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THE ŠPICA PILE-DWELLING SITE – ANALYSES OF ARCHAEOLOGICAL WOOD

KOLIŠČARSKA NASELBINA ŠPICA – RAZISKAVE ARHEOLOŠKEGA LESA

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Abstract / Izvleček

Abstract: We present the investigation of wood discovered during the 2009/2010 archaeological excavations at the prehistoric pile-dwelling settlement of Špica in Ljubljansko barje, Slovenia. The results include data on wood identification, dendrochronological dating and the spatial distribution of the piles. We focussed on smaller sections of the site and dated oak and ash piles with the reference chronologies of the pile-dwelling settlements of Založnica and Parte spanning the period 2659 – 2366 BC. Based on the established dates of tree felling, we identified several construction activities between 2522 and 2406 BC. Due to the time span of the available reference chronologies, it was not possible to date the wood eventually felled before or after 2659 – 2366 BC. The analyses of the wood together with earlier analyses of archaeological artefacts allow a better understanding of the chronological framework of the Špica site, although this study could not exploit the entire research potential of the excavated archaeological wood.

Keywords: Ljubljansko barje, Špica pile-dwelling, Late Copper Age, 3rd millennium BC, archaeological wood, dendrochronology

Izvleček: Predstavljamo raziskavo lesa, odkritega med arheološkimi izkopavanji 2009/2010 na prazgodovinski koliščarski naselbini Špica na Ljubljanskem barju v Sloveniji. Raziskave so v glavnem vključevale identifikacijo lesa, dendrokronološko datiranje in prostorsko razporeditev kolov. Osredotočili smo se na manjše dele najdišča in datirali hrastove in jesenove kole z referenčnimi kronologijami koliščarskih naselbin Založnica in Parte, za obdobje 2659–2366 pr. Kr. Na podlagi ugotovljenih datumov poseka dreves smo identificirali več faz gradbenih aktivnosti med leti 2522 in 2406 pr. Kr. Zaradi časovnega razpona razpoložljivih referenčnih kronologij ni bilo mogoče datirati lesa, ki je bil morda posekan pred letom 2659 ali po letu 2366 pr. Kr. Analize lesa skupaj s predhodnimi analizami arheoloških najdb omogočajo boljše razumevanje kronološkega okvira obstoja kolišča Špica, čeprav v študiji nismo uspeli izkoristiti celotnega potenciala zbranega arheološkega lesa.

Ključne besede: Ljubljansko barje, kolišče Špica, pozna bakrena doba, tretje tisočletje pr. Kr., arheološki les, dendrokronologija

1 INTRODUCTION
1 UVOD

The archaeological site Špica is located in the northern part of the Ljubljansko barje area in central Slovenia in the city of Ljubljana, on the right bank of the river Ljubljanica (Figure 1). The site is bordered to the south by the Ljubljanica River and to the east by the Gruber Canal, which was built at the end of the 18th century to speed up the drainage of excess water from the Ljubljanica. The results of the research of the archaeological finds from Špica funded by the ARIS postdoctoral project "Exchange and mobility dynamics at Ljubljansko barje: Late Copper age pile-dwelling Špica in Ljubljana" indicated that the majority of the finds originate from the middle of the 3rd millennium BC. However, the

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analyses of the archaeological wood from Špica has not yet been presented.

The first mention of the Špica site is dated back to the end of the 19th century, when numerous finds came to light as a result of the repeated regulation of the Ljubljanica river. In the first half of the 20th century multiple discoveries, such as copper, stone, bone and pottery finds, were made in the vicinity of the Špica site. Included in the discoveries were artefacts resembling those known from Dežman's pile-dwellings near Ig, which were discovered and researched by Dragotin Dežman between 1875 and 1877 (Šinkovec, 1995; Šinkovec, 2012; Gaspari, 2012; Leghissa, 2021). In 2009, in the light of the planned renovation of the Špica area, preliminary archaeological investigations were therefore carried out to determine the archaeological potential of the site by drilling core holes in the wider area of Špica park and along the Ljubljanica River and Gruber Canal (Novšak et al., 2009). The results confirmed the existence of pile-dwelling settlement

Figure 1. Location of the Špica site in the city of Ljubljana (source: https://gis.arso.gov.si/atlasokolja; map: E. Leghissa).

Slika 1. Lokacija najdišča Špica v Ljubljani (vir: https://gis.arso.gov.si/atlasokolja; zemljevid: E. Leghissa).

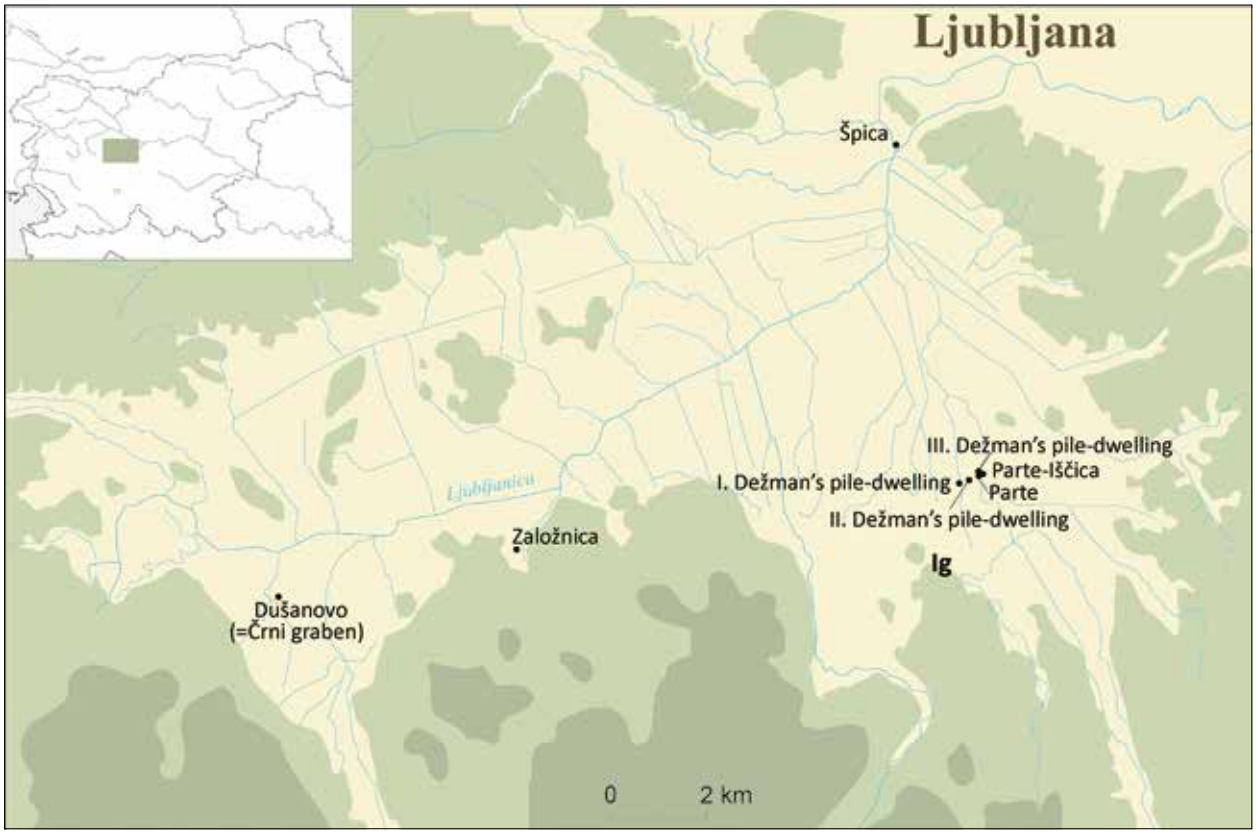

Figure 2. Distribution of the first half and the middle of the 3rd millennium BC pile dwellings in the Ljubljansko barje area, Slovenia. Map: E. Leghissa.

Slika 2. Razporeditev koliščarskih naselbin iz prve polovice in sredine 3. tisočletja pr. Kr. na območju Ljubljanskega barja. Zemljevid: E. Leghissa.

structures. On the basis of the results, rescue archaeological investigations took place in 2009 and 2010 in the area of the planned work of arranging the Špica area and the banks of Gruberjevo nabrežje. The archaeological investigation uncovered a small part of a pile-dwelling settlement, with well-preserved remains of wooden architecture and numerous finds from the Late Copper Age, i.e. most likely from the middle of the 3rd millennium BC (Klasinc et al., 2010; Šinkovec, 2012; Jančar, 2016). The majority of the finds consist of numerous pottery vessels and other objects, comparable to those found at contemporaneous sites in the Ljubljansko barje, such as Parte, II. Dežman's, Založnica and Dušanovo pile-dwellings, which are attributed to the newly defined Ljubljana culture (Figure 2) (Leghissa, 2021; Leghissa, 2024).

2 MATERIALS AND METHODS
2 MATERIALI IN METODE

2.1 ARCHAEOLOGICAL INVESTIGATIONS OF ŠPICA PILE DWELLING IN 2009-2010
2.1 ARHEOLOŠKE RAZISKAVE KOLIŠČARSKEGA NASELJA ŠPICA V LETIH 2009/2010

The archaeological investigation, conducted under the supervision of the Museum and Galleries of Ljubljana and the Institute for the Protection of Cultural Heritage, OE Ljubljana, was carried out by the company Tica Sistem.

The excavations only covered certain areas of Špica, which were then the subject of a planned restoration of this section of the riverbank (see the excavation field borders marked in Figure 6). A total area of almost 750 m² was investigated, of which 463 m² were completely excavated down to the cultural layer, while 284 m² remained untouched. Based on archaeological drillings from 2009, archaeological excavations and geological research, it was found that in prehistoric times a stream ran in the place of today's Gruber Canal, which flowed into a lake and transported material from Grajski grič and Golovec. In the vicinity of today's Ljubljanica, lake sediments were found during archaeological investigations that indicate a lake on whose shores a pile-dwelling settlement was built.

