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ORIGINAL ARTICLE

The diet of Eneolithic (Copper Age, Fourth millennium cal B.C.) pile dwellers and the early formation of the cultural landscape south of the Alps: a case study from Slovenia

Marjeta Jeraj · Anton Velušček · Stefanie Jacomet

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Abstract Analyses were performed of plant remains from the Late Neolithic (in Slovenian terminology corresponding to Eneolithic or Copper Age, ca. 4300–2300 B.C.) pile dwelling Hočevarica in the Ljubljansko barje (Ljubljana Moor), Slovenia. This settlement existed between ca. 3650 and 3550 cal B.C. Seeds, fruits, wooden piles, macroscopic charcoal and pollen from the cultural layers were analysed. The remains of domestic plants such as charred grains of *Hordeum vulgare* (barley), *Triticum monococcum*, *T. dicoccum* (einkorn and emmer wheat) and *Papaver somniferum* (poppy seeds), as well as seeds of weeds such as *Chenopodium album*-type indicate early cultivation in the area. In addition, numerous remains of nuts and berries, especially of *Quercus* sp., *Cornus mas*, *Rubus fruticosus* and *Corylus avellana* demonstrate that the gathering of wild plants was an important part of subsistence. Palaeoecological and archaeobotanical data from Hočevarica further suggest that cleared land was used for agriculture and pastures during the Neolithic, and that different wood was cut for construction and for fuel. The species assemblage from Hočevarica is very similar to those recovered from northern Alpine lake dwelling sites, however, several new taxa (e.g. *Lathyrus sativus, Vicia* sp.) appear in the assemblage. One of the most surprising finds is the seed of wild grape (*Vitis vinifera* ssp. *sylvestris*), which are the oldest on-site remains of grapevine from Slovenia.

Keywords Archaeobotany · Plant economy · Human impact · Lake shore settlement · Eneolithic (Late Neolithic) · Ljubljansko barje · Central Slovenia

M. Jeraj (✉)
Department of Botany, University of Wisconsin-Madison, 132 Birge Hall, 430 Lincoln Drive, Madison, WI 53706-1381, USA
e-mail: mjeraj@wisc.edu

A. Velušček
Institute of Archaeology, Scientific Research Center of the Slovenian Academy of Sciences and Arts, Novi trg 2, 1000 Ljubljana, Slovenia
e-mail: anton.veluscek@zrc-sazu.si

S. Jacomet
Institute for Prehistory and Archaeological Science IPAS, Basel University, Spalenring 145, 4055 Basel, Switzerland
e-mail: stefanie.jacomet@unibas.ch

Introduction

State of research, aims of the study

Pile dwellings from Late Neolithic (including the Eneolithic or Copper Age) and Bronze Age periods are known from different parts of Europe (Menotti 2004). Waterlogged sediments resulted in excellent preservation of the remains of former lakeside settlements. In the circumalpine region, extensive palaeoethnobotanical studies of prehistoric lake-dwelling sites have been conducted in Switzerland (for overviews see Jacomet 2004, 2006, 2007; Jacomet et al. 2004; Jacomet and Brombacher 2005), south-western Germany (Maier 2001, 2004), western Austria (Ruttkay et al. 2004; Kohler-Schneider 2007; Kohler-Schneider and Cannepele 2008) and eastern France (Bocquet et al. 1987; Pétrequin et al. 1998; Lundström-Baudais 1986, 1989a, b, c). Similar studies from the regions south of the Alps are, however, rare and often not representative, or absent altogether (for Italy see Cattani and Carra 2002; Marzatico 2004; for an overview see

Rottoli and Castglioni 2008). Up until now reliable comparisons of the plant economy of Neolithic settlements north and south of the Alps have not been made.

The main focus of this study is to provide first insights on the nutrition, life style, economy and environment of the Late Neolithic (locally Eneolithic) pile dwellers from Hočevarica in the Ljubljansko barje in Slovenia, dating from between approximately 3650 and 3550 cal B.C. (Velušček 2004a). We will also evaluate the impact of the population on the surrounding vegetation and landscape. Finally, in order to discover potential similarities or differences in the nutrition and environment of prehistoric populations, we will compare the archaeobotanical results with Neolithic plant remains from other southern and the northern Alpine pile-dwelling regions, as well as with the results from the Iceman (Oeggl 2000; Dickson et al. 2005, Oeggl et al. 2008)

The history of archaeobotanical research of Slovene pile dwellings

In Slovenia, which occupies the south-eastern corner of the Alps (Fig. 1), approximately 40 prehistoric pile dwellings from the Neolithic, Eneolithic (Copper Age) and Early Bronze Age periods have been recorded. These ancient lacustrine and marshland settlements were all discovered in the central part of the country, across the Ljubljansko barje area (Fig. 1). Archaeological excavations of the settlements were often accompanied by archaeobotanical studies. During initial archaeological excavations in the second half of the 19th until the beginning of the 20th century, archaeobotanical analyses were carried out sporadically (Šercelj 1981–1982; Culiberg 1999). Broken hazelnut shells (*Corylus avellana*), fragments of *Trapa natans* (water chestnut), fruitstones of *Cornus mas* (Cornelian-cherry), acorns (*Quercus* sp.), nutlets of *Crataegus monogyna* (hawthorn) and fruitstones of *Prunus padus* (bird cherry) were recovered among seeds and fruits. The remains of wooden piles mostly belonged to *Populus* sp. (poplar), *Fraxinus* sp. (ash), *Ulmus* sp. (elm), *Quercus* sp. (oak) and *Alnus* sp. (alder).

More detailed archaeobotanical studies from Ljubljansko barje were performed in the second half of the 20th century. They accompanied archaeological excavations of the pile dwellings Maharski prekop, Notranje Gorice and Parte, and were primarily focused on recovered wooden piles (Culiberg 1999). The analyses of more than a thousand piles suggested that the early settlements were mainly constructed of oak (*Quercus robur, Q. petraea, Q. cerris*) and ash (*Fraxinus excelsior, F. ornus*), while the wood from *Sorbus aucuparia* (rowan), *Carpinus betulus* (hornbeam), *Alnus glutionosa* (black alder) and *Corylus avellana* (hazel) was less frequently used as building material (Culiberg and Šercelj 1991; for wood anatomical details see Culiberg et al. 1992). In the less extensive carpological studies charred grains of *Triticum* sp. (wheat) and *Hordeum* sp. (barley), fruitstones of *Cornus mas*, nutlets of *Rubus* sp. (raspberry), seeds of *Vitis vinifera* ssp. *sylvestris* (grape) and broken C*orylus avellana* shells were commonly found (Šercelj 1981–1982). In addition to macro remains, several pollen records from archaeological sites and cores taken nearby also reflected human activities during the early occupation of the area (Šercelj 1981–1982; Culiberg and Šercelj 1991).

In contrast to previous archaeobotanical investigations from Ljubljansko barje, the Hočevarica study was systematically and extensively designed to obtain comprehensive knowledge about the subsistence, activities and surroundings of the Neolithic wetland communities. Analyses of plant macro remains, such as wood, fruits and seeds, from the cultural layers were performed to obtain information on the utilization of the available plant resources by local people. In addition, macroscopic charcoal fragments, which in Slovenia and particularly on Ljubljansko barje have so far not been extensively studied, were analysed. Macro-botanical evidence from Hočevarica was compared with pollen records from an archaeological on-site-profile and with a nearby off-site core (Jeraj 2000, 2004a). The latter better reflects environmental conditions

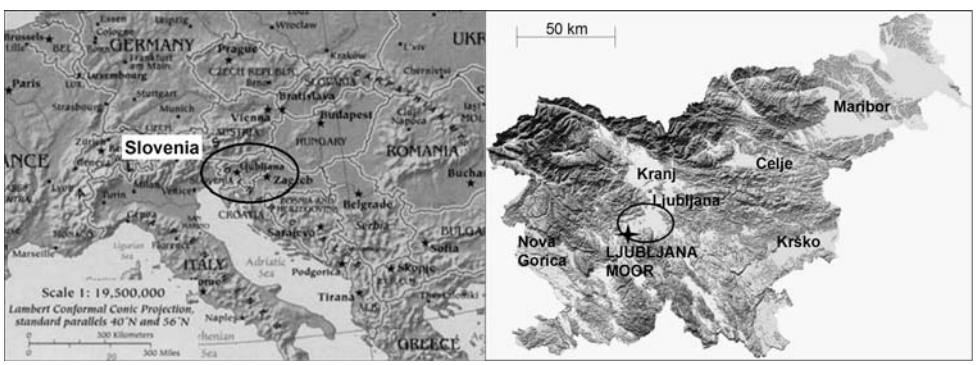

Fig. 1 Location of the Eneolithic pile dwelling Hočevarica in the south-west of the Ljubljana Moor (Ljubljansko barje) in central Slovenia

spatially and temporally, including vegetation distribution and the cultural landscape on the southwestern Ljubljansko barje during the settlement period.

