: The influence of stress and strain in the early development of shaft bones. *Anatomy and Embryology* 172, 1: 49–60.

ASCENZI A., BALISTRERI P., 1975: Aural exostoses in a roman skull excavated at the "Baths of the swimmer" in the ancient town of Ostia. *Journal of Human Evolution* 4: 579–584.

BARTOSIEWICZ L., BONSALL C., 2004: Prehistoric fishing along the Danube. *ANTAEUS* 27: 253–272.

BARTOSIEWICZ L., BONSALL C., ŞIŞU V., 2008: Sturgeon fishing in the middle and lower Danube region. In: C. Bonsall, V. Boroneanţ, I. Radovanović (Eds.): *The Iron Gates in prehistory: new perspectives*. BAR International Series 1893. Pp. 39–54. Archaeopress, Oxford.

BARTOSIEWICZ L., BORONEANŢ V., BONSALL C., STALLIBRASS S., 1995: Schela Cladovei: a preliminary review of the prehistoric fauna. *Mesolithic Miscellany* 16, 2: 2–19.

BARTOSIEWICZ L., BORONEANŢ V., BONSALL C., STALLIBRASS S., 2001: New data on the prehistoric fauna of the Iron Gates: a case study from Schela Cladovei, Romania. In: R. Kertész, J. Makkay (Eds.): *From the Mesolithic to the Neolithic.* Proceedings of the International Archaeological Conference held in the Damjanich Museum of Szolnok, September 22–27, 1996. Pp. 15–21. Archaeolingua, Budapest.

BAUDAIS D., BRUNIER C., CURDY P., DAVID-ELBIALI M., FAURE S., GALLAY A., MAY O., MOINAT P., MOTTET M., VORUZ J.-L., WINIGER A., 1989: Le Néolithique de la région de Sion (Valais). Un bilan. *Bulletin du Centre Genevois d'Anthropologie* 2: 5–56.

BAUDAIS D., KRAMAR C., 1990: *La nécropole néolithique de Corseaux en Seyton, (VD, Suisse)*. Document du Département d'anthropologie et d'écologie de l'Université de Genève, 15 (Cahiers d'archéologie romande ; 51), Lausanne.

BIEL J., 1982: Ein bandkeramischer Friedhof beim Viesenhäuser Hof, Stuttgart-Mühlhausen. *Archäologische Ausgrabungen in Baden-Württemberg, Stuttgart* S: 29–32.

BÖKÖNYI S., 1978: The vertebrate fauna of Vlasac. In: D. Srejović, Z. Letica (Eds.): *Vlasac. A Mesolithic settlement in the Iron Gates.* Vol. 2. Pp. 35–65. Serbian Academy of Sciences and Arts, Beograd.

BONSALL C., 2008: The Mesolithic of the Iron Gates. In: G. Bailey, P. Spikins (Eds.): *Mesolithic Europe*. Pp. 238–279. Cambridge University Press, Cambridge.

BONSALL C., BORONEANŢ V., RADOVANOVIĆ I. (Eds.), 2008a: *The Iron Gates in prehistory: new perspectives*. BAR International Series 1893. Archaeopress, Oxford.

BONSALL C., COOK G., LENNON R., HARKNESS D., SCOTT M., BARTOSIEWICZ L., MCSWEENEY K., 2000: Stable isotopes, radiocarbon and the Mesolithic-Neolithic transition in the Iron Gates. *Documenta Praehistorica* 27: 119–132.

BONSALL C., COOK T., HEDGES R. E. M., HIGHAM T. F. G., PICKARD C., RADOVANOVIĆ I., 2004: Radiocarbon and stable isotope evidence of dietary change from the Mesolithic to the Middle Ages in the Iron Gates: new results from Lepenski vir. *Radiocarbon* 46, 1: 293–300.

BONSALL C., LENNON R., MCSWEENEY K., STEWART C., HARKNESS D., BORONEANT V., BARTOSIEWICZ V., PAYTON R., CHAPMAN J., 1997: Mesolithic and early Neolithic in the Iron Gates: A palaeodietary perspective. *Journal of European Archaeology* 5: 50–92.