The oldest geological layer is represented by the marl layer (in Slovene *polžarica*), within which laminae of sand are found, indicating the action of flowing water, most likely associated with periodic floods of the aforementioned stream and lake. In some areas, the upper part of the marl layer is oxidized, suggesting that parts of the layer were occasionally exposed to air, indicating dry conditions and exposure to oxidation. Above the geological base was documented the cultural layer. Geological and palynological research at the Špica site (Andrič et al., 2017) has shown that a large part of the stratigraphic sequence, deposited between 18,000 and 2,500 BC – that is, between the marl layer and the cultural layer – has eroded. The late glacial and early/middle Holocene sediment is thus missing and was presumably removed by fluvial processes. The cultural layer thickens from south to north, or from the beds of the Ljubljanica River and the Gruber Canal toward the interior. Within the cultural layer, particularly at its top, there is a large quantity of finds and stones. The material is predominantly composed of pottery and bone fragments. Most of the ceramic finds are highly fragmented with rounded edges, indicating horizontal displacement of the material within the pile-dwelling settlement area due to water movement. The cultural layer is thickest in trench 1001/1, located in the central western part of the investigated area. At this location, the number of wooden remains, both vertical and horizontal piles, was the greatest, likely contributing to the preservation of the most finds between the wooden piles. Based on comparisons, the finds most likely date to the mid-3rd millennium BC, corresponding to the Late Copper Age. This area of the site also contains the most stones/rock fragments, most of which originate from the southern edge of the marshland. The cultural layer was overlain by gyttja/layers of organic mud, marking the phase following the abandonment of the pile-dwelling settlement, characterized by the marshification and drying of the lake. The layers of gyttja were in some areas covered by other layers of alluvial origin, formed during later prehistoric periods and the Roman era. The youngest layers date to the Early Modern period and more recent times, which in some areas have reached down to the level of the geological layers (Figure 3) (Klasinc et al., 2010).

Figure 3. View of the layers in section P 1008 at Špica pile dwelling excavation: at the bottom the marl layer is visible, directly overlain by the cultural layer (dark brown layer). The layers between the loess and the cultural layer were most likely removed by fluvial processes (see Andrič et al. 2017). The cultural layer is covered by organic mud / gyttja (light brown layer), followed by floodplain sediments (grey layers), and in the upper part, modern-age deposits and alluvium (yellowish layer) are visible. The section also shows wooden elements and larger stones at the interface between the cultural layer and the gyttja. View towards the northeast. Photo: G. Babič; source: Museums and Galleries of Ljubljana (after Klasinc et al., 2010, Fig. 6).

Slika 3. Pogled na plasti v prerezu P 1008 pri izkopu kolišča Špica: na dnu je vidna polžarica (svetlo siva plast), na kateri leži direktno kulturna plast (temno rjava plast). Plasti med polžarico in kulturno plastjo so bile erodirane najverjetneje zaradi delovanja vode (glej Andrič et al., 2017). Kulturna plast je prekrita z organskim blatom/gyttjjo (svetlo rjava plast). Sledijo poplavni sedimenti (sive plasti) in v zgornjem delu novoveški sedimenti in naplavine (rumenkasta plast). Na prerezu so vidni tudi leseni elementi in večji kamni na stiku med kulturno plastjo in gyttjo. Pogled proti severovzhodu. Fotografija: G. Babič; vir: Muzeji in galerije mesta Ljubljane (po Klasinc et al., 2010, slika 6).

2.2 WOODEN REMAINS, DISCOVERED DURING ARCHAEOLOGICAL INVESTIGATIONS IN 2009/2010

2.2 LESENI OSTANKI, ODKRITI MED ARHEOLOŠKIMI RAZISKAVAMI V LETIH 2009/2010

The wood discovered during archaeological excavations at the Špica site was typologically classified into usable objects (such as parts of spindles and axe shafts), tree remnants (branches, twigs, and weaving remains that formed house walls), and construction or building elements. The latter were the most numerous and were used in the construction of the dwellings or various other structures in the prehistoric pile-dwelling settlement (Figure 4). The total number of identified wooden elements (hereafter referred to as LE after the Slovene term *Lesni Element*) amounts to 2,737. For dendrochronological research and wood species identification, 2,528 LE samples of construction and building elements were collected. Among the discovered LE, the majority are vertical LE (93%), while only 7% were horizontal. Most wooden piles were documented at the level of cultural layers, with some being identified within the gyttja, and only exceptionally in the alluvial deposits above the gyttja. The preservation of LE was, in some places, very poor (especially in areas near the Ljubljanica River). At the level of the marl layer a significant number of posts was discovered, representing fully weathered piles.

More than 60% of all discovered LE were processed in various ways. Some were split on one or both sides, sometimes even on multiple sides. A significant number of LE were sharpened to a point, with some of these also being flattened into planks. Some of the processed piles had burnt tips, indicating that fire was also used by the pile-dwellers in processing wood.

All wooden elements (LE) were numbered during the excavations and documented both descriptively and spatially using a total station. For most of them, samples were taken for dendrochronological analysis. These samples were approximately 20 cm long, typically taken from the lower, better-preserved part of the pile. In rare cases, samples could not be taken due to poor preservation of the pile. After the sampling in the field, the waterlogged samples were sealed in airtight polyethylene bags and transported to the Chair of Wood Science at the Department of Wood Science and Technology, Biotechnical Faculty, University of Ljubljana for wood analyses. Research work was done in the Wood Anatomy and Dendrochronology Laboratory.

Figure 4. Densely hammered upright wooden piles found at two locations of the Špica pile-dwelling site during excavations in 2009/2010. Photo: G. Babič; source: Museums and Galleries of Ljubljana.
Slika 4. Gosto zabiti pokončni leseni koli, najdeni na dveh mestih na kolišču Špica med izkopavanji v letih 2009/2010. Fotografija. G. Babič; vir: Muzeji in galerije mesta Ljubljane.

2.3 WOOD IDENTIFICATION AND DENDROCHRONOLOGY
2.3 IDENTIFIKACIJA LESA IN DENDROKRONOLOGIJA

In 2009 the Chair of Wood Science received 238 samples of piles, followed by a further 2,214 in 2010. All 2,452 wood samples collected over two years were processed according to the standard methodology developed during work on other excavations at Ljubljansko barje under the direction of Anton Velušček (e.g. Čufar et al., 2022; Velušček & Čufar, 2025). The wood was processed as follows:

- surface preparation of cross-sections of 2,452 wood samples,
- macroscopic identification of the wood species,
- preparation of microscopic sections (transverse, radial and tangential) for microscopic wood identification when macroscopic identification was not possible,
- counting the tree rings, measuring the diameters and recording the main characteristics of all samples,
- measurement of tree-ring widths for samples of oak (*Quercus* sp., QUSP), ash (*Fraxinus* sp., FRSP), beech (*Fagus sylvatica*, FASY) and silver fir (*Abies alba*, ABAL) containing ≥45 tree rings,
- cross-dating and attempting to construct tree-ring chronologies of the site and dendrochronologically date the tree-ring series of individual piles using the reference chronologies of Založnica and Parte pile dwellings of the Ljubljansko barje,
- creation of a table with all the important information for each of the samples.

After the wood analyses were completed, the water-saturated samples were vacuum-sealed and stored in airtight polyethylene bags in a cool storage room at the Department of Wood Science and Technology.

2.4 MAPS OF PILE DISTRIBUTION REGARDING WOOD CHARACTERISTICS
2.4 PRIPRAVA NAČRTOV RAZPOREDITVE KOLOV GLEDE NA ZNAČILNOSTI LESA

The individual piles were recorded during the excavation using a total station, which was locked into an absolute coordinate system in use at the time: the Yugoslavia Reduced Gauss-Krüger Transverse Mercator D48. The estimated precision of the measurements falls well within ±0.05 metres. Although the coordinate system is now obsolete, we did not reproject the data for two reasons. First, due to the scale, reprojecting the data would not yield any benefit for our analysis. Second, minor errors could be introduced by this process.

We imported the field data into Golden Software Surfer 8 to map the points. Subsequently, the

data was further processed in ArcGIS Desktop 9.3.1 (the analysis was conducted in 2011-2012) to calculate Kernel Density Estimation (KDE). KDE is a method that provides valuable insights into the intensity and concentration of point data, such as archaeological sites or features. It creates a smooth, continuous surface by placing a kernel function at each point in the dataset and summing these functions to generate a density surface. The kernel function determines the shape and size of the area of influence around each point. Commonly used kernel functions include Gaussian, Epanechnikov, and Uniform kernels. The bandwidth parameter controls the size of the kernel and influences the degree of smoothing applied to the data (e.g., Baxter et al., 1997; Bonnier et al., 2019; Lozić & Štular, 2024).

We empirically determined that a 1 m bandwidth and the "kernel densities" parameter are the most appropriate for our application. We calculated the total kernel density estimations for all piles, as well as separately for oak (QUSP) and ash (FRSP) piles.

3 RESULTS AND DISCUSSION
3 REZULTATI IN RAZPRAVA
3.1 WOOD IDENTIFICATION AND DENDROCHRONOLOGY
3.1 IDENTIFIKACIJA LESA IN DENDROKRONOLOGIJA

Analyses of 2,452 samples of construction and building elements helped us to identify 13 wood species or genera (Table 1). The most common species/genera were ash with 1,460 samples (60%) and oak with 509 (21%). Furthermore, beech (4%), maple (3%), hornbeam (3%), willow (3%), elder (2%), silver fir (1%), and hazel (1%) accounted for 1 to 4%, while poplar, rowan, elm, and birch occurred only sporadically. In 1.6% of the samples, the wood species / genera could not be determined because the wood had deteriorated too much. The selection and proportion of wood species, especially the highest share of ash and oak, is consistent with the situation at the Ljubljansko barje pile-dwelling sites, where ash and oak usually predominate, but have different proportions from site to site (e.g., Čufar & Velušček, 2012; Jančar, 2016; Čufar et al., 2022; Out et al., 2022, 2023).