Study area

Geography, climate and formation of Ljubljansko barje

The Eneolithic settlement Hočevarica (290 m a.s.l. 45°57′30″N, 14°20′00″E) is situated in the southwestern part of the Ljubljansko barje in central Slovenia (Fig. 1). Ljubljansko barje is a 163 km^2 wetland in a tectonic depression in the southern part of the Ljubljana basin with an average altitude of 290 m a.s.l. It lies in the southern alpine foothills region and it has a climate with cold winters and warm summers. The main water sources in the area are rivers with extensive karstic watersheds in the Dinaric Mountains to the south, and rivers coming from the Alpine foothills to the north. Most of the region is a marshy flood plain, while the rest is alluvial fans; in between there are isolated hills (Lovrenčak and Adamič 1998).

Cultivated fields and meadows cover a large proportion of the hinterland, while the margins of the mire are nowadays fairly densely inhabited. Mixed beech forests dominate on the surrounding slopes. According to Melik (1946) the upper sediments from Ljubljansko barje are of lake origin and are proof of the existence of a lake which began to drain several thousand years ago, when intensive colonization of pile dwellers across the entire area of Ljubljansko barje occurred. Thereafter, mires and peat bogs formed in the tectonic depression.

Settlement setting and chronology

The archaeological site Hočevarica is located along the right bank of the Ljubljanica which is the main river in the area. On the basis of soil stratigraphy, recovered artefacts and macrofaunal remains, two settlements or rather two archaeological settlement phases (Fig. 2) were detected throughout the cultural layer at a depth between ca. 185 and 135 cm (Velušček 2004b). Findings from a depth between ca. 185 and 165 cm belong to a first settlement phase that can be ascribed to the second half of the 37th cal B.C., based on ^{14}C-dating of a floating oak-chronology (Velušček 2004a). The very bottom of this layer (ca. 10 cm thick) consisted of an organic layer including burnt material, wooden piles and artefacts. Remains from a depth between ca. 160 and 135 cm were attributed to a second phase, dated to around the first half of the 36th century cal B.C. (Velušček 2004a). In the intermediate sediments, at a depth between ca. 170 and 160 cm, changes in the stratigraphy, the pollen spectrum and concentration of phosphates, as well as mixing of artefacts from phases 1 and 2 were observed. They suggest an interruption of the settlement for a short period of a few to several decades (Velušček 2004b).

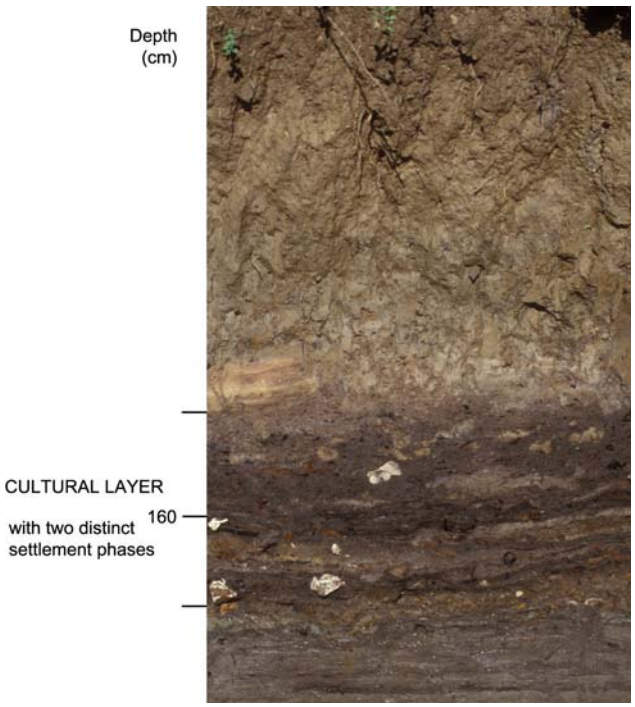

Fig. 2 Soil stratigraphy of the archaeological profile at Hočevarica. The dark layers in the bottom of the profile (around a depth of 160 cm) are the cultural layers which contained abundant artefacts, plant and animal remains. Within the cultural layers two potential settlements or settlement phases were distinguished (Photo A. Velušček)

The Eneolithic or Copper Age lasted in Slovenia from approximately 4300 until 2300 cal B.C. This period is characterized by the appearance of copper objects and an increasing number of settlements. Since similar archaeological finds appeared in the samples from both settlement phases, the site at Hočevarica is best ascribed to a single cultural horizon, characterized by pottery with furrowed incisions, that is chronologically set between the Lasinja culture and the Boleráz-phase of the Baden culture (Velušček 2004c). The older part of the floating oak-chronology from the site Hočevarica overlaps with the chronology from the pile dwelling at Palù di Livenza in northeastern Italy, as shown by the cross-dating of these chronologies (Čufar and Martinelli 2004).

Materials and methods

Seeds and fruits

The samples for archaeobotanical analyses were obtained during a 2 m deep small-scale excavation. The 2 × 4 m^2

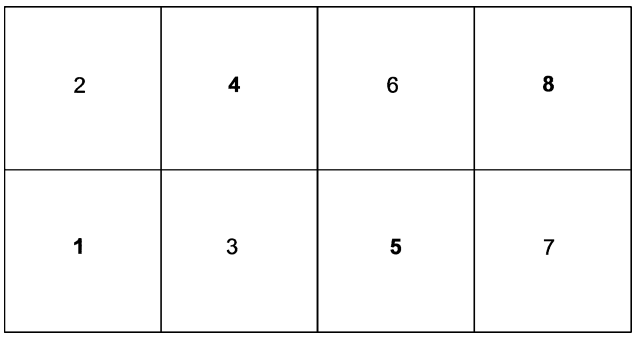

Fig. 3 Scheme of a 2 m deep archaeological excavation (2 × 4 m) at Hočevarica; samples from quadrants 1, 4, 5 and 8 were analysed for archaeobotanical remains

excavated surface was divided into eight 1 m^2 quadrants, and soil samples from the quadrants 1, 4, 5 and 8 were taken from different levels in the cultural layer (Fig. 3). The technique used in this study differed from the one used in the northern Alpine sites. Therefore studies on representativeness, such as those done by Jacomet and Brombacher (2005) which provided useful information, are limited here to charred and lignified material only.

For the analyses of seeds and fruits, 30 soil samples from 11 overlapping sublayers with thicknesses between 2 and 11 cm were collected at a depth between 190 and 124 cm. Settlement phase 1 is represented by 12 samples, the intermediate phase (1/2) by 10 samples, and settlement phase 2 by 8 samples.

The samples were screened under running water and run through three different sieves with 3, 1 and 0.5 mm meshes, respectively. Unfortunately the fractions were dried after sieving which is not appropriate for waterlogged sediments. Therefore only charred remains are represented properly. In the uncarbonised material seeds and fruits with lignified pericarps or testae are predominant whereas taxa with softer tissues are underrepresented or even lacking. This bias has to be considered when evaluating the spectra.

The dried seeds, fruits and their fragments were picked out from the whole fractions, sorted, counted and identified using a stereo microscope with 5× to 50× magnification. For most seeds and fruits we counted every recognizable piece as one. In the case of *Corylus avellana*, the absolute number of recovered nuts was calculated from the ratio between the weight of broken shells and the weight of five complete nuts.

The recovered macro-botanical remains represent a thanatocoenosis, i.e. an assemblage of plant remains that were mostly brought to the site by human or animal activities from different places in the surrounding area, and were later deposited in the cultural layer (Willerding 1991; Behre and Jacomet 1991; Hosch and Jacomet 2001). In contrast to palaeoenvironmental approaches, plant remains from archaeological sites are therefore "ecofacts" and are a result of human selection.

The identification of seeds and fruits was performed by using subfossil and modern reference collections from the Institute of Biology of the ZRC SAZU Ljubljana, the Center for Climatic Research at the University of Wisconsin-Madison, University College, London, and the Institute for Prehistory and Archaeological Science IPAS, Basel, Switzerland as well as manuals by Berggren (1981), Anderberg (1994), Behre (1998), Martinčič et al. (1999), Hillman et al. (1996) and Zohary and Hopf (2000). Plant nomenclature for wild taxa is based on Martinčič et al. (1999), and for domesticated plants on Zohary and Hopf (2000, traditional classification). Grape seeds and charred cereal grains were AMS radiocarbon dated at Beta Analytic Inc. (Miami, FL, USA) and at the University of Arizona (Tucson, AZ, USA).

Charcoal

Eighteen subsamples of 25–50 charcoal pieces were randomly picked out of the sediment, from the quadrants 1, 4, 5 and 8 within the cultural layer. In total 576 fragments were analysed. Six of the samples come from the first settlement phase, eight from the intermediate one, and four from the second settlement phase. The sizes of the charcoal particles range between 0.5 and 5 cm.

Charcoal was identified using a stereo microscope with up to 50× magnification and a compound stereomicroscope with reflective light and 100× to 400× magnification. Each of the fragments was manually fractured in cross, radial and tangential section, and anatomical features in all of these sections were investigated. Depending on the level of preservation, the charcoal fragments were identified to the highest possible taxonomic level—either to the species, genus or to the family—by comparison of the recovered charcoal with slides of freshly cut wood and with wood identification keys (Jacquiot et al. 1973a, b; Grosser 1977; Torelli 1991; Schweingruber 1993). Accurate identification to higher levels was particularly problematic within the Rosaceae family, where several charcoal types, including *Prunus* sp., *Sorbus* sp., *Pyrus/Malus* and *Crataegus* sp. were identified.