BONSALL C., RADOVANOVIĆ I., ROKSANDIĆ M., COOK G., HIGHAM T., PICKARD C., 2008b: Dating burial practices and architecture at Lepenski Vir. *The Iron Gates in prehistory: New perspectives*: 175–198.

BORIĆ D., 2002: The Lepenski Vir conundrum: reinterpretation of the Mesolithic and Neolithic sequences in the Danube Gorges. *Antiquity* 76: 1026–1039.

BORIĆ D., 2007: Mesolithic-Neolithic interactions in the Danube Gorges. In: J. Kozłowski, M. Nowak (Eds.): *Mesolithic-Neolithic interactions in the Balkans and in the Middle Danube basin.* XV World Congress of the International Union for Prehistoric and Protohistoric Sciences, Lisbon, Portugal, 4–9 September 2006. BAR International Series, 1727. Pp. 31–45. Archaeopress, Oxford.

BORIĆ D., FRENCH C., DIMITRIJEVIC V., 2008: Vlasac revisited: formation processes, stratigraphy and dating. *Documenta Praehistorica* 35: 261–287.

BORIĆ D., GRUPE G., PETERS J., MIKIĆ Ž., 2004: Is the Mesolithic-Neolithic subsistence dichotomy real? New stable isotope evidence from the Danube Gorges. *European Journal of Archaeology* 7, 3: 221–248.

BORIĆ D., MIRACLE P., 2004: Mesolithic and Neolithic (dis)continuities in the Danube Gorges: new AMS dates from Padina and Hajdučka Vodenica (Serbia). *Oxford Journal of Archaeology* 23, 4: 341–371.

BORIĆ D., PRICE T. D., 2013: Strontium isotopes document greater human mobility at the start of the Balkan Neolithic. *Proceedings of the National Academy of Sciences U.S.A*. 110, 9: 3298–3303.

BRŮŽEK J., 2002: A method for visual determination of sex, using the human hip bone. *American Journal of Physical Anthropology* 117, 2: 157–168.

CASTEX D., COURTAUD P., HAMBUCKEN-BONTEMPI A., 1993: La détermination sexuelle des séries archéologiques: la validité de certains caractères osseux «extra-coxaux». *Bulletins et Mémoires de la Société d'anthropologie de Paris* 5, 1–2: 225–235.

CHAIX L., 1976: Quelques aspects de la faune néolithique du Valais. *Bulletin de la Murithienne* 93: 57–67.

CHAPLIN J. M., STEWART I. A., 1998: The prevalence of exostoses in the external auditory meatus of surfers. *Clinical Otolaryngology & Allied Sciences* 23, 4: 326–330.

COOPER A., TONG R., RICHARD NEIL, OWENS D., TOMKINSON A., 2010: External auditory canal exostoses in white water kayakers. *British Journal of Sports Medicine* 44: 144–147.

CROWE F., SPERDUTI A., O'CONNELL T. C., CRAIG O. E., KIRSANOW K., GERMONI P., MACCHIARELLI R., GARNSEY P., BONDIOLI L., 2010: Water-related occupations and diet in two Roman coastal communities (Italy, first to third century AD): correlation between stable carbon and nitrogen isotope values and auricular exostosis prevalence. *American Journal of Physical Anthropology* 142, 3: 355–366.

CUNHA E., CARDOSO F., 2001: The osteological series from Cabeço Da Amoreira (Muge, Portuga). *Bulletins et Mémoires de la Société d'Anthropologie de Paris* 13, 3–4: 323–333.

CUNHA E., UMBELINO C., CARDOSO F., 2002: New anthropological data on the Mesolithic communities from Portugal: the shell, middens from Sado. *Human Evolution* 17, 3: 187–197.

DA VEIGA FERREIRA O., 1968: Algumas notas acerca da pesca na antiguidade. *O Arqueólogo Portugûes* 3, 2: 113–133.

DELEYIANNIS F. W. B., COCKCROFT B. D., PINCZOWER E. F., 1996: Exostoses of the external auditory canal in oregon surfers. *American Journal of Otolaryngology* 17, 5: 303–307.

DENAIRE A., 2009: Radiocarbon dating of the Western European Neolithic: comparison of the dates on bones and dates on Chorcoals. *Radiocarbon* 51, 2: 657–674.

