

*K. JERBIĆ, L. SHINDO, A. FERREIRA DOMÍNGUEZ,
E. ARAGÓN NÚÑEZ, I. KONCANI UHAČ,
J. BENJAMIN*



PROCJENA DENDROKRONOLOŠKOG POTENCIJALA POTOPLJENOG PRAPOVIJESNOG SOJENIČKOG NASELJA U UVALI ZAMBRATIJA U ŠIREM KONTEKSTU PRAPOVIJESNIH SOJENICA U HRVATSKOJ

AN ASSESSMENT OF THE DENDROCHRONOLOGICAL POTENTIAL ON THE SUBMERGED PREHISTORIC PILE-DWELLING IN ZAMBRATIJA BAY WITHIN THE WIDER CONTEXT OF PREHISTORIC PILE-DWELLINGS IN CROATIA

dr. sc. Katarina Jerbić
Flinders University, College of Humanities, Arts and Social
Sciences, Adelaide, South Australia, Australia
University of Bern, Faculty of Philosophy and History, Institute of
Archaeological Sciences, Switzerland
katarina.jerbic@unibe.ch

dr. sc. Lisa Shindo
University of Bern, Faculty of Philosophy and History, Institute of
Archaeological Sciences, Switzerland
Service archéologique de Nice Côte d'Azur, France
shindo.lisa@gmail.com

dr. sc. Alba Ferreira Domínguez
Aix Marseille Université, CNRS, Centre Camille Jullian, Aix-en-
Provence, France
albaferreiradominguez@gmail.com

dr. sc. Enrique Aragón Núñez
Flinders University, College of Humanities, Arts and Social
Sciences, Adelaide, South Australia, Australia
The University of Almeria, Spain
enrique.aragon@ual.es

dr. sc. Ida Koncani Uhač
Arheološki muzej Istre, Pula, Hrvatska
ida.koncani-uhac@ami-pula.hr

dr. sc. Jonathan Benjamin
Flinders University, College of Humanities, Arts and Social
Sciences, Adelaide, South Australia, Australia
jonathan.benjamin@flinders.edu.au

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Katarina Jerbić PhD
Flinders University, College of Humanities, Arts and Social
Sciences, Adelaide, South Australia, Australia
University of Bern, Faculty of Philosophy and History, Institute
of Archaeological Sciences, Switzerland
katarina.jerbic@unibe.ch

Lisa Shindo PhD
University of Bern, Faculty of Philosophy and History, Institute
of Archaeological Sciences, Switzerland
Service archéologique de Nice Côte d'Azur, France
shindo.lisa@gmail.com

Alba Ferreira Domínguez PhD
Aix Marseille Université, CNRS, Centre Camille Jullian, Aix-
en-Provence, France
albaferreiradominguez@gmail.com

Enrique Aragón Núñez PhD
Flinders University, College of Humanities, Arts and Social
Sciences, Adelaide, South Australia, Australia
The University of Almeria, Spain
enrique.aragon@ual.es

Ida Koncani Uhač PhD
Archaeological Museum of Istria, Pula, Croatia
ida.koncani-uhac@ami-pula.hr

Jonathan Benjamin PhD
Flinders University, College of Humanities, Arts and Social
Sciences, Adelaide, South Australia, Australia
jonathan.benjamin@flinders.edu.au

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Na dubini od tri metra u sjevernojadranskoj uvali Zambratija podvodni su arheolozi zabilježili postojanje više od 120 drvenih pilota i ostale nalaze koji potječu iz potopljenog naselja, datiranog u razdoblje kasnog neolitika do ranog brončanog doba. Radi se o dobro očuvanom tresetištu koje pokriva dio morskog dna u potopljenoj kraškoj vrtači. Od arheoloških nalaza pronađene su tipološki određiva keramika i kamene alatke. Ovaj rad predstavlja izvorne rezultate ciljane arheološke i dendrokronološke procjene nalazišta iz 2017. te daje pregled arheoloških nalaza u njihovu širem regionalnom kontekstu. Rezultati uključuju 62-godišnju plivajuću dendrokronološku sekvencu usklađenu metodom wiggle-matching, koja datira pronađenu prapovijesnu arhitekturu na lokalitetu između 4041. i 3934. godine pr. Kr. (s vjerojatnošću od 95,4%). U kombinaciji s dokazima o drugim prapovijesnim sojenicama u Hrvatskoj, rezultati iz uvale Zambratija sugeriraju potrebu za revizijom zemljopisnog širenja fenomena europskih prapovijesnih sojenica, što je predmet rasprave u europskoj arheologiji od 19. stoljeća.