The wood was collected to carry out dendrochronological dating. Oak and ash are best suited for this purpose. The samples contained 45 or more tree rings and were dendrochronologically analysed for 85 (27%) of the oak samples and 394 (17%) of the ash ones (Table 2). Additionally, we measured nine (8%) of the beech and nine (31%) of the silver fir samples which could not be cross-dated. The ash piles were predominantly 4 to 12 cm in diameter, while the oak piles were generally larger (Figure 5). In other sites, the oaks with diameters of 20 cm or more were usually split lengthwise before being used as piles (e.g., Oat et al., 2023; Čufar et al., 2022). However, at the Špica site there were only 36 split oaks (7%) and only 11 (2%) of these were dendrochronologically analysed.t

Before we started to cross-date the tree-ring series of the dendrochronologically measured samples we created maps showing the distribution and arrangement of piles from different wood species to identify potential structures to be dated.

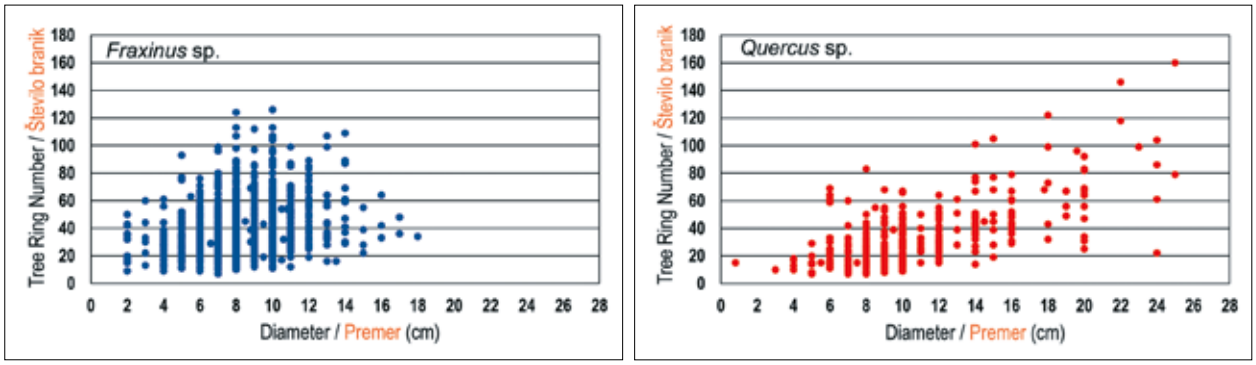

Figure 5. Ash (*Fraxinus* sp.) and oak (*Quercus* sp.) from the Špica pile-dwelling site: number of tree rings vs. diameter.

Slika 5. Jesen (*Fraxinus* sp.) in hrast (*Quercus* sp.) s kolišča Špica: število branik in premeri.

Table 1. Wood species of 2,452 samples of piles and other construction elements collected at the Špica pile-dwelling site.
Preglednica 1. Lesne vrste 2452 vzorcev kolov in drugih konstrukcijskih elementov, zbranih na kolišču Špica.

	Scientific name Latinsko ime	Code Koda	English name Angleško ime	Slovenian name Slovensko ime	Number Število	% %
1	*Fraxinus* sp.	FRSP	ash	jesen	1460	59.5
2	*Quercus* sp.	QUSP	oak	hrast	509	20.8
3	*Fagus sylvatica*	FASY	beech	bukev	110	4.5
4	*Acer* sp.	ACSP	maple	javor	77	3.1
5	*Carpinus betulus*	CPBE	hornbeam	beli gaber	75	3.1
6	*Salix* sp.	SASP	willow	vrba	62	2.5
7	*Alnus glutinosa*	ALGL	elder	jelša	50	2.0
8	*Abies alba*	ABAL	silver fir	jelka	29	1.2
9	*Corylus avellana*	COAV	hazel	leska	21	0.9
10	*Populus* sp.	POSP	poplar	topol	12	0.5
11	*Sorbus torminalis*	SOTE	rowan	brek	3	0.1
12	*Ulmus* sp.	ULSP	elm	brest	3	0.1
13	*Betula* sp.	BEPE	birch	breza	1	<0.1
14		INID	not identified	neidentificiran	40	1.6
				SUM	2452	

Table 2. Ash (*Fraxinus* sp.) and oak (*Quercus* sp.) from the Špica pile-dwelling site: total number of samples, average (minimum, maximum) number of tree rings, average (minimum, maximum) diameter and number of dendrochronologically analysed samples of each species.
Preglednica 2. Jesen (*Fraxinus* sp.) in hrast (*Quercus* sp.) s kolišča Špica: skupno število vzorcev, povprečno (najmanjše, največje) število branik, povprečni (najmanjši, največji) premer in število dendrokronološko analiziranih vzorcev posamezne vrste.

	Total number of samples Skupno število vzorcev	Number of tree rings Average (Min.-Max.) Število branik Povprečje (min.-maks.)	Diameter (cm) Premer (cm)	Dendrocronologically analysed samples Št. dendrokronološko analiziranih vzorcev
Fraxinus sp.	1460	40 (7-126)	8 (2-18)	394 (27%)
Quercus sp.	509	33 (7-160)	11 (1-25)	85 (17%)

3.2 DISTRIBUTION OF THE WOOD FINDS ON THE ARCHAEOLOGICAL SITE
3.2 RAZPORED LESENIH NAJDB NA ARHEOLOŠKEM NAJDIŠČU

The remains of the predominant ash wood were evenly distributed over the entire excavation site, while the oak was found only in certain places (Figure 6). Other wood species (marked in yellow in Figure 6) are distributed throughout the site and often intermixed with ash. The distribution of piles on the site is important with regard to aiding dendrochronological dating and its interpretation, especially if the archaeological constructions were built and rebuilt in different phases and different time periods, as is often the case (e.g., Čufar & Velušček, 2003; Velušček & Čufar, 2004).

The distribution of piles at Špica in certain sections of the excavation field indicates parallel lines running in a NE-SW direction, similar to those found at other pile dwellings on the Ljubljansko barje. However, the dense arrangement of piles in some parts (Figures 4, 7) of the excavated Špica

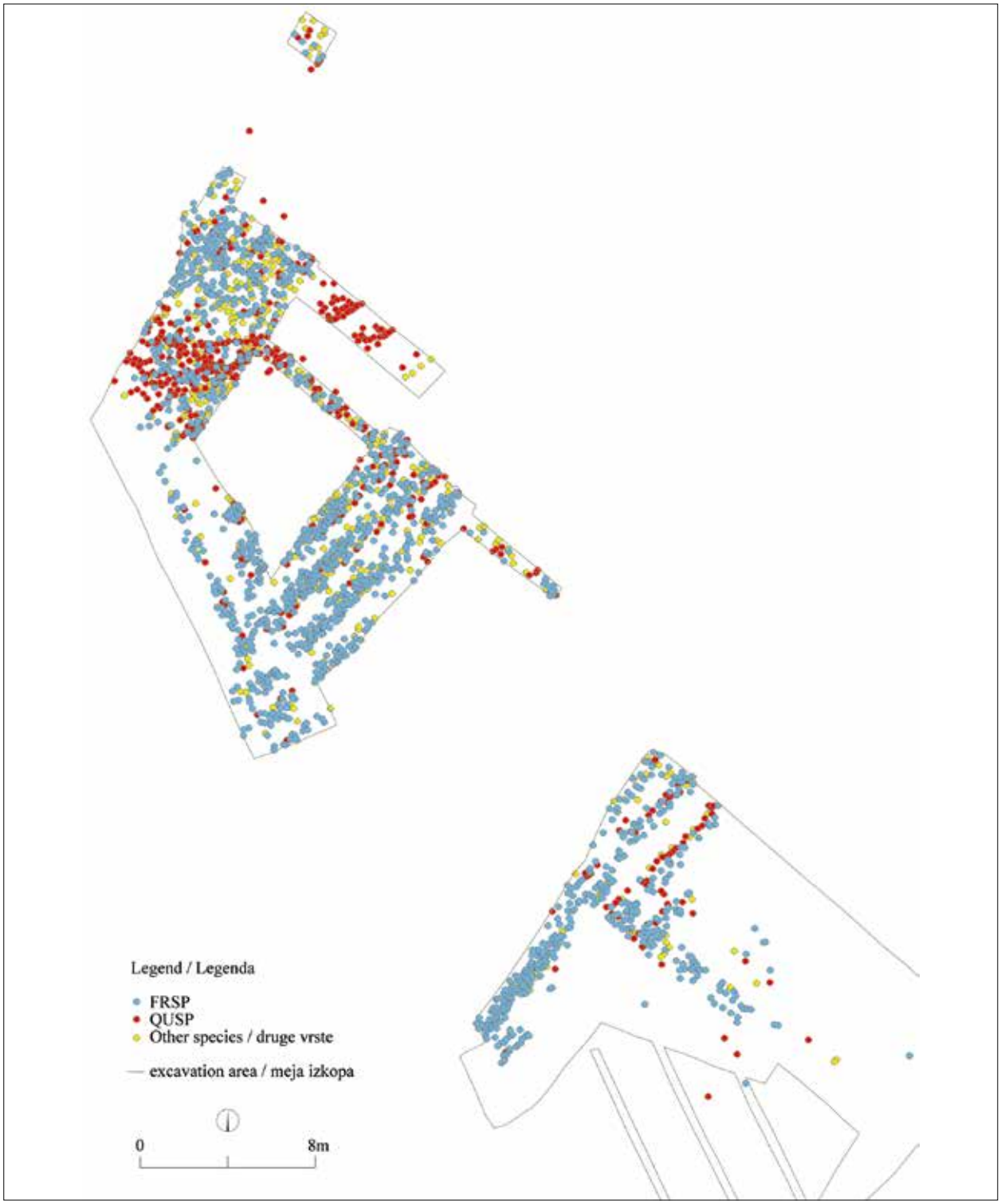

Figure 6. Distribution of 2,452 piles and other construction elements of different tree species on the ground plan of the Špica pile-dwelling site. Both the vertical piles (93% of all samples) and the horizontal elements (7%) are marked with points. FRSP – ash (*Fraxinus* sp.), QUSP – oak (*Quercus* sp.). Map: B. Štular.
Slika 6. Razpored 2452 kolov in drugih konstrukcijskih elementov iz lesa različnih drevesnih vrst na tlorisu kolišča Špica. Vertikalni koli (93 % elementov) in horizontalni elementi (7 %) so označeni s pikami. FRSP–jesen (*Fraxinus* sp.), QUSP–hrast (*Quercus* sp.). Zemljevid: B. Štular.