Wooden piles

A total of 361 samples from the wooden piles were collected from the Hočevarica drainage ditch, alongside the archaeological excavation trench, and from the trench itself (Čufar and Velušček 2004). The preparation and identification of the 10–20 cm long samples were carried out by

the dendrochronologists in the Department of Wood Science and Technology, University of Ljubljana, Slovenia (Table 3).

Pollen

Sediment samples for pollen analyses were obtained from the 2 m deep northern exposure of the archaeological excavation (opposite the profile shown in Fig. 2). They were taken from 2 to 5 cm thick layers with different sediment composition, from a depth between 190 and 105 cm; layers above 105 cm were contaminated by modern activities and thus not suitable for an analysis. Pollen samples 1 cm^3 in volume were taken from the sediment using small glass tubes. Pollen extraction was based on the method of Faegri and Iversen (1989). Pollen and other microfossils were examined using a compound microscope at magnifications of 100×, 200×, 320× and 450×. Identification was performed using keys and images from several manuals, Faegri and Iversen (1989), Dickson (1988), Moore et al. (1991) and Reille (1992), and by comparison with reference material from modern pollen collections (Institute of Biology of the ZRC SAZU, Ljubljana, Slovenia and the Center for Climatic Research, University of Wisconsin). For each sample a minimum of 400 arboreal pollen grains was counted; the basic sum includes all determinable arboreal and non-arboreal pollen and fern spores. Pollen diagrams were prepared using the Tilia 2.0.b.5 program (Grimm 1991). Plant taxonomy in the pollen diagrams follows Reille (1992). A sample of organic sediment from a depth of 142.5 cm was AMS radiocarbon dated at the University of Arizona (Tucson, AZ, USA).

Results

Seeds and fruits

About 30,000 remains of seeds and fruits larger than 3 mm and several thousand remains in the size range between 0.5 and 3 mm were recovered from the 30 soil samples (Table 1). The preservation of the remains varied from undamaged to more or less broken specimens. Cereal grains and seeds of other cultural plants were preserved in charred state (fossil), while the rest of the plant remains were mostly uncharred (subfossil). A list of the identified plant taxa, their abundance, ubiquity in the two settlement phases as well as in the intermediate phase, and their presence in different fractions is shown in Table 1. For the following presentation of the results the taxa are grouped into various categories, based on their today's economical/nutritional as well as ecological indicator values. For detailed descriptions of the remains see Jeraj (2004a).

Cultural plants

Cultural plants are represented by cereal grains, oil crops and pulses (Table 1; Fig. 4a, c). The large amounts of charred cereal grains spread through all parts of both cultural layers indicate that cereals played an important role in the nutrition of the Eneolithic population at Hočevarica. Further, they suggest agricultural activities in the surroundings during both settlement phases.

The most important cereal crops were cultivated *Hordeum vulgare* (six-rowed barley), *Triticum monococcum* and *T. dicoccum* (*T. turgidum* ssp. *dicoccum*; Fig. 4a). The most frequently identified cereal is *Hordeum* with 726 grains. Some cereal grains were poorly preserved, thus identification to genus or species was impossible. The under representation of rachis parts, chaff, pericarp and testa fragments seems to be caused by the inappropriate recovery technique ("Materials and methods").

Cereal grains from the lowest part of the cultural layer between 190 and 181 cm were radiocarbon dated to 4800 ± 40 B.P. (3650–3530 cal B.C.).

Charred seeds of *Papaver somniferum* were the only remains of oil crops (Fig. 4c). They were quite frequent and present in all samples. According to Fritsch (1979) it is not possible to distinguish between domesticated (ssp. *somniferum*) and wild forms (ssp. *setigerum*) on the basis of seed morphology. Therefore it remains unclear whether this poppy was domesticated or not.

Most interestingly, no remains of *Linum usitatissimum* (flax) were found. However, this is perhaps due to inappropriate recovery techniques for non-lignified subfossil plant tissues, and future investigations are needed to show if flax is really absent. Indeed, very recent studies using appropriate methods showed that flax was present in the Eneolithic in Slovenia (Tolar-Korenčič, personal communication).

Pulses, including *Lathyrus sativus* (grass pea) and *Vicia* sp., were recovered in small numbers at Hočevarica. Their charred seeds were found only in sediments from settlement phase 1.

Plants gathered from wild stands

The remains of wild nuts, fruits and seeds were dominant in the archaeobotanical assemblage from Hočevarica, suggesting that in addition to cultivation of domesticates wild food resources were widely collected by the Eneolithic farmers (Table 1; Fig. 4d–i). They were mostly preserved

Table 1 Remains of seeds and fruits from Hočevarica, recovered from thirty 5l samples from the cultural layer (Fig. 2): 12 samples taken from settlement phase 1 between ca. 185 and 168 cm; 10 samples taken from the intermediate phase 1/2 between ca. 168 and 160 cm; 8 samples taken from settlement phase 2 between ca. 160 and 135 cm

Ecological group	Preserved part	Sum	Ubiquity (%)			Fraction (mm)		Dominant
			Phase 1	Phase 1/2	Phase 2	>3	0.5–3	
Cultivated plants								
Cereals	Charred grains	1,558	100	100	100	+		+
Hordeum vulgare		726	100	100	100	+		
Triticum monococcum		189	91.7	90	100	+		
T. dicoccum		116	91.7	80	75	+		
T. monococcum/dicoccum		32	41.7	50	25	+		
Triticum sp.		42	66.7	50	50	+		
Cerealia		453	100	100	100	+		
Oil crops	Charred seeds							
Papaver somniferum		1,146	100	100	100	+	+	
Pulses	Charred seeds	2	8.3	0	0			
Lathyrus sativus		1	8.3	0	0		+	
Vicia sp.		1	8.3	0	0		+	
Gathered wild plants								
Berries and nuts								
Cornus mas	Fruit stones	4,018	100	100	100	+		+
Cornus sanguinea	Fruit stones	796	91.7	100	100	+		
Corylus avellana	Broken shells	1,312	100	100	100	+		
Fragaria vesca	Nutlets	1,745	100	100	100		+	
Malus sylvestris	Seeds	10	25	0	0	+		
Physalis alkekengi	Seeds	8	0	0	11.1		+	
Prunus avium	Fruit stones	2	8.3	0	0	+		
Prunus spinosa	Fruit stones	201	91.7	100	87.5	+		
Quercus sp.	Acorn fragments	9,439	100	100	100	+		+
Rubus fruticosus	Fruit stones	4,245	100	100	100	+	+	+
Trapa natans	Fruit spines	308	91.7	90	100	+		
Vitis vinifera ssp. *sylvestris*	Pips	8,221	100	100	100	+		+
Weeds								
Chenopodium album type	Seeds	1,000's	100	100	100		+	+
Other wild plants								
Ruderal weeds								
Galeopsis tetrahit	Seeds	145	25	0	0		+	
Rumex sp.	Achenes	6	8.3	0	12.5		+	
Sambucus ebulus	Seeds	215	91.7	80	100	+	+	
Urtica dioica	Achenes	378	91.7	100	100		+	
Woodland								
Tilia cordata	Fruits	25	25	30	75	+		
Tilia cf. *platyphyllos*	Fruits	1	8.3	0	0	+		
Viburnum lantana	Seeds	46	50	30	75	+		
Aquatic								
Carex sp. bicarpellate	Achenes	8	16.7	0	0		+	
Cyperaceae	Diaspores	74	83.3	30	25	+		
Najas marina	Seeds	51	58.3	40	37.5	+	+	
Nuphar luteum	Seeds	40	58.3	0	0	+		
Potamogeton cf. *natans*	Drupes	25	58.3	10	25	+	+	

Table 1 continued

Ecological group	Preserved part	Sum	Ubiquity (%)			Fraction (mm)		Dominant
			Phase 1	Phase 1/2	Phase 2	>3	0.5–3	
Schoenoplectus lacustris	Achenes	78	50	30	12.5		+	
Scirpus sylvaticus	Achenes	58	58.3	30	25		+	
Meadow, pasture								
Caryophyllaceae	Seeds	18	41.7	30	50		+	
Thalictrum sp.	Achenes	159	91.7	70	87.5		+	

Ubiquity (presence of a taxon in *x*% of all samples) is calculated for each phase, respectively. The presence of taxa in two separate fractions (>3 mm and <3 mm) and their dominance are also given. Identified taxa are grouped into various categories, based on their economical/nutritional and ecological indicator values

in an uncharred (subfossil) state. Species with strongly lignified (or otherwise resistant) seed/fruit-walls are well represented.