DI BARTOLOMEO J., 1979: Exostoses of the external auditory canal. *Annals of Otology, Rhinology, and Laryngology* 88: 2–20.

DINU A., 2010: Mesolithic fish and fishermen of the Lower Danube (Iron Gates). *Documenta Praehistorica* 37: 299–310.

DUPONT C., TRESSET A., DESSE-BERSET N., GRUET Y., MARCHAND G., SCHULTING R. J., 2009: Harvesting the seashores in the Late Mesolithic of Northwestern Europe: a view from Brittany. *Journal of World Prehistory* 22: 93–111.

DUTOUR O., 1992: Activités physiques et squelette humain: le difficile passage de l'actuel au fossile. *Bulletins et Mémoires de la Société d'Anthropologie de Paris* 4, 3–4: 233–241.

FILIPO R., FABIANI M., BARBARA M., 1982: External ear canal exostosis: a physiopathological lesion in aquatic sports. *The Journal of Sports Medicine and Physical Fitness* 22, 3: 329–336.

FOWLER E. P., OSMUN P. M., 1942: New bone growth due to cold water in the ears. *Archives of Otolaryngology* 36, 4: 455–466.

FRAYER D. W., 1988: Auditory exostoses and evidence for fishing at Vlasac. *Current Anthropology* 29, 2: 346–349.

GLUCKSMANN A., 1942: The role of mechanical stresses in bone formation in vitro. *Journal of Anatomy* 76, 3: 231–239.

GREGG J. B., MCGREW R. N., 1970: Hrdlicka revisited (external auditory canal exostoses). *American Journal of Physical Anthropology* 33, 1: 37–40.

HARRISON D. F. N., 1962: The relationship of osteomata of the external auditory meatus to swimming. *Annals of The Royal College of Surgeons of England* 31: 187–201.

HONNEGGER M., DESIDERI J., 2003: Archéologie et anthropologie de la nécropole du Néolithique moyen de Barmaz (Valais, Suisse). In: P. Chambon, J. Leclerc (Eds.): *Les pratiques funéraires néolithiques avant 3500 av. J.-C. en France et dans les régions limitrophes*. Pp. 219–230. Société Préhistorique Française, Paris.

HURST W., BAILEY M., HURST B., 2004: Prevalence of external auditory canal exostoses in Australian surfboard riders. *The Journal of Laryngology & Otology* 118: 348–351.

HUTCHINSON D. L., DENISE C. B., DANIEL H. J., KALMUS G. W., 1997: A reevalution of the cold water etiology of external auditory exostoses. *American Journal of Physical Anthropology* 103: 417–422.

ITO M., IKEDA M., 1998: Does cold water truly promote diver's ear? *Undersea & Hyperbaric Medicine* 25, 1: 59–62.

JACKES M., LUBELL D., MEIKLEJOHN C., 1997: Healthy but mortal: human biology and the first farmers of western Europe. *Antiquity* 71: 639–658.

JACKES M., MEIKLEJOHN C., 2004: Building a method for the study of the Mesolithic-Neolithic transition in Portugal. *Documenta Praehistorica* 11: 89–111.

JACKES M., MEIKLEJOHN C., 2008: The paleodemography of Central Portugal and the Mesolithic-Neolithic transition. In: J.-P. Bocquet-Appel (Ed.): *Recent advances in palaeodemography*. Pp. 209–258. Springer, Dordrecht.

JOVANOVIĆ B., 2008: Micro-regions of the Lepenski Vir culture: Padina in the Upper Gorge and Hajdučka Vodenica in the Lower Gorge of the Danube. *Documenta Praehistorica* 35: 1–36.

JURMAIN R., 1999: *Story from the skeleton*. Gordon and Breach Publishers, Amsterdam.

JURMAIN R., ALVES CARDOSO F., HENDERSON C. Y., VILLOTTE S., 2012: Bioarchaeology's Holy Grail: The reconstruction of activity. In: A. L. Grauer (Ed.): *A companion to paleopathology*. Pp. 531–552. Wiley-Blackell, New-York.