KLJUČNE RIJEČI: dendrokronologija; prapovijesne sojenice; potopljena prapovijest

At the site of Zambratija Bay in the northern Adriatic Sea, underwater archaeologists recorded over 120 wooden piles and material culture from a Late Neolithic to early Bronze Age submerged settlement at a depth of three metres under water. Situated in a sunken karstic depression off the Croatian coast, the seabed was partly covered with a well-preserved peat bed. Archaeological material included typologically identifiable ceramic and stone tool artefacts. This article presents original results derived from a 2017 targeted archaeological and dendrochronological assessment of the site and reviews the archaeological findings in their wider regional context. Results include a wiggle-matched 62-year floating dendrochronological sequence of the found prehistoric architecture dating the site to 4041-3934 cal BC (95.4% probability). Combined with evidence on other prehistoric pile-dwellings in Croatia, the results from Zambratija Bay suggest a need to revise the geographical expansion of the European Prehistoric Pile Dwellings phenomenon, which has been a topic of debate in European archaeology since the 19th century.

KEY WORDS: dendrochronology; prehistoric pile-dwellings; submerged Prehistory

UVOD

U sklopu zaštitnog arheološkog pregleda provedenog 2008. godine (Koncani Uhač 2008, 2009) u uvali Zambratija u sjevernoj Hrvatskoj, otkriveni su na -2,4 do -3,1 m dubine drveni ostaci potopljenog prapovijesnog sojeničkog naselja. Nalazi na morskom dnu isprva su opisani kao okomito postavljeni ili zabijeni drveni piloti, smješteni u blizini i oko platforme od organskog treseta te okruženi raspršenim prapovijesnim artefaktima. U ovoj uvali otkrivena su još dva podvodna arheološka lokaliteta iz kasnijih razdoblja; ostaci drvenog brončanodobnog šivanog broda, nalaz koji je izazvao značajnu pozornost (Koncani Uhač i Uhač 2012; Koncani Uhač i sur. 2017a, 2019; Boetto i sur. 2015), te potopljeni nasip izgrađen u rimskom razdoblju (Koncani Uhač 2019). Pronađeni arheološki nalazi i ostaci arhitekture ukazuju na sličnosti između ovog potopljenog nalazišta i prapovijesnih sojenica oko alpskih jezera (Menotti 2004c; Hafner 2014).

U nastavku predstavljamo usporedno istraživanje rezultata s podacima dobivenim iz terenskog rada i laboratorijskih istraživanja provedenih između 2017. i 2022. Također, razmatramo druge potvrđene prapovijesne sojenice u Hrvatskoj, a koje se sve nalaze unutar područja koje na postojećoj karti prapovijesne Europe karakterizira evidentni manjak sojeničarskih naselja.

ISTRAŽIVANJE NALAZIŠTA OD 2008. DO 2015.

Između 2008. i 2015. godine na lokalitetu je provedeno nekoliko manjih istraživanja, uključujući pregled uz pomoć *multi-beama* (*višesopnog sonara*) te probna arheološka iskapanja (Benjamin i sur. 2011; Koncani Uhač i Čuka 2015; Koncani Uhač i Čuka 2018). Do sada je nađeno više od 120 drvenih stupova, od kojih su neki vidljivi na površini morskog dna, a neki su snimljeni tijekom iskopavanja nakon otklanjanja površinskog sloja. Oko tresetne platforme zabilježeni su i ulomci kućnog lijepa, tako da se drveni piloti tumače kao elementi arhitekture (Koncani Uhač i Čuka 2015). Rezultati *multi-beam* pregleda podmorja ukazuju da se ovo potopljeno nalazište nalazi na rubu prirodne kraške vrtače (sl. 1). Postojanje tresetne platforme upućuje na postojanje slatkovodnog ili bočatog okoliša prije prodora mora. Platforma je ugrubo pravokutnog oblika te se prostire po plitkim sjeverozapadnim rubovima potopljene vrtače i pokriva površinu od oko 30 × 67 m, orijentirano otprilike u smjeru sjeveroistok-jugozapad.