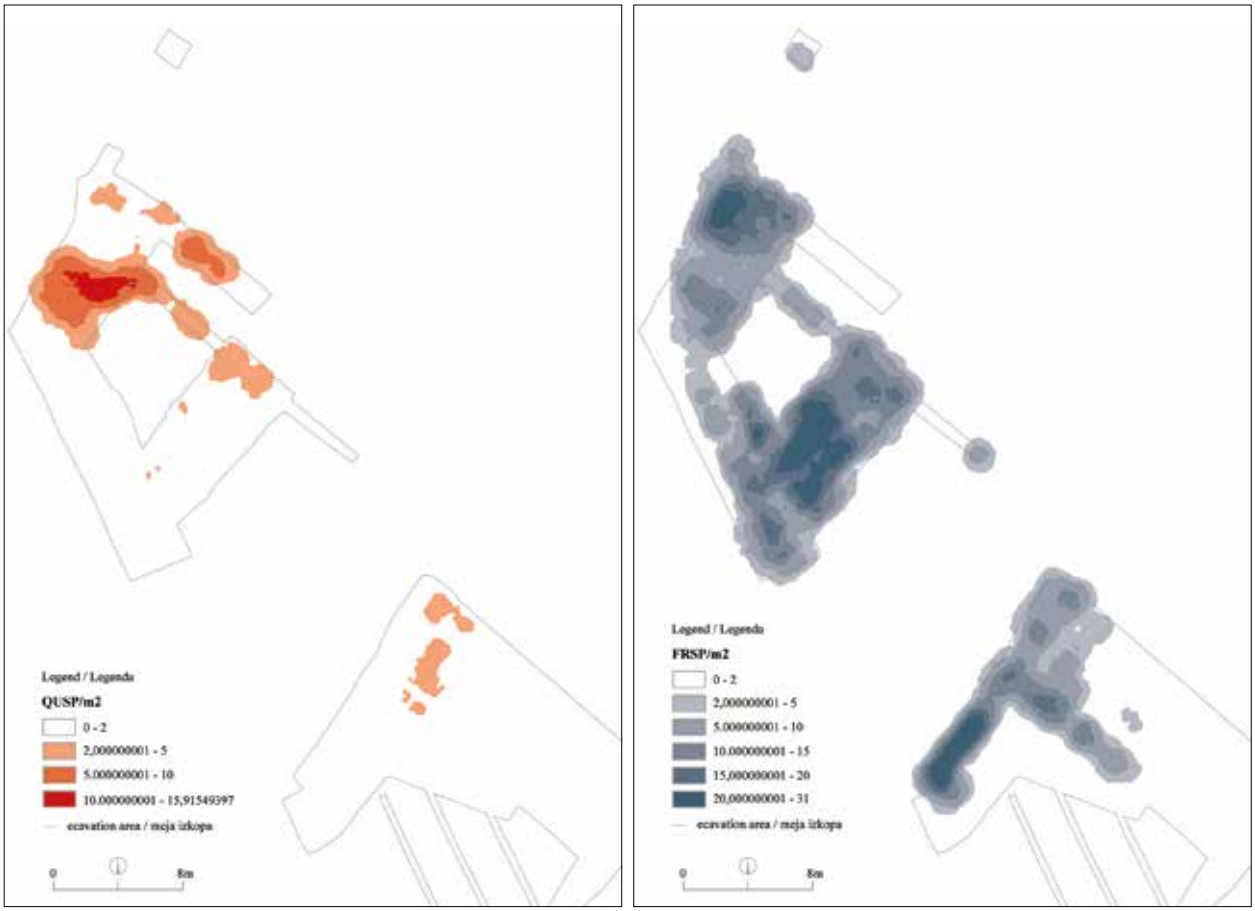

Figure 7. Density of oak (QUSP) piles (left) and ash (FRSP) piles (right) at the Špica pile-dwelling site. Map: B. Štular.

Slika 7. Gostota hrastovih (QUSP) kolov (leva slika) in jesenovih kolov (FRSP) (desno) na kolišču Špica. Načrt: B. Štular.

differs slightly from the pile density discovered at, for example, the Parte, Parte-Iščica, Založnica, and Dušanovo pile dwellings (Čufar et al., 1997; 1999; Čufar & Velušček, 2003). It appears that the piles at Špica were placed more densely than those at the Parte pile dwelling, for example (Harej, 1978, 1981-1982, 1987; see also Leghissa, 2017, Fig.13). This suggests that there were presumably more repairs of the constructions on this site, as indicated by the numerous piles placed next to one another, or the ones which were damaged when the pile dwellers were driving new piles into the ground (Figure 8) as previously discussed by Jančar (2016). Fluctuating water levels may have played an important role in this, as indicated by some horizontally lying wooden piles and discussed by Jančar (2016), particularly in the western part of the area that has been explored, and this issue deserves additional analysis. Different construction phases are also assumed, based on the different typology regarding diameter, form and processing marks on the piles. Another possible explanation for the dense arrangement of piles is that the structure may not have been a dwelling, but rather a different type of construction, such as a palisade, dock or similar facility.

3.3 DENDROCHRONOLOGY
3.3 DENDROKRONOLOGIJA

Since much of the pottery and other archaeological objects are similar to those from the mid-3rd millennium BC pile dwellings of Založnica and Parte, for which we have overlapping oak and ash reference chronologies spanning the period 2659 – 2366 BC (Figure 9) (Čufar et al., 2022). The oak chronology of Založnica ZALQUSP1 was dated to an end date of 2417 ± 18 cal BC on the basis of several

Figure 8. Example of wooden piles, tightly driven next to each other on the Špica pile-dwelling site; the upper oak pile LE877 was pounded later than the lower ash pile LE878 (left), and some of the different diameters and forms of wood samples analysed in the laboratory (right). Photo: (left) G. Babič; source: Museums and Galleries of Ljubljana, (right) L. Krže.

Slika 8. Primer lesenega kola, tesno zabitega ob drugem kolu, na kolišču Špica; zgornji hrastov kol je bil zabit kasneje kot spodnji jesenov kol (levo) in različna tipologija vzorcev, pripravljenih za raziskave v laboratoriju (desno). Fotografija: (levo) G. Babič; vir: Muzeji in galerije mesta Ljubljane, (desno) L. Krže.

C14-dated samples and the wiggle-matching method. The other oak and ash chronologies (Figure 9) were dendrochronologically dated with ZALQUSP1. It should be noted that the chronologies given can be used for dating wood from the period they cover, but not for dating wood (if present at the site) from younger or older periods outside this time span.

To find out whether the wooden structures from Špica can be dated with the available chronologies, we have attempted to cross-date the tree-ring series of all oak and ash samples to create one or more local chronologies for Špica based on the overlapping series (e.g. Čufar et al., 2015). The local chronology usually includes and dates all elements with overlapping tree-ring series where the same date of tree felling indicates the same construction phase. This approach did not work in Špica, and we were unable to reconstruct ground plans of objects (houses), as was possible in Parte Iščica, for example (Velušček et al., 2000).

However, it was possible to date some individual piles with the given reference chronologies. For this purpose, we randomly selected specific areas (trenches and quadrants) (Figure 10, Table 3) and attempted to date all dendrochronologically analysed piles in each area. Finally, the individual piles shown in Figures 10, 11 and 12 were dendrochronologically dated. After checking whether the wood samples contained the outer tree-ring below the bark (waney edge), we obtained seven felling dates of individual piles or pile groups distributed throughout the archaeological site (Figure 10). Their felling dates (the position of end dates on the chronologies ZALFRSP1 and ZALQUSP1) were between 2522 and 2406 ±18 cal BC. The dendro-

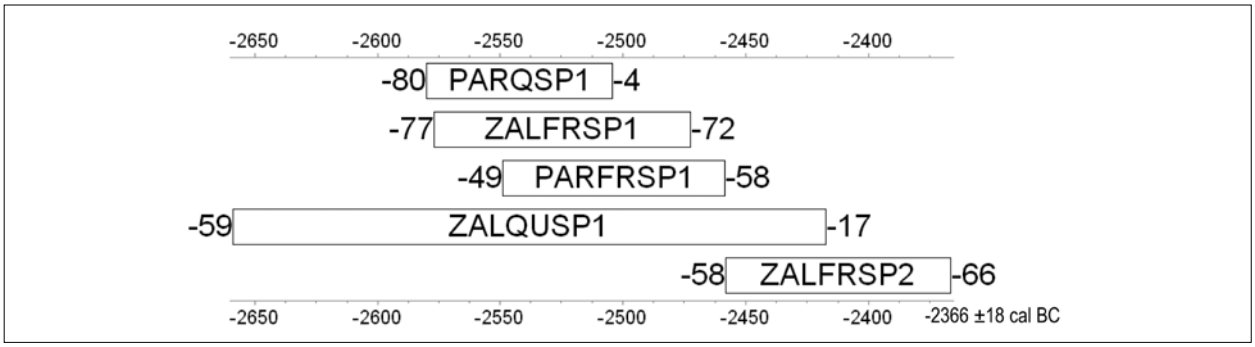

Figure 9. Time spans of the chronologies of oak (QUSP) and ash (FRSP) from the pile-dwelling settlements of Parte (PAR) and Založnica (ZAL) dated by C14 and wiggle-matching methods and spanning the period of 2659 – 2366 BC.