Fragments of uncharred *Quercus* sp. cupulae (Fig. 4d) were one of the most frequent macro remains from the site. Among the berries recovered, uncharred pips of *Vitis vinifera* ssp. *sylvestris* (wild grapevine) predominated (Fig. 4e). In general they were well preserved with the exceptions of stalks, which were often partially or completely broken away. Their round shape points clearly to

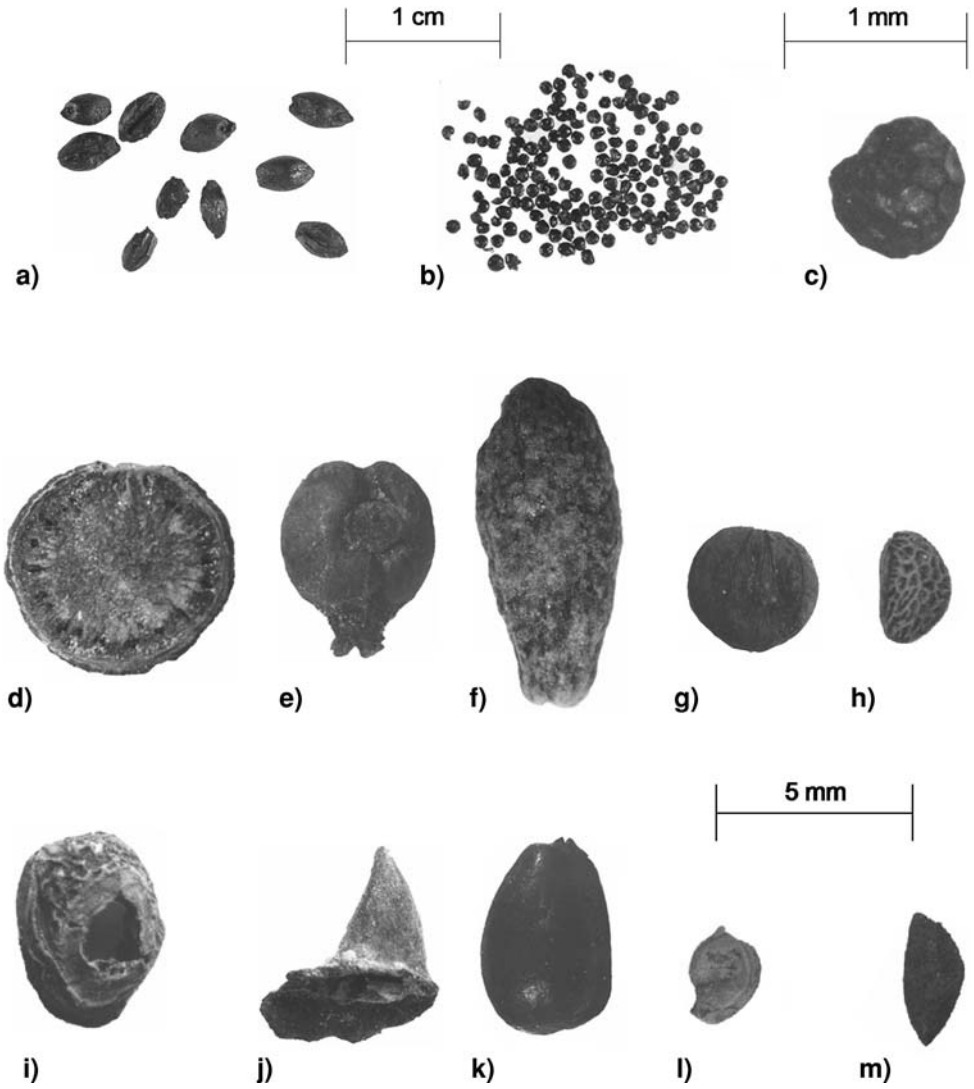

Fig. 4 The most frequent remains of fruits and seeds found at Hočevarica: charred grains of cereals including *Hordeum vulgare, Triticum dicoccum, T. monococcum* (**a**), seeds of agricultural weeds *Chenopodium album* type (**b**) and *Papaver somniferum* seeds (**c**). Among gathered berries and nuts *Quercus* sp. (**d**), *Vitis vinifera* ssp. sylvestris (**e**), *Cornus mas* (**f**), *Cornus sanguinea* (**g**), *Rubus fruticosus* (**h**) and *Prunus spinosa* (**i**) were most frequent. Aquatic plants and sedges were represented by fruit spines of *Trapa natans* (**j**), seeds of *Nuphar luteum* (**k**) and diaspores of *Potamogeton* cf. *natans* (**l**) and Cyperaceae (**m**)

wild grape (Tolar-Korenčič, personal communication). The radiocarbon date of the pips found at a depth between 159 and 142 cm is 4780 ± 40 B.P. (3640–3520 cal B.C.). They represent the oldest evidence for wild grapevine in Slovenia.

Fruit stones of *Cornus mas*, *C. sanguinea* (dogwood), *Prunus spinosa* (blackthorn) and *Rubus fruticosus* (blackberry), fragments of *Corylus avellana*, nutlets of *Fragaria vesca* (wild strawberry) and spines of *Trapa natans* fruits were also present throughout the sampled sequence (Fig. 4e–j). Among the *Corylus* remains, broken shells prevailed while whole nuts were very rare. The estimated absolute number of recovered hazelnuts represented only a small portion of all recovered fruits and seeds.

The seeds of *Malus sylvestris* (crab apple) were, with the exception of one, all carbonized. Like fruit stones of *Prunus avium* (cherry) they were only retrieved from the sediments of the settlement phase 1. The only representative of the family Solanaceae, seeds of *Physalis alkekengi* (winter-cherry), were found in the sediments of the settlement phase 2.

The most ubiquitous seeds (thousands) were those of the crop weed and ruderal plant *Chenopodium album* (-type); they entirely dominated the macrofossil fraction smaller than 3 mm (Fig. 4b). The seeds of this plant have an important nutritional value since they are rich in proteins and starch, thus they were very likely gathered as a supplemental grain (Behre 2007). Many other wild plants (see next paragraph and Discussion) might have been used in different ways. However, this is difficult to prove. It is known from ethnographic sources that a large variety of wild plants was and is still used by rural communities (e.g. Ertug 2000).

Other wild plants

Other wild plant remains reflect different parts of the surrounding vegetation of the site, such as weed assemblages, meadows and pasturelands, woodland and its margins, and aquatic as well as lake shore habitats (Table 1).

Crop weeds and plants of abandoned fields or other ruderal places were represented by several thousand seeds of *Chenopodium album* type as mentioned above, and small quantities of *Galeopsis tetrahit* (common hemp-nettle), *Sambucus ebulus* (dwarf elder) and Caryophyllaceae. Typical of ruderal places were *Urtica dioica* (common nettle) and *Sambucus ebulus*. Species probably growing on nearby pastureland were represented by seeds of Caryophyllaceae (possibly from genus *Stellaria* or *Silene*), *Thalictrum* sp. (meadow-rue) and *Rumex* sp. (sorrel).

Woodland species included *Tilia cordata, T.* cf. *platyphyllos* (lime) and *Viburnum lantana* (wayfaring-tree). Their seeds and fruits were, with the exception of *T.* cf. *platyphyllos*, found in the deposits from both settlement phases and from the intermediate phase.

Aquatic and lake-shore plants were dominated by Cyperaceae (Fig. 4m), including achenes of *Schoenoplectus lacustris* (common club-rush), *Scirpus sylvaticus* (wood club-rush) and *Carex* sp. (sedge, bicarpellate). In addition, seeds of *Najas marina* (holly-leaved naiad) and *Nuphar lutea* (yellow water lily) (Fig. 4k), and drupes of *Potamogeton* cf. *natans* (broad-leaved pondweed) (Fig. 4l), were found.

Charcoal

Wood charcoal taxa from Hočevarica and their ubiquity in layers from different settlement phases are shown in Table 2. Identified tree and shrub taxa belong to riparian woodland and mixed forest from the surrounding foothills. They mainly reflect exploitation of wood for fuel and timber.

The majority of charcoal fragments examined came from *Corylus avellana* and *Fraxinus excelsior/ornus* from the mixed forest assemblage, and *Alnus glutinosa* from the riparian woodland assemblage. Riparian woodland taxa, occurring less frequently, included *Populus* sp., *Salix* sp. (willow) and *Frangula alnus* (buckthorn). *Alnus* and *Populus* were found in all settlement phases (phase 1, intermediate phase 1/2, phase 2), while *Salix* was present in phases 1 and 1/2, and *Frangula* in phases 1/2 and 2.

Corylus and two ash species *Fraxinus excelsior* and *F. ornus*, dominant in the mixed forest charcoal assemblage, occurred in samples from all settlement phases. *Corylus* was present in every sample in every sediment phase, and *Fraxinus excelsior* in every sample from phases 1 and 1/2. *Fagus* (beech) and three species of maple, *Acer campestre, A. platanoides* and *A. pseudoplatanus*, although represented by fewer charcoal pieces, were also ubiquitous in the three settlement phases. Rare in terms of charcoal pieces, but commonly occurring in all three phases were: *Quercus robur/petraea/cerris*, *Betula* sp. (birch), *Sorbus* sp., *Pyrus/Malus* (pear/apple) and *Prunus* sp. (plum). *Crataegus* sp., *Euonymus europaeus* (spindle), *Cornus* sp. and *Juglans regia* (walnut) were found only in settlement phase 1, *Carpinus betulus* only in the intermediate phase and *Viburnum opulus* (guelder-rose) only in settlement phase 2. Conifers were represented by small amounts of *Abies alba* (fir), *Juniperus communis* (juniper), *Taxus baccata* (yew) and *Pinus sylvestris* (pine) charcoal.