KAREGEANNES J. C., 1995: Incidence of bony outgrowths of the external ear canal in U.S. Navy divers. *Undersea Hyperb. Med* 22, 3: 301–306.

KENNEDY G. E., 1986: The relationship between auditory exostosis and cold water: a latitudinal analysis. *American Journal of Physical Anthropology* 71: 401–415.

KROON D. F., LAWSON M. L., DERKAY C. S., HOFFMANN K., MCCOOK J., 2002: Surfer's ear: external auditory exostoses are more prevalent in cold water surfers. *Otolaryngology – Head and Neck Surgery* 126, 5: 499–504.

KURZ G., 1991: Archäologische Untersuchungen beim Viesenhäuser Hof, Stuttgart-Mühlhausen. *Archäologische Ausgrabungen in Baden-Württemberg, Stuttgart*: 50–53.

KURZ G., 1992: Vorgeschichtliche Siedlungen und Gräber beim Viesenhäuser Haf, Stuttgart-Mühlhausen. *Archäologische Ausgrabungen in Baden-Württemberg, Stuttgart*: 61–64.

KURZ G., 1993: Zum Abschluß der Ausgrabungen beim Viesenhäuser Hof, Stuttgart-Mühlhausen. *Archäologische Ausgrabungen in Baden-Württemberg, Stuttgart*: 34–38.

LUBELL D., JACKES M., SCHWARCZ H., KNYF M., MEIKLEJOHN C., 1994: The Mesolithic-Neolithic transition in Portugal: isotopic and dental evidence of diet. *Journal of Archaeological Science* 21, 2: 201–216.

MANZI G., SPERDUTI A., PASSARELLO P., 1991: Behavior-induced auditory exostoses in imperial Roman society: evidence from coeval urban and rural communities near Rome. *American Journal of Physical Anthropology* 85, 3: 253–260.

MARCHAND G., 2001: Les traditions techniques du Mésolithique final dans le sud du Portugal: les industries lithiques des amas coquilliers de Várzea da Mó et de Cabeço do Rebolador (fouilles M. Heleno). *Revista Portuguesa de Arqueologia* 4, 2: 47–110.

MARCHAND G., 2005: Interpretar as mudanças dos sistemas técnicos do Mesolítico final em Portugal. *O Arqueologo Português* 4, 23: 171–196.

MEIKLEJOHN C., BOSSET G., VALENTIN F., 2010: Radiocarbon dating of Mesolithic human remains in France. *Mesolithic Miscellany* 21, 1: 10–56.

MEIKLEJOHN C., ROKSANDIĆ M., JACKES M., LUBELL D., 2009: Radiocarbon dating of Mesolithic human remains in Portugal. *Mesolithic Miscellany* 20, 1: 4–16.

MEIKLEJOHN C., ZVELEBIL M., 1991: Health status of European populations at the agricultural transition and the implications for the adoption of farming. In: H. Bush, M. Zvelebil (Eds.): *Health in past societies. Biocultural interpretations of human skeletal remains in archaeological remains.* BAR International Series. Pp. 129–143. Archaeopress, Oxford.

MILNER N., CRAIG O. E., BAILEY G. N., PEDERSEN K., ANDERSEN S. H., 2004: Something fishy in the Neolithic? A re-evaluation of stable isotope analysis of Mesolithic and Neolithic coastal populations. *Antiquity* 78, 299: 9–22.

MOINAT P., 2007: Cistes en pierre et coffres en bois, inhumations simples et dépôts complexes: un bilan des pratiques funéraires à Vidy (Lausanne, Vaud) et à Chamblandes (Pully, Vaud). In: P. Moinat, P. Chambon (Eds.): *Les cistes de Chamblandes et la place des coffres dans les pratiques funéraires du Néolithique moyen occidental.* Actes du colloque de Lausanne, 12 et 13 mai 2006. Mémoires de la Société Préhistorique Française, 43. Pp. 195–220.

MURAIL P., BRŮŽEK J., BRAGA J., 1999: A new approach to sexual diagnosis in past populations. Practical adjustements from Van Vark's procedure. *International Journal of Osteoarchaeology* 9, 1: 39–53.