Slika 9. Razponi kronologij hrasta (QUSP) in jesena (FRSP) s koliščarskih naselbin Parte (PAR) in Založnica v obdobju 2659–2366 pr. Kr. datiranih s pomočjo radiokarbonske metode in metode wiggle-matching.

chronologically defined difference between the earliest and the latest end date was 116 years.

The details of the units in Figure 10 enabled us to verify the locations of the dendrochronologically measured ash (FRSP) and oak (QUSP) wood elements and to distinguish them from the elements of other species and unmeasured oak and ash elements. The situation in the units was very different.

Unit A contained oak, ash and other species but only one ash-wood element could be dated to an end date of 2456 BC. Unit B contained mainly oak elements (Figure 10). Two of them could be dated to 2454 BC. Unit C contained ash, oak and other wood species. Two ash elements were dated to 2483 BC. Unit D also contained ash, oak and other wood species, and the density of the piles was lower. Two ash piles located close to each other were dated, one to 2481 BC and another to 2515 BC. They belonged to two phases of construction, 34 years apart (Figure 11).

In unit E, the density of the wooden elements was high. Ash wood predominated, but most elements were not measured as they contained too few tree rings. Two ash samples were dendrochronologically dated with the end year of 2522 BC and thus represented the oldest dated elements. The other undated piles contained relatively few tree rings and numerous growth anomalies. They probably belong to different construction phases (Figure 12). In unit F in the immediate vicinity, we were able to identify four oak elements arranged in a row. All of them had the same felling date of 2406 BC and represent the youngest dated construction. The ash piles in their immediate vicinity could not be dated.

The detailed investigation provided us with felling dates for 14 wooden elements, which made it possible to recognize at least four periods of building activities with the following end dates: around 2522 BC (unit E, D), around 2483 BC (unit D, C), around 2456 BC (units A, B) and around 2406 BC (unit F). The closely spaced end dates (e.g. 2456 and 2454) indicate a particular building activity (and intensive logging) over a number of years,

Table 3. Areas of dendrochronological analyses (A – F) marked in Figure 10 and the corresponding surveyed trenches and quadrants documented during the 2009/2010 excavations.

Preglednica 3. Območja dendrokronoloških analiz (A – F), označena na Sliki 10 ter pripadajoče raziskane sonde in kvadranti, dokumentirani med izkopavanji v letih 2009/2010.

Dendrochronologically investigated units / Območja dendrokronoloških raziskav	Trench / Sonda	Quadrant / Kvadrant
A	1001/1	AR28, AR29
B	1001/2	AO28, AO29, AN29, AN30
C	1001/3	AN28, AN29
D	1005	AM30, AL30, AL31
E	1006	AH30, AI30, AI31
F	1006	AI31, AI32, AH32

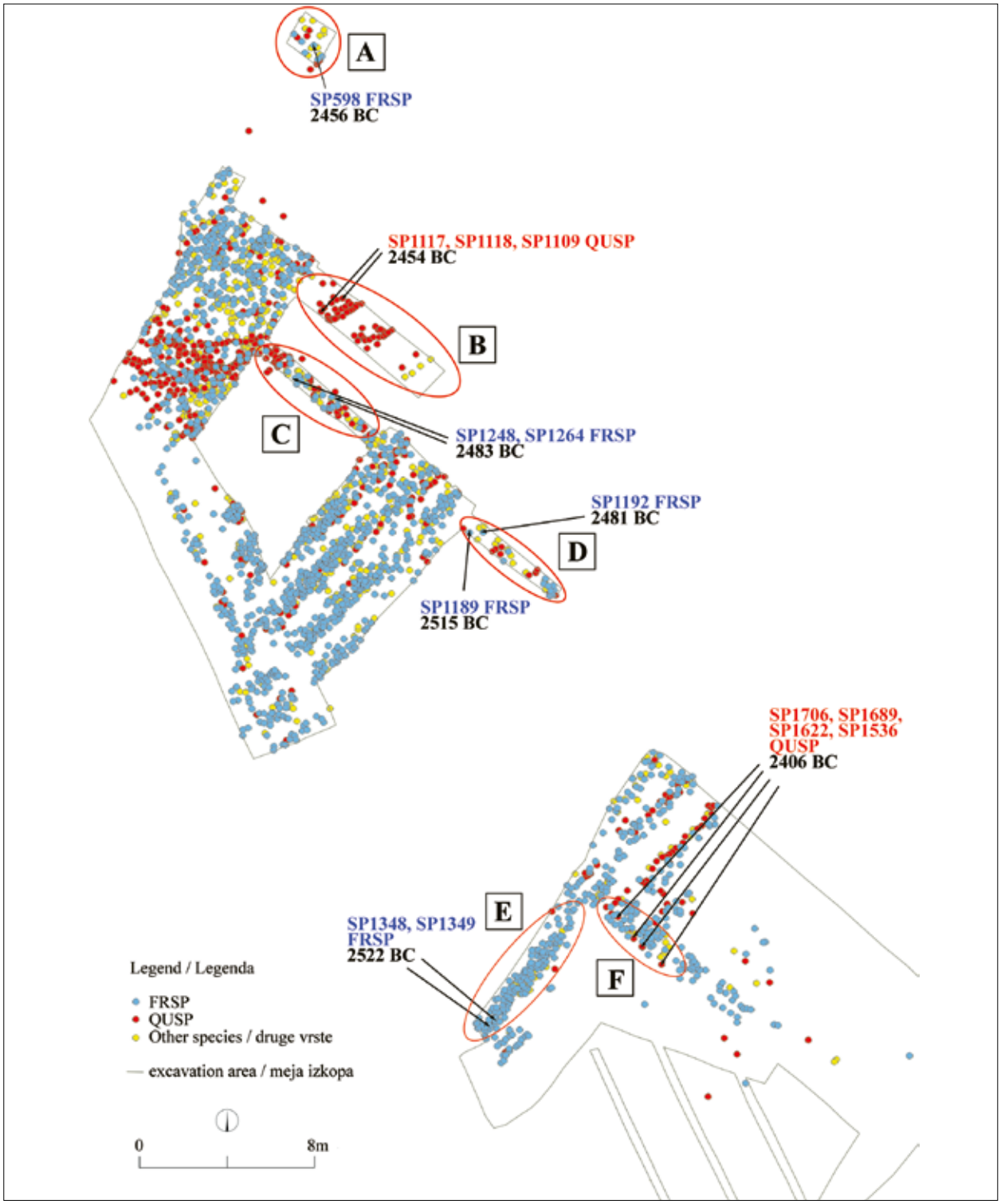

Figure 10. Dendrochronologically analysed units A, B, C, D, E, F of the Špica pile-dwelling site. The arrows point to the locations of the dated piles (SP*) of ash FRSP (*Fraxinus* sp.) and oak QUSP (*Quercus* sp) and the felling dates. Map: B. Štular and K. Čufar.

Slika 10. Dendrokronološka raziskava enot A, B, C, D, E, F na kolišču Špica. Puščice kažejo mesta datiranih kolov (SP*) jesena FRSP (*Fraxinus* sp.) in hrasta QUSP (*Quercus* sp.) in datumi poseka lesa pr. Kr. Zemljevid: B. Štular in K. Čufar.

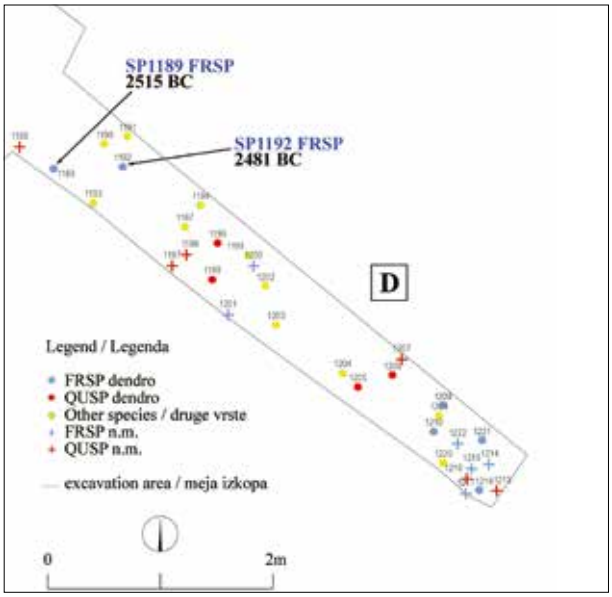

Figure 11. Dendrochronological analysis of unit D: dendrochronologically examined and dated ash FRSP and oak QUSP Legend, dendro – dendrochronologically measured, n.m. – not measured, for excavated units see Table 3. Map: B. Štular and K. Čufar.

Slika 11. Dendrokronološko raziskano območje D: vzorci jesena FRSP in hrasta QUSP. Legenda, dendro – dendrokronološko merjeni, n.m. – nemerjeni, other species–druge lesne vrste, za izkopane enote prim. preglednica 3. Zemljevid: B. Štular in K. Čufar.