Wooden piles

From the 2 × 4 m^2 excavation surface (Fig. 5) and a 70 m long draining-ditch 361 wooden piles of eight different

Table 2 Spectrum of wood charcoal taxa, identified from 18 samples at Hočevarica, and their ubiquity in layers from different settlement phases

Ecological group	Total sum	Total (%)	Ubiquity (%)			Dominant
			Phase 1	Phase 1/2	Phase 2	
Riparian woodland	156	27.0				
Alnus glutinosa	144	25.0	100	100	100	+
Frangula alnus	2	0.3	0	12.5	25	
Populus sp.	7	1.2	50	25	50	
Salix sp.	3	0.5	16.7	25	0	
Mixed forest	420	73.0				
Deciduous	273	70.9				
Betula sp.	6	1.0	16.7	37.5	25	
Acer campestre	21	3.7	100	50	100	
Acer platanoides	13	2.3	50	62.5	50	
Acer pseudoplatanus	7	1.2	16.7	12.5	50	
Carpinus betulus	1	0.2	0	12.5	0	
Cornus sp.	1	0.2	16.7	0	0	
Corylus avellana	147	25.6	100	100	100	+
Crataegus sp.	5	0.9	33.3	0	0	
Euonymus sp.	1	0.2	16.7	0	0	
Fagus sylvatica	29	5.0	100	50	75	
Fraxinus excelsior	64	11.1	100	100	75	+
Fraxinus ornus	30	5.2	66.7	75	50	+
Juglans regia	2	0.3	33.3	0	0	
Prunus sp.	16	2.8	100	25	50	
Pyrus/Malus	20	3.5	100	50	50	
Quercus sp.	23	4.0	83.3	50	75	
Sorbus sp.	21	3.7	100	50	50	
Viburnum sp.	1	0.0	0	0	25	
Conifers	12	2.1				
Abies alba	9	1.5	16.7	37.5	25	
Juniperus communis	1	0.2	0	12.5	0	
Pinus sp.	1	0.2	0	0	25	
Taxus baccata	1	0.2	16.7	0	0	
	576	100.0				

Six samples belong to the first settlement phase, eight to the intermediate one, and four to the second settlement phase. Identified trees and shrub taxa belong to various environments such as riparian woodland and mixed forest from the surrounding foothills

taxa (Table 3) were identified (Čufar and Velušček 2004). The majority of the samples (59%) belong to *Fraxinus* sp. and 16% to *Quercus* sp. Approximately one quarter of the samples were identified as *Alnus* sp., *Abies* sp., *Taxus* sp., *Acer* sp., *Populus* sp. and *Corylus* sp.

Several species of *Fraxinus* and *Quercus* grow in Slovenia, however, the wood of the different species of ash and oak cannot be anatomically distinguished (Čufar and Velušček 2004). On the basis of the local ecology, ash piles from Hočevarica presumably belong to *Fraxinus excelsior* or *F. ornus*, and oak piles can be attributed to *Quercus robur* or *Q. petraea* (Čufar et al. 1998). Mixed oak forests including the species mentioned were already growing around Ljubljansko barje at the beginning of the Holocene (Šercelj 1996).

Other plant macroremains

In addition to seeds, fruits, charcoal and wood from Hočevarica, numerous remains of mosses, probably from the family Drepanocladaceae, were recovered from below the cultural layer at a depth of between 190 and 178 cm.

Immediately below the cultural layer *Neckera crispa* leaves and oogonia of freshwater green algae (*Chara* sp.) were also found in small quantities (Fig. 6).

Pollen analyses from the archaeological profile

Pollen from the archaeological profile, including the entire cultural layer, contributes to the vegetation and landscape

Fig. 5 Wooden piles in the excavation trench from Hočevarica, recovered within the cultural layer. They mostly belong to *Fraxinus ornus/excelsior* and *Quercus robur/petraea* (after Čufar and Velušček 2004)

Table 3 Percentages of different wood genera represented by wooden piles at the Hočevarica pile dwelling (after Čufar and Velušček 2004)

Taxon	Wooden piles (%)
Fraxinus	59
Quercus	16
Alnus	9
Abies	5
Taxus	2
Acer	2
Populus	2
Corylus	1
Unidentified	4

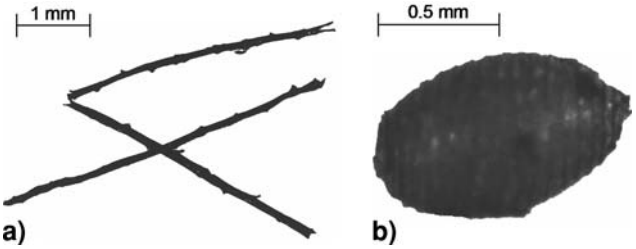

Fig. 6 Remains of moss, probably from the family Drepanocladaceae (**a**), and Oogonium of Characeae (**b**) from Hočevarica

history of the settlement at Hočevarica (Fig. 7). The pollen spectra slightly below (zone C1) and above the cultural layer (zone C5) reflect the natural pollen rain of the surroundings. The pollen spectra of the cultural layers between ca. 187 and 142 cm, in addition to the natural pollen rain, also contain information about plants which were brought into the settlement by human and animal activities (cf. Heitz-Weniger 1978; Brombacher and Hadorn 2004).

At the bottom of the diagram (zone C1) arboreal pollen—*Alnus, Corylus, Fagus* and mixed oak forest taxa—is predominant. This zone represents the pre-settlement period just before the onset of settlement. A minor presence of anthropogenic indicators, such as cereals (Cerealia), suggests a minor human impact in the near vicinity.

The start of zone C2 and the start of zone C3 are both characterized by a sudden marked increase in non-arboreal pollen (NAP), especially of Cerealia and Chenopodiaceae. Their pollen content is mainly of anthropogenic origin. The values of NAP vary strongly within the zones, suggesting very local on-site activities.

An abrupt decrease in pollen of the Cerealia-type, accompanied by an increase in grass (Poaceae) and Chenopodiaceae values in the uppermost part of zone C2 (170 and 165 cm), possibly indicates a short-term abandonment of the settlement; this is also suggested by other palaeoenvironmental studies from Hočevarica including sedimentological and archaeological analyses (Velušček 2004b). In zone C3, as in zone C2, very high NAP (primarily due to Cerealia) shows import of pollen by settlers and their domestic animals.

In zone C4, the uppermost part of the cultural layer, an increase in AP and a simultaneous decrease in NAP indicate that cultivated areas gradually became abandoned. A radiocarbon date of 4780 ± 40 B.P. (3640–3520 cal B.C.) for the organic sediment from the middle of this zone corroborates the dating of the pile-dwelling settlement to within the Eneolithic period. The pollen spectrum of zone C5, located above the cultural layer, again consists of regional pollen rain from the surroundings. Predominantly arboreal pollen, including *Alnus*, *Corylus* and less frequently *Quercus*, *Tilia*, *Carpinus*, *Ostrya* (hop-hornbeam) and *Cornus*, reflects the presence of riparian woodland as well as mixed oak forest in the vicinity.

Discussion

Subsistence economy

Numerous remains of domesticated and wild plants in the cultural layer suggest that both agriculture and gathering were important for the subsistence economy of the pile dwellers at Hočevarica. The fruits and seeds recovered as well as the pollen indicate that the vegetarian part of their diet included cereals, oil crops, pulses, berries, nuts and edible weeds (Table 1). They were brought to the site by human activities. Since they were found together with bones of wild and domestic animals (Toškan and Dirjec 2004), pottery and architectural features associated with houses on piles (Velušček 2004b), the majority presumably reflects farming, foraging and housekeeping activities, as