MURAIL P., BRUZEK J., HOUËT F., CUNHA E., 2005: DSP: a tool for probabilistic sex diagnosis using worlwide variability in hip-bone measurements *Bulletins et Mémoires de la Société d'Anthropologie de Paris* 17, 3–4: 167–176.

NEHLICH O., BORIĆ D., STEFANOVIĆ S., RICHARDS M. P., 2010: Sulphur isotope evidence for freshwater fish consumption: a case study from the Danube Gorges, SE Europe. *Journal of Archaeological Science* 37, 5: 1131–1139.

OKUMURA M. M. M., CÉLIA H. C. B., EGGERS S., 2007: Auditory exostoses as an aquatic activity marker: a comparison of coastal and inland skeletal remains from tropical and subtropical regions of Brazil. *American Journal of Physical Anthropology* 132, 4: 558–567.

ÖZBEK M., 2012: Auditory exostoses among the Pre-Pottery Neolithic inhabitants of Çayönü and Aşıklı, Anatolia; its relation to aquatic activities. *International Journal of Paleopathology* 2, 4: 181–186.

PÉQUART M., PÉQUART S.-J., 1934: La nécropole mésolithique de l'Ile d'Hoëdic (Morbihan). *L'Anthropologie* 44: 1–20.

PÉQUART M., PÉQUART S.-J., BOULE M., VALLOIS H., 1937: *Téviec, station-nécropole mésolithique du Morbihan*. Archives de l'Institut de Paléontologie Humaine, Mémoire 18, Paris.

PONCE P., GHIDINI G., GONZÁLEZ-JOSÉ R., 2008: External auditory exostosis "at the end of the world" the southernmost evidence according to the latitudinal hypothesis. In: M. Brickley, M. Smith (Eds.): *Proceedings of the Eighth Annual Conference of the British Association for Biological Anthropology and Osteoarchaeology.* British Archaeological Reports S1743. Pp. 101–107. Archaeopress, Oxford.

RADOSAVLJEVIĆ-KRUNIĆ S., 1986: Résultats de l'étude anthroplogique des squelettes provenant du site Ajmana. *Cahiers des Portes de Fer* 3: 51–58.

RADOVANOVIĆ I., 1996: *The Iron Gates Mesolithic*. Ann Arbor, Michigan.

RADOVANOVIĆ I., 2006: Further notes on Mesolithic-Neolithic contacts in the Iron Gates region and the Central Balkans. *Documenta Praehistorica* 33: 107–124.

RICHARDS M. P., HEDGES R. E. M., 1999: Stable isotope evidence for similarities in the types of marine foods used by Late Mesolithic humans at sites along the Atlantic Coast of Europe. *Journal of Archaeological Science* 26, 6: 717–722.

RICHARDS M. P., PRICE T. D., KOCH E., 2003: Mesolithic and Neolithic subsistence in Denmark: new stable isotope data. *Current Anthropology* 44, 2: 285–295.

ROCHE J., DA VEIGA FERREIRA O., 1967: Les fouilles récentes dans les amas coquillers Mésolithiques de Muge (1952–1965). *Separata do Arqueólogo Português* 3, 1: 19–41.

ROKSANDIĆ M., 1999: *Transition from Mesolithic to Neolithic in the Iron Gates Gorge: physical anthropology perspective.* Unpublished Ph.D. dissertation. Department of Anthropology, Simon Fraser University, Vancouver.

ROTTIER S., MORDANT C., CHAMBON P., THEVENET C., 2005: Découverte déplus d'une centaine de sépultures du Néolithique moyen à Gurgy, les Noisats (Yonne). *Bulletin de la Société préhistorique française* 2, 3: 641–645.

SCHULTING R. J., 1998: Slighting the sea: the transition to farming in northwest Europe. *Documenta Praehistorica* 25: 203–218.

SCHULTING R. J., RICHARDS M. P., 2001: Dating women and becoming farmers: new palaeodietary and AMS dating evidence from the Breton Mesolithic cemeteries of Téviec and Hoëdic. *Journal of Anthropological Archaeology* 20, 3: 314–344.

SLADIĆ M., 1986: Kula près de Mihajlovac – Un site préhistorique. *Cahiers des Portes de Fer* 3: 432–442.