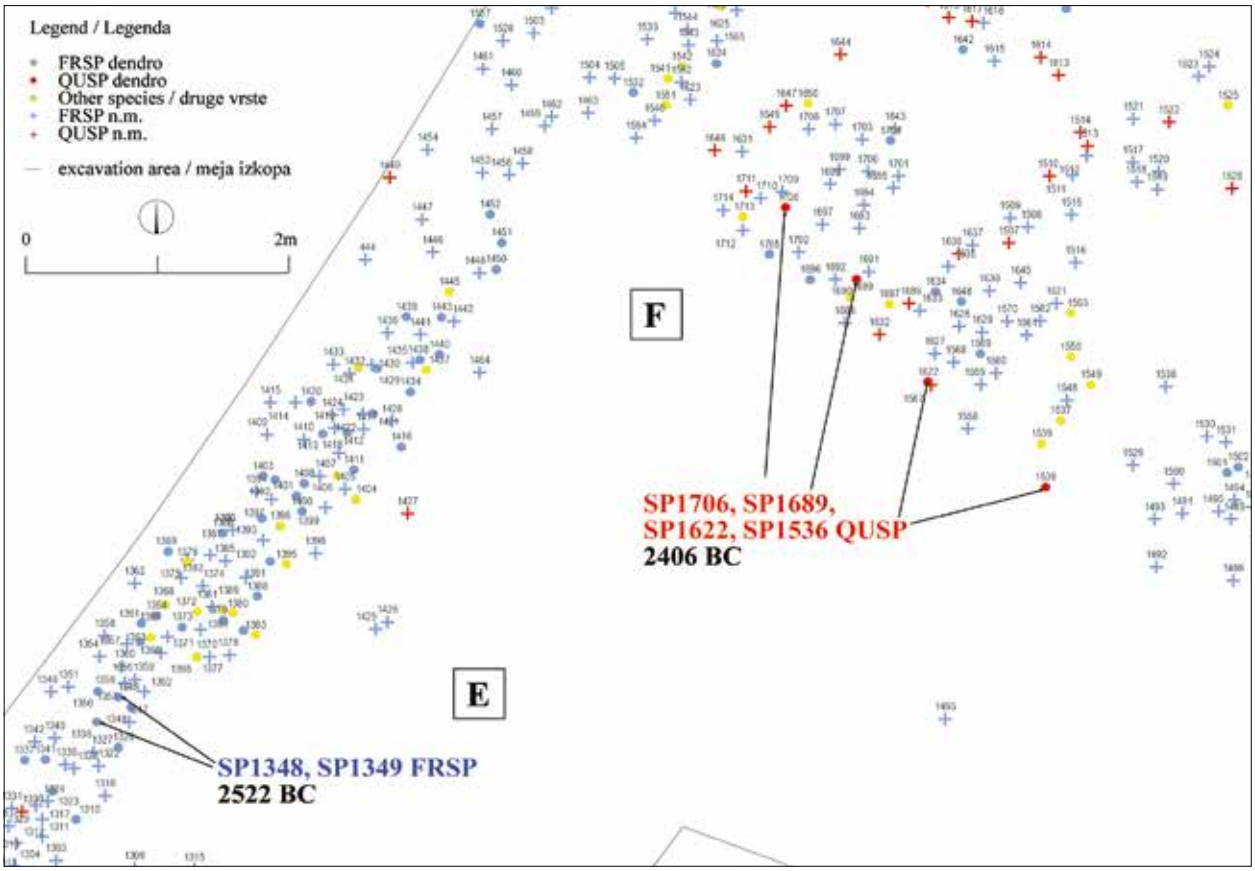

Figure 12. Dendrochronologically analysed units E with two dated ash FRSP elements and F with four dated oak QUSP piles in the row (red dots) with an end date of 2406 cal BC, while the ash FRSP piles (blue dots) could not be dated. Map: B. Štular and K. Čufar Map: B. Štular and K. Čufar.

Slika 12. Dendrokronološko raziskano območje E z dvema FRSP koloma in območje F (sonda 1006) s 4 datiranimi hrastovimi QUSP koli, postavljenimi v vrsti (rdeče pike) z datumom zadnje branike 2406 kal. pr. Kr., medtem ko jesenovih FRSP kolov (modre pike) nismo mogli datirati. Zemljevid: B. Štular, dopolnila K. Čufar.

which is consistent with the results of other sites on the Ljubljansko barje. Slightly deviating end dates may also be a result of missing external parts of the wooden elements, which were caused by the processing of wood or decay over time.

Felling activities between 2522 and 2406 BC, i.e. a period of 116 years, seem to represent one of the longest documented time spans for felling activities in Ljubljansko barje. One of the longest construction periods documented in Ljubljansko barje so far was that of the Založnica pile-dwelling site, where the period of settlement of 80-90 years (Velušček & Čufar, 2003) has been extended to about 140 years due to the recent precise radiocarbon wiggle-matching dates for ZALFRSP2 chronology (Figure 9). However, most of the other sites on Ljubljansko barje seemed to indicate felling activities for a shorter period, e.g. 60 years or only two decades or even less (Velušček & Čufar, 2014) which could appear also due to relatively small excavation areas. The long construction period documented in Špica is consistent with the relatively large excavation area and large number of piles discovered. The results indicate that the buildings were probably repaired and restored, and that several phases of settlement in the same area are also likely.

The results presented here show that so far only relatively few wood samples have been dated and that this study could not utilize the full research potential of the wood from Špica. Future research should thus aim to carry out the dendrochronological dating of more wooden elements. In addition, radiocarbon and wiggle-matching analyses should be used to support the dating of the wood, which was presumably felled outside the time span of the reference chronologies.

4 CONCLUSIONS
4 ZAKLJUČKI

Analyses of the archaeological wood in the Špica pile-dwelling settlement showed that ash was the most common type of wood, followed by oak. Ash was also predominant in other pile-dwelling settlements of the Ljubljansko barje that existed in the 3rd millennium BC, at Parte-Iščica, Parte, Založnica and Dušanovo (e.g. Velušček et al., 2000). Ash was distributed over the entire area studied, while oak was mainly found in the north-western part (trench 1006). Other tree species were beech, maple, hornbeam, willow, alder, silver fir and hazel. The latter tree species were also found in other pile-dwelling sites in the Ljubljansko barje.

For the dendrochronological analyses, the reference chronologies of the Parte and Založnica pile-dwelling sites were used, as the pottery material found there is most comparable to that from Špica. The oak and ash chronologies from Založnica and Parte were dated using C14 and wiggle matching with an accuracy of ±18 years. They cover the period 2659 – 2366 ±18 cal BC and make it possible to date the wood that grew or was felled in the middle of the 3rd millennium BC over a period of about 300 years. With the available chronologies, it was not possible to determine whether some piles date from younger or older periods outside the 300-year time span, as there are no dated chronologies for the periods immediately before or after 2659 – 2366 BC.

The dendrochronological analyses have confirmed the contemporaneity of Špica with the Parte and Založnica sites, which are archaeologically defined within the framework of the Ljubljana culture (for the latter, see Leghissa, 2021 and the literature cited there). In particular, the finds from the second Dežman pile-dwelling settlement near Ig are also attributed to this culture (Leghissa, 2017, 2021).

Dendrochronological analyses in selected parts of the Špica excavating area indicate a timeframe of felling activity between 2522 and 2406 BC, covering a period of 116 years between the earliest and latest felling dates. This period appears to represent one of the longest documented time spans of felling activity at a site (Špica), but we cannot confirm whether the area was occupied in one or more phases of settlement of the same area.

The study of the wood complements and clarifies the results of recent investigations of the pottery and other archaeological finds from Špica (Leghissa, 2024), although we were only able to date a small number of wooden elements. Therefore, we can conclude that further research is recommended to exploit the full research potential of the excavated archaeological wood.

5 SUMMARY

5 POVZETEK

Ostanki koliščarske naselbine Špica se nahajajo v Ljubljani na desnem bregu reke Ljubljanice (slika 1). Območje predstavlja severni del Ljubljanskega barja (slika 2). Na jugu meji na reko Ljubljanico, na vzhodu pa na Gruberjev prekop, ki je bil zgrajen konec 18. stoletja. Prve omembe najdišča Špica segajo v konec 19. stoletja, ko so zaradi večkratne regulacije Ljubljanice prišle na dan številne najdbe. V prvi polovici 20. stoletja je bilo v okolici najdišča Špica odkritih več najdb, kot so bakrene, kamnite, koščene in keramične najdbe. Leta 2009 so bile ob načrtovani prenovi območja Špice opravljene raziskave, s katerimi je bil ugotovljen arheološki potencial najdišča (Novšak et al., 2009). Rezultati so potrdili obstoj koliščarskih naselbinskih struktur. Na podlagi teh rezultatov so v letih 2009 in 2010 potekale zaščitne arheološke raziskave na območju načrtovanih del ureditve območja Špice in bregov Gruberjevega prekopa. Te arheološke raziskave so odkrile del koliščarske naselbine z dobro ohranjenimi ostanki lesene arhitekture in številnimi najdbami iz pozne bakrene dobe, tj. najverjetneje iz sredine 3. tisočletja pr. Kr. (Klasinc et al., 2010; Šinkovec, 2012). Med najdbami so številne keramične posode in drugi predmeti, ki so primerljivi s keramičnim repertoarjem ljubljanske kulture in zastopane na drugih sočasnih najdiščih na Ljubljanskem barju, kot so Parte, Dežmanova kolišča, Založnica in Dušanovo (Leghissa, 2021; Leghissa, 2024).

Arheološke raziskave v letih 2009 in 2010 je pod nadzorom Muzeja in galerij mesta Ljubljane in Zavoda za varstvo kulturne dediščine, OE Ljubljana, izvedlo podjetje Tica Sistem. Izkopavanja so zajela le določena območja Špice, ki so bila nato predmet načrtovane obnove tega dela nabrežja. Raziskana je bila skupna površina skoraj 750 m², od tega je bilo 463 m² v celoti izkopanih do kulturne plasti, 284 m² pa je ostalo nedotaknjenih. Arheološke najdbe so bile najbolj celovito raziskane v okviru podoktorskega projekta Elene Leghissa z naslovom »Dinamike izmenjave in mobilnosti na Ljubljanskem barju: pozno bakrenodobno kolišče Špica v Ljubljani«. V okviru analize in ovrednotenja stratigrafske slike in keramičnih najdb s Špice je bilo ugotovljeno, da sodi kolišče Špica v okvir na novo definirane ljubljanske kulture, v kateri se odražajo še elementi tradicije predhodne vučedolske kulture in vplivi kultur vrvičaste keramike in zvončastih čaš (Leghissa, 2021; Leghissa, 2024 in Leghissa, v pripravi).