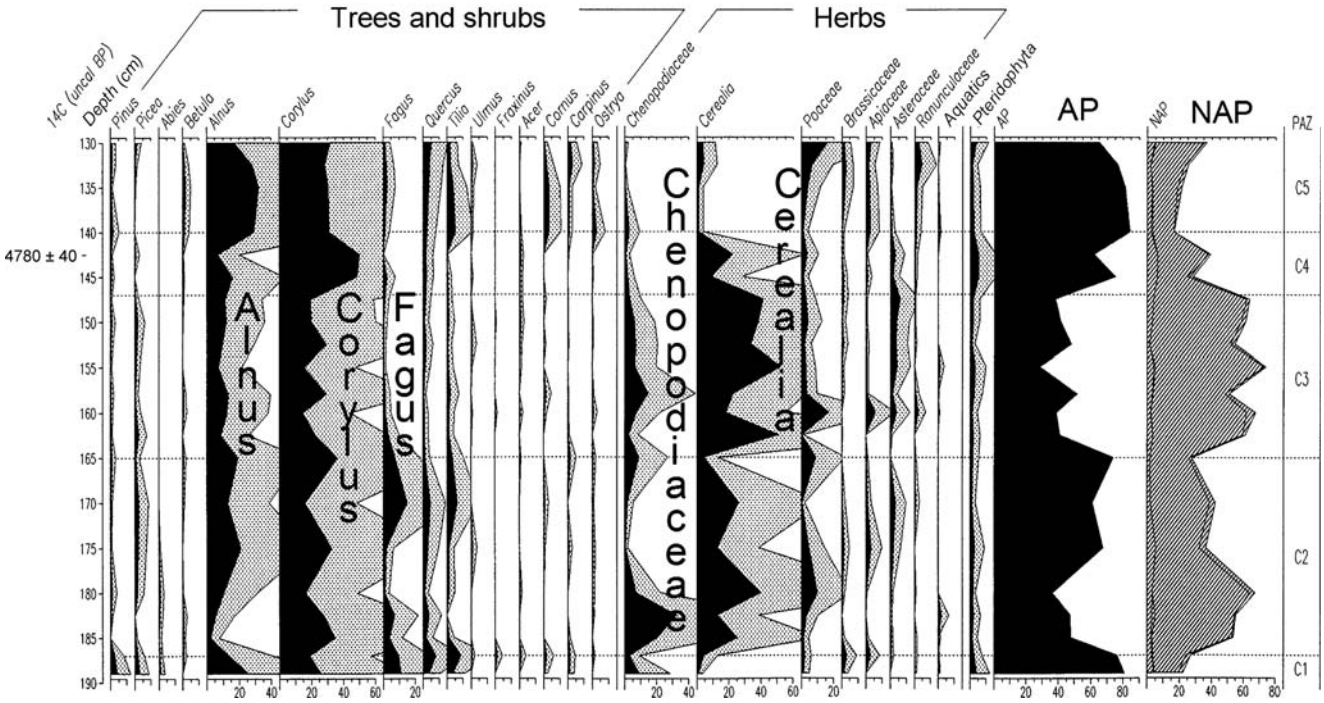

Fig. 7 Pollen from the archaeological profile at Hočevarica, including the cultural layer and the layers slightly above and below it. The pollen sum counted varied from 500 to 1,000 grains and the basic pollen sum includes all determinable arboreal and non-arboreal pollen and fern spores. The spectra mainly represent the vegetation and landscape history of the area around the Eneolithic pile dwelling

also known from many other lake-dwelling settlements (e.g. Jacomet et al. 2004).

The spectrum of domesticated plants from Hočevarica shows many similarities to, but also some differences from other pile dwelling sites dated to the fourth millennium B.C. north and south of the Alps. The remains of cereals (Cerealia), which played a crucial role in the Neolithic diet as an essential source of carbohydrates and vitamins B and E, were found in large quantities in most of the investigated sites north of the Alps (Jacomet 2004, 2006, 2007; Jacomet et al. 2004). Six-rowed *Hordeum vulgare*, *Triticum monococcum* and *T. diccocum* were cultivated everywhere, although in varying amounts. *Hordeum* was very common circumalpine, and was found also with the Iceman (Oeggl et al. 2008). Glume wheats, *T. monococcum*, *T. dicoccum*, show different patterns in sites north and south of the Alps (Rottoli and Castiglioni 2008; Jacomet 2008). While south of the Alps, including Slovenia, they seem to be of great importance during the early part of the fourth millennium B.C. (Jeraj 2002), north of the Alps they become more important only during the second half of this millennium. *T. monococcum* and *T. dicoccum* were found also with the Iceman (Oeggl et al. 2008). On the other hand, during the fourth millennium B.C. tetraploid naked wheat *(Triticum durum/turgidum)* was very important in the northern alpine pile-dwelling area, particularly in its western part (Jacomet 2007). In contrast, this cereal seems to have been rare in regions closer to the south of the Alps and was absent from Hočevarica; it is also not recorded with the Iceman (Rottoli and Castiglioni 2008; Oeggl et al. 2008; Jacomet 2008). However, common millet *(Panicum miliaceum)*, absent from Hočevarica and several other localities from the fourth millennium B.C. north and south of the Alps, was recovered with the Iceman (although not certainly identified) and in the Late Neolithic assemblages from Northern Italy (Heiss and Oeggl 2008; Rottoli and Castiglioni 2008).

Among the other domesticated plants, *Papaver somniferum* and most probably *Linum usitatissimum* were spread across the entire pile dwelling area. Though no finds of flax were made at Hočevarica, its remains appeared during recent investigations of Ljubljansko barje, dated to the late fourth millennium B.C. (T. Tolar-Korenčič, personal communication), and therefore we conclude that *Linum* was also cultivated south of the Alps. *Papaver somniferum*, also recovered regularly in a carbonized state at Hočevarica, was probably used either for food, as a source of oil or as a medicine. Results from lake shore settlements north of the Alps show that under waterlogged circumstances (and when fractions are not dried) over 95% of poppy seeds are preserved in a subfossil (uncharred) state (Table 32 in Jacomet et al. 1989). Therefore one can conclude that *Papaver* was a

very important cultural plant during the Eneolithic in Slovenia.

In contrast to cereals and oil/fibre crops, domesticated legumes seemed to have played a minor role in Neolithic nutrition around the Alps in the fourth millennium B.C. This is indicated by small quantities of *Pisum sativum* recovered from a limited number of sites north of the Alps (Jacomet 2004, 2006). Also, south of the Alps, in Northern Italy, such remains seem to be very rare (Rottoli and Castiglioni 2008). Interestingly, two legumes not recorded so far from the circumalpine settlements of the fourth millennium B.C., *Lathyrus sativus* and a *Vicia* species, were recovered in small numbers at Hočevarica. In Slovenia, *Lathyrus sativus* is not known from any other Neolithic sites, while *Vicia* sp. was found in the layers from the cave Ajdovska jama, dated between 5350 ± 160 and 4824 ± 104 B.P. (Culiberg et al. 1992). *L. sativus* was present in the Near East, Aegean and west Mediterranean Neolithic settlements (Zohary and Hopf 2000); it seems to belong to the early Neolithic crop assemblage or became part of it soon after the establishment of grain agriculture. Similarly, *Vicia*, including *V. faba, V. ervilia* and *V. sativa*, is commonly present in Mediterranean and Near East Neolithic archaeological contexts. *V. sativa* has been reported from several other Neolithic and Bronze Age European sites, while *V. faba* and *V. ervilia* seem to appear in temperate European regions only by the end of the Neolithic or in the Bronze Age (Zohary and Hopf 2000). Many *Vicia* seeds closely resemble wild forms, thus identification is unreliable, especially when only a few and poorly preserved seeds are recovered.

Many seeds and fruits of wild plants were collected at Hočevarica, presumably along the forest edges and in clearings around the settlement. Fruits of *Cornus sanguinea*, *Prunus spinosa* (sloes), *Fragaria vesca* and *Rubus fruticosus*, and also storable fruits such as hazelnuts and acorns, were widely important as shown by their constant occurrence in prehistoric sites of Neolithic and Early Bronze Age lake-shore settlements elsewhere on the Ljubljansko barje (Culiberg 1999).

The availability of fruits of *Cornus mas* seems to be spatially limited since they were found at Hočevarica and in other settlements south of the Alps, but only very rarely north of the Alps (for a compilation of the northern alpine situation, see e.g. Hosch and Jacomet 2004, pp 155–156). In contrast, *Rubus idaeus*, common in most pile dwelling sites, were missing in the Hočevarica assemblage. Also *Malus sylvestris*, very common almost everywhere, were recovered only in small quantities on Ljubljansko barje. Again this bias may result from the improper handling of the retrieved samples (see Methods).

In Hočevarica, as in other circumalpine pile dwelling sites, *Chenopodium album* was represented by very large numbers of seeds. This weed also, with seeds rich in starch and proteins, was probably used for food (for uses in other settlements see Brombacher 1997; Jacomet 2006, 2007; Bieniek 2002; Behre 2007). Leaves of *Chenopodium* and of some herbs such as *Urtica dioica* were also presumably eaten.

Besides land resources, settlers from Hočevarica and other Neolithic pile dwellings around the Alps took advantage of the vicinity and accessibility to wetland areas, as documented by the remains of aquatic plants like *Trapa natans*. These people used the fruits of the water chestnut for food and probably as medicine and in rituals, and their seeds for making flour (Culiberg 1999).

Finally, kernels from gathered plants were used also for the fabrication of beads. For example, *Prunus spinosa* fruit stones were hollow and a few had two opposing, almost circular, holes in the endocarp, suggesting that they could have been made artificially by humans rather than gnawed by rodents. Similarly, drilled stones were also recovered in some contemporaneous lake-dwelling settlements north of the Alps (cf. Fig. 114b in Hosch and Jacomet 2004).

Wood exploitation

The analyses of charcoal and wooden piles from the archaeological site suggest that—as in other places—wood was extensively used by the Eneolithic settlers from Hočevarica. The results (Tables 2, 3) show that the houses and supporting platforms were constructed of robust wood such as *Fraxinus excelsior/ornus* and *Quercus robur/petraea* (Čufar et al. 1998; Čufar and Velušček 2004), while softer wood such as *Corylus avellana* and *Alnus glutinosa* was preferred for firewood (Jeraj 2004b).