INTRODUCTION

Wooden remains of a submerged prehistoric settlement were found at 2.4 – 3.1 metres below mean sea level (MSL) in Zambratija Bay, northern Croatia, during a pre-development archaeological survey in 2008 (Koncani Uhač 2008, 2009). The features on the seabed were initially described as vertically placed or driven wooden piles positioned near and around a platform of organic peat and surrounded by scatters of prehistoric artefacts. Two other underwater archaeological sites from later periods were found in the Bay: the remains of a Bronze Age wooden sewn boat which garnered significant attention (Koncani Uhač and Uhač 2012, Koncani Uhač et al. 2017a, 2019, Boetto et al. 2015), and a submerged embankment built in the period of Roman Antiquity (Koncani Uhač 2019). A review of material culture and architecture indicates that the submerged site demonstrates similarities to the prehistoric pile-dwellings around the Alpine lakes (Menotti 2004c, Hafner 2014).

Below we present comparative research of the results with data derived from original fieldwork and lab-based research conducted between 2017 and 2022. We also discuss other confirmed prehistoric pile-dwellings in Croatia, all of which are positioned within an evident 'pile-dwelling gap' on the current European prehistoric map.

RESEARCH ON THE SITE BETWEEN 2008 AND 2015

A few small-scale investigations were conducted on the site between 2008 and 2015, including a multi-beam survey and test excavations (Benjamin et al. 2011, Koncani Uhač and Čuka 2015, Koncani Uhač and Čuka 2018). More than 120 wooden piles have now been identified, either protruding vertically from the seabed, or recorded during excavation. Clay plaster fragments were recorded around the peat platform which, together with the architectural distribution of the wooden piles, have been interpreted to represent architectural components (Koncani Uhač and Čuka 2015). A multi-beam sonar survey of the seabed showed that the submerged site lies on the outskirts of a natural karstic depression (Fig. 1). The peat platform indicates that a freshwater or brackish environment existed there prior to marine transgression. The peat forms a broadly rectangular shape, spreads across the north-western shallow edges around the submerged sinkhole and covers an area approximately 30 x 67 m, oriented roughly northeast-southwest.

Prvotni su podaci upućivali na postojanje naselja oko 4200. godine pr., tijekom prijelaza iz neolitika u bakreno doba na istarskom poluotoku (sl. 2, sl. 3), te da se na tom području možda povremeno obitavalo sve do kasnog brončanog doba (Koncani Uhač i Čuka 2015). Koncani Uhač i Čuka (Koncani Uhač i Čuka 2015) donose podatak da je s nalazišta prikupljeno ukupno 727 ulomaka keramike, što uključuje površinske nalaze i materijal iz iskopanih sondi. Za 294 ulomka se utvrdilo da su dijelovi posuda, među kojima su nalazi oboda i ručki. Od toga je 29 ulomaka pouzdano pripisano poznatim prapovijesnim kompleksima na istarskom poluotoku, u rasponu od kasnog neolitika/ranog bakrenog doba do brončanog doba (Koncani Uhač i Čuka 2015). Ovdje utvrđena starost materijalne kulture temelji se na usporedbi ulomaka iz Zambratije s tipološkim sličnostima nađenim na drugim arheološkim nalazištima, gdje su stratigrafski zatvoreni konteksti i pouzdane radiokarbonske determinacije dali sigurne datume (Buršić-Matijašić 1994; Vitasović 1999; Zlatunić 2019; Forenbaher i Kaiser 2006). Te su korelacije temeljene na pregledu literature o arheološkim istraživanjima na istarskom poluotoku, posebice za razdoblja kasnog neolitika, bakrenog i brončanog doba, koja obuhvaćaju period između 4252. godine pr. Kr. (Forenbaher i sur. 2013; Jerbić Percan 2011) i 901. godine pr. Kr. (Hänsel i sur. 2005).

Dio nalaza keramike iz Zambratije iz kontekstualiziranih slojeva u sondama 1 i 5 pokazuje sličnost s prepoznatljivim nakovanskim stilom. Na istarskom poluotoku keramika nakovanskog stila nalazi se u kontekstualiziranim slojevima koji pokrivaju radiokarbonski raspon starosti između 4252. do 4048. godine pr. Kr. te 3959. do 3797. godine pr. Kr. (Forenbaher i sur. 2013). Zajedno s prvim datumom od 4230. do 3980. godine pr. Kr., nakovanska keramika ukazuje na početak naseljavanja potopljenog naselja u ranom bakrenom dobu. Među ostalim zabilježenim tragovima materijalne kulture još je i 45 cijepanih kremenih alatki pronađenih u sondi 5 (Koncani Uhač i sur. 2017b), kao i žrvnjevi te brusni kameni razbacani po morskom dnu, koji su za sada još neobjavljeni. Drugi značajni arheološki nalazi uključuju ostatke kopnene i vodene faune i botaničke ostatke, koji također zahtijevaju daljnju analizu (Koncani Uhač i Čuka 2015; Koncani Uhač i sur. 2017b).