Les, odkrit med arheološkimi izkopavanji na najdišču Špica, je bil tipološko razvrščen na uporabne predmete (kot so deli vreten in nasadov sekir), ostanke dreves (veje, vejice in ostanki pletiv, ki so tvorili stene hiš) ter gradbene oziroma stavbne elemente (sliki 3, 4). Slednji so bili najštevilčnejši in so predstavljali ostanke predvsem v tla zabitih kolov bivališč ali različnih drugih struktur v prazgodovinski koliščarski naselbini. Skupaj so identificirali 2737 lesenih elementov, v tej študiji pa smo opravili identifikacijo lesa in dendrokronološke raziskave 2528 vzorcev lesa elementov, med katerimi so prevladovali vertikalni v zemljo zabiti koli (93 %), le 7 % pa je bilo horizontalnih elementov. Večina lesenih elementov je bila dokumentirana na ravni kulturnih plasti, nekaj jih je bilo identificiranih znotraj gmote in le izjemoma v naplavinah nad gmoto. Ohranjenost lesa je bila ponekod zelo slaba (zlasti na območjih v bližini reke Ljubljanice). Na nivoju marmorne plasti je bilo odkrito precej lesa, ki predstavlja v celoti obdelane kole.

Več kot 60 % vseh odkritih lesenih elementov je bilo obdelanih na različne načine. Nekateri so bili celi, več jih je bilo razcepljenih ali obdelanih v tramove. Precejšnje število lesenih elementov je imelo obdelane konice za zabijanje v tla, nekateri pa so bili cepljeni v deske. Nekateri obdelani elementi so imeli ožgane konice, kar kaže na to, da so prebivalci koliščarske naselbine pri obdelavi lesa uporabljali tudi ožiganje.

Vsi leseni elementi so bili med izkopavanji oštevilčeni ter opisno in prostorsko dokumentirani s pomočjo tahimetra. Iz večine od njih so bili odvzeti vzorci za dendrokronološko analizo. Ti vzorci so bili večinoma približno 20 cm debeli koluti in so bili običajno odvzeti s spodnjega, bolje ohranjenega dela kola. V redkih primerih zaradi slabe ohranjenosti kola vzorcev ni bilo mogoče odvzeti. Po vzorčenju na terenu v letih 2009 in 2010 so bili z vodo napojeni vzorci shranjeni v neprepustnih polietilenskih vrečkah in prepeljani na Oddelek za lesarstvo Biotehniške fakultete Univerze v Ljubljani za analizo lesa na Katedri za tehnologijo lesa–Laboratoriju za anatomijo in dendrokronologijo.

Vseh 2452 vzorcev lesa je bilo obdelanih po standardni metodologiji, ki so jo razvili pri delu na drugih izkopavanjih na Ljubljanskem barju v obdobju 1994–2024 pod vodstvom Antona Velušča (npr. Čufar & Velušček, 2004, 2025; Velušček, 2004; Čufar et al., 2022). Raziskava je potekala v naslednjih korakih:

- površinska priprava prečnih prerezov 2452 vzorcev lesa,
- makroskopska identifikacija lesnih vrst,
- priprava mikroskopskih preparatov (prečnih, radialnih in tangencialnih prerezov) za mikroskopsko identifikacijo lesa, če makroskopska identifikacija ni bila mogoča,
- štetje branik, merjenje premerov in beleženje glavnih značilnosti posameznih vzorcev,
- merjenje širine branik za vzorce hrasta (*Quercus* sp., QUSP), jesena (*Fraxinus* sp., FRSP), navadne bukve (*Fagus sylvatica*, FASY) in navadne jelke (*Abies alba*, ABAL), ki so vsebovali ≥45 branik (497 vzorcev),
- sinhroniziranje zaporedij širin branik in dendrokronološko datiranje z referenčnimi kronologijami Oddelka za lesarstvo BF UL za Ljubljansko barje,
- izdelava preglednice rezultatov z vsemi pomembnimi podatki za vsak vzorec.

Po končanih analizah lesa so bili z vodo napojeni vzorci v vakuumsko zaprtih polietilenskih vrečkah shranjeni v hladnem prostoru s konstantno temperaturo okoli 13 °C na Oddelku za lesarstvo.

Analiziranih 2452 vzorcev je pripadalo 13 lesnim vrstam ali rodovom (preglednica 1). Najpogostejša rodova sta bila jesen (*Fraxinus* sp.), 1460 (60 %) vzorcev in hrast (*Quercus* sp.), 509 (21 %) vzorcev. Ostale dokaj dobro zastopane vrste lesa so bile: navadna bukev (*Fagus sylvatica*) (4 %), javor (*Acer* sp.) (3 %), beli gaber (*Carpinus betulus*) (3 %), vrba (3 %) (*Salix* sp.), črna jelša (*Alnus glutionosa*) (2 %), navadna jelka (*Abies alba*) (1 %) in navadna leska (*Crylus avellana*) (1 %). Ostale vrste, topol (*Populus* sp.), jerebika (*Sorbus* sp.), brest (*Ulmus* sp.) in breza (*Betula* sp.) so se pojavile le občasno (Preglednica 1). Pri 1,6 % vzorcev ni bilo mogoče določiti lesne vrste/rodu, ker je bil les preveč poškodovan. Izbor in delež lesnih vrst se ujemata s stanjem na drugih koliščih na Ljubljanskem barju, kjer običajno prevladujeta jesen in hrast, ki pa imata od kolišča do kolišča različen delež (npr. Čufar & Velušček, 2012; Čufar et al., 2022; Out et al., 2022; 2023).

Les je bil raziskan z namenom dendrokronološkega datiranja in s tem določitve oz. potrditve starosti kolišča Špica. Za dendrokronološke raziskave kolišč imata največji pomen hrast in jesen ter tudi bukev in jelka s 45 ali več branikami. Glede na to smo dendrokronološko raziskali 85 vzorcev hrasta in 394 vzorcev jesena ter le po 9 vzorcev bukve in jelke (preglednica 1, 2) in se v nadaljevanju posvetili predvsem jesenovim in hrastovim elementom. Premer jesenovih kolov je bil večinoma od 4 do 12 cm, medtem ko so bili premeri hrastovih kolov na splošno nekoliko večji (preglednica 2, slika 5).

Lega kolov različnih vrst na načrtu kolišča kaže, da so jesen in druge drevesne vrste dokaj enakomerno razporejene po območju, hrast pa je prisoten samo v določenih delih kolišča. Hkrati smo ugotovili, da gostota v tla zabitih kolov po površini kolišča variira (slike 6, 7). Tam, kjer je bila gostota kolov največja, so že na terenu opazili, da so med uporabo utrjevali konstrukcije z naknadno zabitimi koli (slika 8). Poudariti moramo tudi, da načrti, ki smo jih pripravili, ne razlikujejo vertikalnih kolov, ki so prevladovali, in morebitnih horizontalno ležečih elementov.

Ker je bil velik del arheoloških najdb (keramike) podoben tistim s koliščarskih naselij Parte in Založnica iz sredine 3. tisočletja pr. Kr. (slika 9), smo kronologije teh kolišč s časovnim razponom 2659–2366 pr. Kr. uporabili za datiranje lesa s Špice (npr. Čufar et al., 2022). Omenjene kronologije so bile datirane s pomočjo radiokarbonske metode in metode wiggle-matching z natančnostjo ± 18 let. Za datiranje vzorcev s Špice smo kot običajno skušali najprej sinhronizirati zaporedja širin branik vzorcev posameznih vrst, da bi sestavili eno ali več lokalnih kronologij za kolišče Špica. Ker ta pristop ni dal zadovoljivih rezultatov, smo v naslednjem koraku na načrtu kolišča določili 6 območij (A, B, C, D, E, F) (slika 10), kjer smo pregledali vse dendrokronološko izmerjene lesene elemente, ki smo jih skušali datirati z referenčnimi kronologijami. Ta pristop je bil uspešen in je omogočil datiranje več kot 14 lesenih elementov, razporejenih po celotnem arheološkem najdišču (slika 10). Najmlajši datirani koli iz lesa jesena se nahajajo na območju F, najstarejši pa na območju E (sliki 10 in 13).

Podrobna raziskava nam je omogočila, da smo prepoznali vsaj štiri obdobja gradbenih aktivnosti z naslednjimi končnimi datumi: okoli 2522 pr. Kr. (enota E, D), okoli 2483 pr. Kr. (enota D, C), okoli 2456 pr. Kr. (enoti A, B) in okoli 2406 pr. Kr. (enota F). Razlike v datacijah, ki znašajo le nekaj let (npr. 2456 in 2454), nakazujejo isto gradbeno fazo, ki je kot običajno trajala več let, kar je skladno z rezultati drugih najdišč na Ljubljanskem barju. Nekoliko različni končni datumi so lahko tudi posledica manjkajočih zunanjih delov lesenih elementov (manjkajoča ena ali več branik pod skorjo), zaradi obdelave, obrabe ali razkroja lesa.

Zaradi časovnega razpona razpoložljivih referenčnih kronologij smo lahko ugotovili samo datume poseka lesa oz. postavitve konstrukcij znotraj obdobja 2659–2366 pr. Kr., lesa, morebiti posekanega pred ali po omenjenem obdobju, pa na ta način nismo mogli prepoznati oz. datirati, ker za obdobje neposredno pred letom 2659 in po letu 2366 pr. Kr. nimamo referenčnih kronologij.

Izbor lesnih vrst na kolišču Špica, kjer je najpogostejša vrsta jesenovina in nato hrastovina, je podoben kot na koliščih iz 3. tisočletja pr. Kr., Parte-Iščica, Parte, Založnica in Dušanovo (npr. Velušček et al., 2000; Čufar & Velušček, 2012, 2025; Čufar et al., 2022).