Furthermore, the palynologically recorded woodland clearance during the settlement period corresponds to the most abundant remains of wooden piles. While *Fraxinus* appeared to be the most common timber, its pollen was very rare in both on and off-site pollen records (Jeraj 2004a). The same applies to *Quercus*. In contrast, a large amount of *Alnus* and *Corylus* pollen was found, but pile remains of these taxa were found rarely or not at all. The higher pollen production of *Alnus* and *Corylus* compared with that of *Fraxinus* and *Quercus*, as well as different distances of the trees from the site, may also explain their frequent appearance in the pollen records (Moore et al. 1991). The strong representation of *Fraxinus* as wooden piles and charcoal fragments, and its rare occurrence in the surrounding landscape as suggested by the pollen data, suggest a high selective pressure imposed by the Hočevarica dwellers. Such selection of particular types of wood in the vicinity of settlements, especially of *Quercus* and *Fraxinus*, is also evident from other dendrological

studies of prehistoric sites on Ljubljansko barje (Culiberg and Šercelj 1991).

Conclusions

Archaeobotanical studies of seeds, fruits, charcoal and wood, in combination with pollen records from Hočevarica indicate the existence of an Eneolithic agricultural community on the south-western Ljubljansko barje. They further reflect the impact of early farmers and their domestic animals (goats/sheep, cattle and pigs) on the surrounding vegetation and landscape. Domestic plants like cereals and *Papaver somniferum* were cultivated, and the available wild plant resources were extensively exploited.

In general, the subsistence economy of the Hočevarica settlers shows strong similarities to other circumalpine lakeshore settlements of the same age. However, there are also some differences, such as the lack of tetraploid naked wheat which seems to appear only more to the west. Other differences, like the high importance of *Cornus mas* and *Trapa natans*, are mainly due to the different ecological settings south of the Alpine chain. Also the strong representation of *Vitis vinifera* ssp. *sylvestris* has to be seen in this context. The grape seeds were dated to 4780 ± 40 B.P. (3640–3520 cal B.C.), and represent the oldest remains of wild grapevine from Slovenia.

Finally, it hast to be emphasized that the dominance of uncharred taxa with lignified diaspores or the lack of cereal chaff is very probably due to an inappropriate handling of the samples during and after sieving. Future investigations therefore will probably supplement the plant part and the species list considerably.

References

Anderberg AL (1994) Atlas of seeds and small fruits of northwest-European plant species with morphological descriptions. Part 4: resedaceae-umbelliferae. Risbergs Tryckeri AB, Uddevalla

Behre KE (1998) Urgeschichtliche Kulturpflanzenfunde aus den nordwestdeutschen Geestgebeiten. Probleme der Küstenforschung im südlichen Nordseegebeit 25:281–302

Behre KE (2007) Collected seeds and fruits from herbs as prehistoric food. Veget Hist Archaeobot, doi:10.1007/s00334-007-0106-x

Behre KE, Jacomet S (1991) The ecological interpretation of archaeobotanical data. In: van Zeist W, Wasylikova K, Behre KE (eds) Progress in old world palaeoethnobotany. Balkema, Rotterdam, pp 81–108

Berggren G (1981) Atlas of seeds and small fruits of northwest-european plant species with morphological descriptions. Part 3: salicaeae–cruciferae. Berlings Arlov, Stockholm

Bienek A (2002) Archaeobotanical analysis of some early Neolithic settlements in the Kujawy region, central Poland, with potential plant gathering activities emphasized. Veget Hist Archaeobot 11:33–40

Bocquet A, Brochier JL, Emery-Barbier A, Lundstrom-Baudais K, Orcel C, Vin F (1987) A submerged Neolithic village: charavines "Les Baigneurs" in Lake Paladru, France. In: Coles JM, Lawson AJ (eds) Europaean wetlands in prehistory. Clarendon Press, Oxford, pp 33–54

Brombacher C (1997) Archaeobotanical investigations of Late Neolithic lakeshore settlements (Lake Biel, Switzerland). Veget Hist Archaeobot 6:167–186

Brombacher C, Hadorn P (2004) Untersuchungen der Pollen und Makroresten aus den Profilsäulen. In: Jacomet S, Leuzinger U, Schibler J (eds) Die neolithische Seeufersiedlung Arbon Bleiche 3. Umwelt und Wirtschaft. Amt für Archäologie des Kantons Thurgau, Frauenfeld, pp 50–65

Cattani L, Carra ML (2002) Dati plaeobotanici dell'insediamento di Castellaro Lagusello (MN). In: Aspes A (ed) Preistoria Veronese. Contributi e aggiornamenti. 2ª serie, Sezione Scienze dell'Uomo 5 . Museo Civico di Storia Naturale, Verona, pp 124–134

Culiberg M (1999) Palaeobotany in slovene archaeology. Arheološki Vestnik 50:323–331

Culiberg M, Šercelj A (1991) Razlike v rezultatih raziskav makroskopskih rastlinskih ostankov s kolišč na Ljubljanskem barju in pelodnih analiz—dokaz človekovega vpliva na gozd [Die Unterschiede zwischen den Resultaten der Untersuchungen der makroskopischen Reste aus Pfahlbauten und den Pollenanalysen—ein Beweis für den Einfluss des Menschen auf die Wälder]. Poročilo O Raziskovanju Paleolitika, Neolitika in Eneolitika v Sloveniji 19:249–256

Culiberg M, Horvat M, Šercelj A (1992) Karpološke in antrakotomske analize rastlinskih ostankov iz neolitske jamske nekropole Ajdovska jama (Carpological and anthracotomical analyses of plant remains from Neolithic necropole cave Ajdovska jama). Poroč Razisk Paleolit Neolit Eneolit Slov 20:111–126

Čufar K, Martinelli N (2004) Teleconnection of chronologies from Hočevarica and Palù di Livenza, Italy. In: Velušček A (ed) Hočevarica. An Eneolithic pile dwelling in the Ljubljansko barje. Založba ZRC, Ljubljana, pp 286–289

Čufar K, Velušček A (2004) Dendrochronological research of the Hočevarica pile dwelling settlement. In: Velušček A (ed) Hočevarica. An Eneolithic pile dwelling in the Ljubljansko barje. Založba ZRC, Ljubljana, pp 274–280

Čufar K, Levanič T, Velušček A (1998) Dendrochronological investigations in the pile dwellings Spodnje mostišče 1 and 2 and Hočevarica from the Ljubljansko barje, Slovenia. Arheološki Vestnik 49:75–92

Dickson C (1988) Distinguishing cereal from wild grass pollen. Circaea 5:67–71

Dickson JH, Oeggl K, Handley LL (2005) The Iceman reconsidered. Sci Am 15:4–13

Ertug F (2000) An ethnobotanical study in Central Anatolia (Turkey). Econ Bot 54:155–182

Faegri K, Iversen J (1989) Textbook of pollen analysis. 4th edn., Wiley, Chicester

Fritsch R (1979) Zur Samenmorphologie des Kulturmohns (*Papaver somniferum* L.). Kulturpflanze 27:217–227

Grimm EC (1991) Tilia and Tilia Graph. Illinois State Museum, Springfield

Grosser D (1977) Die Hölzer Mitteleuropas. Ein mikrophotographischer Lehratlas, Berlin

Heitz-Weniger A (1978) Pollenanalytische Untersuchungen an den neolithischen und spätbronzezeitlichen Seerandsiedlungen Kleiner Hafner, Grosser Hafner und Alpenquai im untersten Zürichsee (Schweiz). Botanische Jahrbücher für Systematik, Pflanzengeschichte und Pflanzengeographie 99:48–107

Heiss AG, Oeggl K (2008) The plant remains from the Iceman site—new results on the glacier mummy's environment. Veget Hist Archaeobot (in press). doi:10.1007/s00334-007-0140-8

Hillman GC, Mason D, de Moulins D, Nesbitt M (1996) Identification of archaeological remains of wheat: the 1992 London workshop. Circea 12:195–209

Hosch S, Jacomet S (2001) New aspects of archaeobotanical research in central European Neolithic Lake dwelling sites. Environ Archaeol 6:59–71

Hosch S, Jacomet S (2004) Ackerbau und Sammelwirtschaft. Ergebnisse der Untersuchung von Samen und Früchten. In: Jacomet S, Schibler J, Leuzinger U (eds) Die neolithische Seeufersiedlung Arbon Bleiche 3: Wirtschaft und Umwelt. Amt für Archäologie des Kantons Thurgau, Frauenfeld, pp 112–157

Jacomet (2004) Archaeobotany. A vital tool in the investigation of lake-dwellings. In: Mennoti F (eds) Living on the Lake in Prehistoric Europe. 150 years of lake-dwelling research. 1st edn., Routledge, London, pp 162–177

Jacomet S (2006) Plant economy of the northern Alpine lake dwellings—3500–2400 cal. BC. In: Karg S, Baumeister R, Schlichtherle H, Robinson DE (eds) Economic and environmental changes during the 4th and 3rd millennia BC. Proceedings of the 25th symposium of the AEA September 2004 Bad Buchau, Germany. Environ Archaeol 11:64–83

Jacomet S (2007) Neolithic plant economies in the northern Alpine foreland (Central Europe) from 5500 to 3500 cal. BC. In: Colledge S, Conolly J (eds) The origin and spread of domestic plants in southwest Asia and Europe. Left Coast Press, California, pp 221–258

Jacomet S (2008) Plant economy and village life in Neolithic lake dwellings at the times of the Alpine Iceman. Veget Hist Archaeobot (in press). doi:10.1007/s00334-007-0138-2