SLADIĆ M., 2007: The architecture of early prehistoric settlements on the site of Kula at Mihajlovac [Архитектура раних праисторијских насеља на локалитету Кула код Михајловца]. *Archaica* 1: 9–40.

SREJOVIĆ D., LETICA Z. (Eds.), 1978: *Vlasac. A Mesolithic settlement in the Iron Gates. Vol. 1, Archaeology*. Serbian Academy of Sciences and Arts, Beograd.

STALIO B., 1986: Le site préhistorique Ajmana à Mala Vrbica. *Cahiers des Portes de Fer* 3: 27–35.

STANDEN V. G., ARRIAZA B. T., SANTORO C. M., 1997: External auditory exostosis in prehistoric Chilean populations: a test of the cold water hypothesis. *American Journal of Physical Anthropology* 103: 119–129.

THOMAS J., 2003: Thoughts on the 'repacked' Neolithic revolution. *Antiquity* 77: 67–74.

TIMOFEEV I., NOTKINA N., SMITH I. M., 2004: Exostoses of the external auditory canal: a long-term follow-up study of surgical treatment. *Clinical Otolaryngology* 29, 6: 588–594.

UMBELINO C. I. S., 2006: *Outros sabores do passado: as análises de oligoelementos e de isótopos estáveis na reconstituição da dieta das comunidades humanas do Mesolítico Final e do Neolítico Final-Calcolítico do território português*. PhD thesis. Departamento de Antropologia, Universidade de Coimbra, Coimbra.

VAN GILSE P. H. G., 1938: Des obervations ultérieures sur la genèse des exostoses du conduit externe par l'irritation d'eau froide. *Acta Oto-Laryngologica*: 343–352.

VELASCO-VAZQUEZ J., BETANCOR-RODRIGUEZ A., ARNAY-DE-LA ROSA M., GONZALEZ-REIMERS E., 2000: Auricular exostoses in the prehistoric population of Gran Canaria. *American Journal of Physical Anthropology* 112, 1: 49–55.

VILLOTTE S., 2008: Les marqueurs ostéoarticulaires d'activité. In: P. Charlier (Ed.): *Ostéo-archéologie et techniques médico-légales : tendances et perspectives. Pour un "Manuel pratique de paléopathologie humaine"*. Pp. 383–389. Editions De Boccard, Paris.

VILLOTTE S., PERRÉARD-LOPRENO G., 2012: Apprentissage et reproductibilité d'une méthode de cotation de l'aspect osseux des enthèses fibrocartilagineuses: résultats d'un test effectué lors du Workshop de la Société Suisse d'Anthropologie (Genève, 25 et 26 Juin 2010). *Bulletin de la Société Suisse d'Anthropologie* 18, 1: 5–25.

WHITE R. D., ANANTHAKRISHNAN G., MCKEAN S. A., BRUNTON J. N., HUSSAIN S. S. M., SUDARSHAN T. A., 2012: Masses and disease entities of the external auditory canal: radiological and clinical correlation. *Clinical Radiology* 67, 2: 172–181.

ŽIVALJEVIĆ I., 2012: Big fish hunting: interpretation of stone clubs from Lepenski Vir. In: N. Vasić (Ed.): *Harmony of nature and spirituality in stone.* Proceedings of the 2nd International Conference in Kragujevac, Serbia, March 15–16, 2012. Pp. 195–206. Stone Studio Association, Belgrade.

Sébastien Villotte
Anthropologie des Populations Passées et Présentes
PACEA, UMR 5199
Université Bordeaux 1 – CNRS
Bat. B8, Avenue des Facultés
33405, Talence
France
E-mail: s.villotte@pacea.u-bordeaux1.fr

Sofija Stefanović
Laboratory for Bioarchaeology
Department of Archaeology
Faculty of Philosophy
University of Belgrade,
Čika Ljubina 18–20,
11000, Belgrade
Serbia
E-mail: smstefan@f.bg.ac.rs

Christopher J. Knüsel
Department of Archaeology
University of Exeter
Laver Building
North Park Road
Exeter, Devon, EX4 4QE
United Kingdom
E-mail: c.j.knusel@exeter.ac.uk