Dendrokronološke analize na Špici so potrdile kronološko sočasnost s kolišči Parte in Založnica, ki sta opredeljeni v okvir ljubljanske kulture (Leghissa, 2021 in tam citirana literatura). V okvir slednje kulture so opredeljene tudi najdbe, predvsem z drugega Dežmanovega kolišča pri Igu (Leghissa, 2017, 2021). Zaenkrat so dendrokronološke analize na izbranih delih raziskanega območja Špice pokazale, da so gradbene aktivnosti zaznane v časovnem okvirju med leti 2522 in 2406 pr. Kr., kar zajame obdobje 116 let med posekom najstarejšega in najmlajšega datiranega kola. Tak časovni razpon predstavlja enega najdaljših dokumentiranih časovnih razponov gradbenih posegov na kolišču na Ljubljanskem barju. Do sedaj je bilo najdaljše dokumentirano obdobje gradbenih aktivnosti zabeleženo na kolišču Založnica, kjer je znašalo približno 80–90 let (Velušček & Čufar, 2003), vendar najnovejše datiranje kronologije ZALFRSP2 nakazuje daljši, to je 140 let dolg razpon gradbenih aktivnosti (slika 9). Na večini drugih kolišč so zabeležili gradbene aktivnosti v krajšem obdobju, npr. 60 ali 20 let ali manj, kar je lahko tudi posledica relativno majhnega raziskanega območja (Velušček & Čufar, 2014). Dolgo obdobje gradbenih aktivnosti na Špici lahko nakazuje tudi popravila ali obstoj več poselitvenih faz istega območja, kar smo zabeležili tudi na terenu (slika 8). Glede na to, da je bilo izkopno polje na Špici razmeroma veliko, tudi to povečuje verjetnost za najdbo kolov iz daljšega časovnega obdobja.

Predstavljene raziskave lesa dopolnjujejo in pojasnjujejo ugotovitve nedavnih raziskav keramike in drugih arheoloških najdb s Špice (Leghissa, 2024 in v pripravi), čeprav moramo poudariti, da naša študija še zdaleč ni izkoristila celotnega raziskovalnega potenciala arheološkega lesa s Špice.

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REFERENCES
VIRI

Andrič, M., Verbič, T., Lomax, J., & Tolar, T. (2017). Človekov vpliv na okolje v prazgodovini: primer z obrežja Ljubljanice pri Špici (Ljubljana) = Embankment of the Ljubljanica River at Špica (Ljubljana) and human impact on the environment in late prehistory. Arheološki vestnik, 68: 479–498.

Baxter, M. J., Beardah, C. C., & Wright, R. V. S. (1997). Some archaeological applications of kernel density estimates. Journal of Archaeological Science, 24(4), 347–354. DOI: https://doi.org/10.1006/jasc.1996.0119

Bonnier, A., Finné, M., & Weiberg, E. (2019). Examining land-use through GIS-based kernel density estimation: A re-evaluation of legacy data from the Berbati-Limnes survey. Journal of Field Archaeology, 44(2), 70–83. DOI: https://doi.org/10.1080/00934690.2019.1570481

Čufar, K., Levanič, T., & Velušček, A. (1997). Dendrokronološke raziskave na kolišču Založnica in Parte = Dendrochronological investigations in the pile dwellings Založnica and Parte from the Ljubljana moor. Arheološki vestnik, 48: 15–26.

Čufar, K., Levanič, T., & Velušček, A. (1999). Dendrokronološke raziskave na kolišču Parte–Iščica, Ljubljansko barje, Slovenija = Dendrochronological investigations in the pile dwelling Parte–Iščica, Ljubljana moor, Slovenia. Zbornik gozdarstva in lesarstva, 58: 165–188.

Čufar, K., & Velušček, A. (2003). Dendrokronološke raziskave na Založnici–najmlajši znani bakrenodobni koliščarski naselbini na Ljubljanskem barju. Zbornik gozdarstva in lesarstva, 71: 137–158.

Čufar, K., & Velušček, A. (2004). Dendrokronološke raziskave na koliščarski naselbini Hočevarica = Dendrochronological research of the Hočevarica pile dwelling settlement. In: Velušček, A. (ed.), *Hočevarica: eneolitsko kolišče na Ljubljanskem barju = an eneolithic pile dwelling in the Ljubljansko barje*, (Opera Instituti archaeologici Sloveniae, 8). Ljubljana: Inštitut za arheologijo ZRC SAZU: = Institute of archaeology at ZRC SAZU: Založba ZRC: = ZRC Publishing, 274–280.

Čufar, K., Tegel, W., Merela, M., Kromer, B., & Velušček, A. (2015). Eneolithic pile dwellings south of the Alps precisely dated with tree-ring chronologies from the north. Dendrochronologia, 35, 91–98. DOI: https://doi.org/10.1016/j.dendro.2015.07.005

Čufar, K., & Velušček, A. (2012). Les s koliščarskih naselbin na Ljubljanskem barju in njegov raziskovalni potencial. Les, 64 (3-4): 49–56.

Čufar, K., Merela, M., Krže, L., & Velušček, A. (2022). Dendrochronology and absolute dating of pile-dwellings on Ljubljansko Barje. Les/Wood, 71(1): 57–70. DOI: https://doi.org/10.26614/les-wood.2022.v71n01a06

Gaspari, A. (2012). Zgodovinski pregled in perspektiva podvodnega arheološkega raziskovanja v Sloveniji, v: A. Gaspari in M. Erič (ur.), *Potopljena preteklost: arheologija vodnih okolij in raziskovanje podvodne kulturne dediščine v Sloveniji: zbornik ob 128-letnici Dežmanovih raziskav Ljubljanice na Vrhniki (1884–2012)*, Radovljica, 13–72.

Harej, Z. (1978). Kolišče v Partih pri Igu na Ljubljanskem barju. – Poročilo o raziskovanju neolita in eneolita v Sloveniji 6, 61–94.

Harej, Z. (1981-1982). Kolišče v Partih pri Igu na Ljubljanskem barju–Raziskovanja 1978. in 1979. leta. – Poročilo o raziskovanju neolita in eneolita v Sloveniji 9-10, 31–99.

Harej, Z. (1987). Kolišče v Partih pri Igu na Ljubljanskem barju – raziskovanja leta 1981. – Poročilo o raziskovanju neolita in eneolita v Sloveniji 15, 141–193.

Jančar, M. (2016). Lesene stavbne ostaline na arheološkem najdišču Špica. Diplomsko delo. Oddelek za arheologijo, Filozofska fakulteta Univerze v Ljubljani.

Klasinc, R., Ravnik, M., Kusetič, J., Jančar, M., & Vučković, S. (2010). Poročilo o zaščitnih arheoloških izkopavanjih na najdišču Špica. – Neobjavljeno poročilo, Kranj 2010.

Leghissa, E. (2017). Dežmanova kolišča pri Igu in njihovo mesto v pozni bakreni in zgodnji bronasti dobi (The Dežman (Deschmann) pile dwellings near Ig in the Late Copper and Early Bronze ages). PhD thesis / Doktorsko delo. Oddelek za arheologijo, Filozofska fakulteta Univerze v Ljubljani.

Leghissa, E. (2021). Deschmann's pile-dwelling sites near Ig and the cultural-chronological attribution of the Late Copper Age Ljubljana culture / Kulturna in časovna umestitev poznobakrenodobne ljubljanske kulture na Dežmanovih koliščih pri Igu. Arheološki vestnik 72, 7–52. DOI: https://doi.org/10.3986/AV.72.01

Leghissa, E. (2024). The re-definition of Ljubljana culture in Ljubljansko barje: from a chrono-typological point of the ceramic finds. Proceedings of the international conference The Transformation of Europe in the Third Millennium BC, part 1 (in print).

Lozić, E., & Štular, B. (2024). Archaeological LiDAR in Mediterranean Karst landscapes. A multiproxy dating method for archaeological landscape and a case study from prehistoric Kras plateau (Slovenia). Archaeological Prospection. DOI: https://doi.org/10.1002/arp.1954

Novšak, M., Verbič, T., & Erjavec, R. (2009). Arheološko vrednotenje vrtin na lokaciji Špica in brežina Gruberjevega nabrežja s pristaniščem.–*Terensko poročilo*, Ljubljana. (Arhiv najdišča, hrani Muzej in galerije mesta Ljubljane).

Out, W. A., Hänninen, K., Merela, M., Velušček, A., Vermeeren, C., & Čufar, K. (2023a). Evidence of woodland management at the Eneolithic pile dwellings (3700–2400 BCE) in the Ljubljansko Barje, Slovenia Plants, 12, 291. DOI: https://doi.org/10.3390/plants12020291

Out, W. A., Hänninen, K., Merela, M., Velušček, A., Vermeeren, C., & Čufar, K. (2022). Woodland management at the pile dwellings in the Ljubljansko barje: research data. URL: https://repozitorij.uni-lj.si/IzpisGradiva.php?lang=slv&id=142470 (25. Okt. 2024)

Šinkovec, I. (1995). Katalog posameznih kovinskih najdb bakrene in bronaste dobe. – V: B. Teržan (ur.), Depojske in posamezne kovinske najdbe bakrene in bronaste dobe na Slovenskem I / Hoards and individual metal finds from the Eneolithic and Bronze Ages in Slovenia I. – Katalogi in monografije 29, 29–127.

Šinkovec, I. (2012). Kolišče na Špici v Ljubljani. – v: Andrej Gaspari, Miran Erič (ur.), *Potopljena preteklost. Arheologija vodnih okolij in raziskovanje podvodne kulturne dediščine v Sloveniji*, Radovljica, str. 251–258.

Velušček, A., Čufar, K., & Levanič, T. (2000). Parte-Iščica, arheološke in dendrokronološke raziskave. Arheološki vestnik, 51: 83-107.

Velušček, A., & Čufar, K. (2025). Pile-Dwellings at Ljubljansko Barje, Slovenia – 25 Years of Dendrochronology. In Ballmer, A., Hafner, A., Tinner, W. (eds.) Prehistoric Wetland Sites of Southern Europe. Natural Sciences in Archaeology, Springer Cham., 221–231. DOI: https://doi.org/10.1007/978-3-031-52780-7_13