Jacomet S, Brombacher C (2005) Reconstructing intra-site patterns in Neolithic lakeshore settlements: the state of archaeobotanical research and future prospects. In: Della Casa P, Trachsel M (eds) WES'04-Wetland Economies and Societies. Proceedings of the international conference in Zurich, Chronos, Zürich, pp 69–94

Jacomet S, Brombacher C, Dick M (1989) Archäobotanik am Zürichsee. Ackerbau, Sammelwirtschaft und Umwelt von neolithischen und bronzezeitlichen Seeufersiedlungen im Raum Zürich. Ergebnisse von Untersuchungen pflanzlicher Makroreste der Jahre 1979–1988. Orell Füssli, Zürich

Jacomet S, Leuzinger U, Schibler J (2004) Die neolithische Seeufersiedlung Arbon Bleiche 3. Umwelt und Wirtschaft. Amt für Archäologie des Kantons Thurgau, Frauenfeld

Jacquiot C, Trenard Y, Dirol D (1973a) Atlas d́anatomie des bois des angiospermes. Tome I—texte. Paris

Jacquiot C, Trenard Y, Dirol D (1973b) Atlas d́anatomie des bois des angiospermes. Tome II—planches. Paris

Jeraj M (2000) Palynological investigations of the profile from the pile dwelling Hočevarica. Arheološki vestnik 51:109–112

Jeraj M (2002) Archaeobotanical evidence for early agriculture at Ljubljansko barje (Ljubljana Moor), central Slovenia. Veget Hist Archaeobot 11:277–288

Jeraj M (2004a) Archaeobotanical and palaeoecological reconstruction of the southwestern Ljubljana Moor (Ljubljansko barje), Slovenia. Dissertation school of environmental sciences, Nova Gorica Polytechnic

Jeraj M (2004b) Palaeobotanical analyses of the Hočevarica pile dwelling. In: Velušček A (ed) Hočevarica. An Eneolithic pile dwelling in the Ljubljansko barje, Ljubljana, pp 56–64

Kohler-Schneider M (2007) Early agriculture and subsistence in Austria—a review of Neolithic plant records. In: Colledge S, Conolly J (eds) The origin and spread of domestic plants in southwest Asia and Europe. Left Coast Press, California, pp 209–220

Kohler-Schneider M, Cannepele A (2008) Late Neolithic agriculture in eastern Austria—archaeobotanical results from sites of the Baden, Jevišovice cultures (3600–2800 B.C.) Veget Hist Archaeobot (in press). doi:10.1007/s00334-007-0129-3

Lovrenčak F, Adamič MO (1998) Ljubljansko barje. In: Perko D, Adamič MO (eds) Slovenija-pokrajine in ljudje. Ljubljana, pp 380–391

Lundström-Baudais K (1986) Étude paléoethnobotanique de la station III de Clairvaux. In: Pétrequin P (ed) Les Sites Littoraux Néolithigues de Clairvaux-Les-Lacs (Jura) I. Problématique générale. L'exemple de la Station. Patis, pp 311–404

Lundström-Baudais K (1989a) Etude des paléosemences de la station. In: Pétrequin P (ed) Les sites littoraux néolithiques de Clairvaux-les-Lacs (Jura). II Le Néolithique moyen. Éditions de la Maison des sciences de l'homme, Paris

Lundström-Baudais K (1989b) L'intégration de la station VIII dans l'ensemble des études de paléosemences des sites de Clairvaux. In: Pétrequin P (éd) Les sites littoraux néolithiques de Clairvaux-les-Lacs (Jura). II Le Néolithique moyen. Éditions de la Maison des sciences de l'homme, Paris

Lundström-Baudais K (1989c) Les macrorestes végétaux du niveau V de la Motte-aux-Magnins. In: Pétrequin P (ed) Les sites littoraux néolithiques de Clairvaux-les-Lacs (Jura) II: Le Néolithique moyen. Éditions de la Maison des Sciences de l'Homme, Paris, pp 417–439

Maier U (2001) Archäobotanische Untersuchungen in der neolithischen Ufersiedlung Hornstaad-Hörnle IA am Bodensee. In: Maier U, Vogt R (eds) Botanische und pedologische Untersuchungen zur Ufersiedlung Hornstaad-Hörnle IA, Siedlungsarchäologie im Alpenvorland VI. Forschungen und Berichte zur Vor- und Frühgeschichte in Baden-Württemberg 74, Theiss, Stuttgart, pp 9–384

Maier U (2004) Archäobotanische Untersuchungen in jung- und endneolithischen Moorsiedlungen am Federsee. Ökologischer und ökonomischer Wandel am vorgeschichtlichen Federsee Band I. Janus, Freiburg

Martinčič A, Wraber T, Jogan N, Ravnik V, Podobnik A, Turk B, Vreš B (1999) Mala flora Slovenije. Ključ za določanje praprotnic in semenk [Flora of Slovenia. Key for identification of Pteridophyta and Spermatophyta]. 3th edn., Tehniška založba, Ljubljana

Marzatico F (2004) 150 years of lake dwelling research in northern Italy. In: Mennoti F (eds) Living on the lake in Prehistoric Europe. 150 years of lake-dwelling research. 1st edn., Routledge, London , pp 83–97

Melik A (1946) Ljubljansko mostiščarsko jezero in dediščina po njem. Dela SAZU, Ljubljana

Menotti F (2004) Living on the lake in Prehistoric Europe. 150 years of lake-dwelling research. 1st edn, Routledge, London

Moore PD, Webb JA, Collinson ME (1991) Pollen analysis. 2nd edn. Blackwell, London

Oeggl K (2000) The diet of the Iceman. In: Bortenschlager S, Oeggl K (eds) The Iceman and his natural environment. The man in the ice 4:89–115

Oeggl K, Kofler W, Schmidl A (2008) New aspects on the diet of the Neolithic Tyrolean Iceman "Ötzi". Veget Hist Archaeobot (in press)

Pétrequin P, Arbogast RM, Bourquin-Mignot C, Lavier C, Viellet A (1998) Demographic growth, environmental changes and technical adaptations: responses of an agricultural community from the 32nd to the 30th centuries B.C. World Archaeol 30:181–192

Reille M (1992) Pollen et Spores d'Europe et d'Afrique du Nord, Marseille

Rottoli M, Castiglioni E (2008) Prehistory of plant growing and collecting in northern Italy, based on carpological remains from the early Neolithic to the Chalcolithic (c. 5600–2100 cal B.C).

Veget Hist Archaeobot (in press). doi:10.1007/s00334-007-0139-1

Ruttkay E, Cichocki O, Pernicka E, Pucher E (2004) Prehistoric lacustrine villages on the Austrian lakes: past and recent research developments. In: Mennoti F (ed) Living on the lake in Prehistoric Europe. 150 years of lake-dwelling research. 1st edn., Routledge, London, pp 50–68

Schweingruber FH (1993) Trees and wood in dendrochronology: morphological, anatomical, and tree-ring analytical characteristics of trees frequently used in dendrochronology. Springer, Berlin

Šercelj A (1981–1982) Pomen botaničnih raziskav na koliščih Ljubljanskega barja [Die Bedeutung der botanischen Untersuchungen in den Pfahlbauten auf dem Moor von Ljubljana]. Poročilo o raziskovanju paleolitika, neolitika in eneolitika v Sloveniji 9–10:101–106

Šercelj A (1996) Začetki in razvoj gozdov v Sloveniji [The origins and development of forests in Slovenia]. Slovenska akademija znanosti in umetnosti, Ljubljana

Torelli N (1991) Makroskopska in mikroskopska identifikacija lesa (macroscopic and microscopic identification of wood). Biotehniška fakulteta, Oddelek za lesarstvo, Ljubljana

Toškan B, Dirjec J (2004) Hočevarica—an analysis of macrofauna remains. In: Velušček A (ed) Hočevarica. An Eneolithic pile dwelling in the Ljubljansko barje. Založba ZRC, Ljubljana, pp 76–132

Velušček A (2004a) Conclusion. In: Velušček A (ed) Hočevarica. An Eneolithic pile dwelling in the Ljubljansko barje. Založba ZRC, Ljubljana, pp 307–313

Velušček A (2004b) Hočevarica: field research, stratigraphy and the material finds. In: Velušček A (ed) Hočevarica. An Eneolithic pile dwelling in the Ljubljansko barje. Založba ZRC, Ljubljana, pp 33–55

Velušček A (2004c) Hočevarica and the pottery with furrowed incisions (HKBV) in central Slovenia and neighboring regions. In: Velušček A (ed) Hočevarica. An Eneolithic pile dwelling in the Ljubljansko barje. Založba ZRC, Ljubljana, pp 231–262

Willerding U (1991) Präsenz, Erhaltung und Repräsentanz von Pflanzenresten in archäologischem Fundgut. In: van Zeist WA, Wasylikowa K, Behre K-E (eds) Progress in old world palaeoethnobotany. Balkema, Rotterdam, pp 25–51

Zohary D, Hopf M (2000) Domestication of plants in the old world: the origin and spread of cultivated plants in West Asia, Europe and the Nile Valley. 3rd edn. Oxford University Press, Oxford