Jedna trokutasta ručka keramičke posude nađena je na površini morskog dna te je na temelju tipologije pripisana brončanom dobu (Koncani Uhač i Čuka 2015). Taj je predmet, nađen izvan kulturnog ili kronološkog konteksta, manje pouzdan od artefakata iz stratificiranih

The initial data suggested that the settlement existed around 4200 cal BC during the Neolithic – Copper Age transition on the Istrian Peninsula (Fig. 2, Fig. 3), and the area has potentially been used intermittently until as late as Late Bronze Age (Koncani Uhač and Čuka 2015). According to Koncani Uhač and Čuka (Koncani Uhač and Čuka 2015) a total of 727 ceramic fragments were collected from the site which included surface finds and material from the excavation trenches. 294 fragments were determined to be parts of vessels, including rims and handles. Of those, 29 fragments were confidently attributed to known prehistoric complexes in the Istrian Peninsula, ranging from the Late Neolithic/Early Copper Age to the Bronze Age (Koncani Uhač and Čuka 2015). The age of material culture determined here was presumed by comparative correlation of the Zambratija fragments to typological similarities found at other archaeological sites, where stratigraphically closed contexts and reliable radiocarbon determinations provided secure dates (Buršić-Matijašić 1994, Vitasović 1999, Zlatunić 2019, Forenbaher and Kaiser 2006). These correlations were drawn through a review of literature regarding archaeological research on the Istrian Peninsula particularly of the Late Neolithic, Copper Age and Bronze Age range on the Istrian Peninsula which spans between 4252 cal BC (Forenbaher et al. 2013, Jerbić Percan 2011) and 901 cal BC (Hänsel et al. 2005).

A part of the Zambratija ceramic assemblage from contextualised layers in trenches 1 and 5 show a resemblance to a recognisable Nakovana style. On the Istrian Peninsula, Nakovana-style pottery is found in contextualised layers covering a radiocarbon age range between 4252–4048 and 3959–3797 cal BC (Forenbaher et al. 2013). Together with the 4230–3980 cal BC radiocarbon date from Zambratija, Nakovana-style ceramics set the beginning of occupation of the submerged settlement to the Early Copper Age. Further traces of material culture, such as 45 knapped flint tools excavated from Trench 5 (Koncani Uhač et al. 2017b), grinding stones and whetstones scattered around the seabed were also recorded, though these remain unpublished. Other archaeologically significant finds included terrestrial and aquatic faunal remains and botanical remains, which also require further analysis (Koncani Uhač and Čuka 2015; Koncani Uhač et al. 2017b).

A single ceramic triangular handle was found on the seabed surface, typologically attributed to the Bronze Age (Koncani Uhač and Čuka 2015). Since that object was out of cultural or chronological context, it is less reliable than artefacts from stratified layers, but it should

slojeva, no ipak ga treba uzeti u obzir. Pet ulomaka perforiranih lijevaka nađeno je unutar stratigrafskih slojeva. Posude ove vrste, koje se obično povezuju s proizvodnjom mliječnih prerađevina i stoga smatraju pokazateljima naseljenosti, nalaze se u brončanodobnim slojevima duž istočne obale Jadrana (Zlatunić 2019; Komšo 2008). Ti ulomci u Zambratiji pružaju izravne ili neizravne dokaze o kulturnom kontinuitetu, što se može potkrijepiti i spomenutim otkrićem brončanodobnog šivanog broda, udaljenog otprilike 50 metara od naselja. Uzorci s broda dali su datum u rasponu od 1120. do 930. godine pr. Kr. (Koncani Uhač i Uhač 2012; Boetto i sur. 2015; Koncani Uhač i sur. 2017a). Obilje keramike s metličastim ukrasom, što se smatra odlikom one korištene za vrijeme šireg raspona, od neolitika do brončanog doba (Čović 1983; Petrić 1979; Buršić-Matijašić 1994), također ukazuje na neprekinuti kronološki slijed.

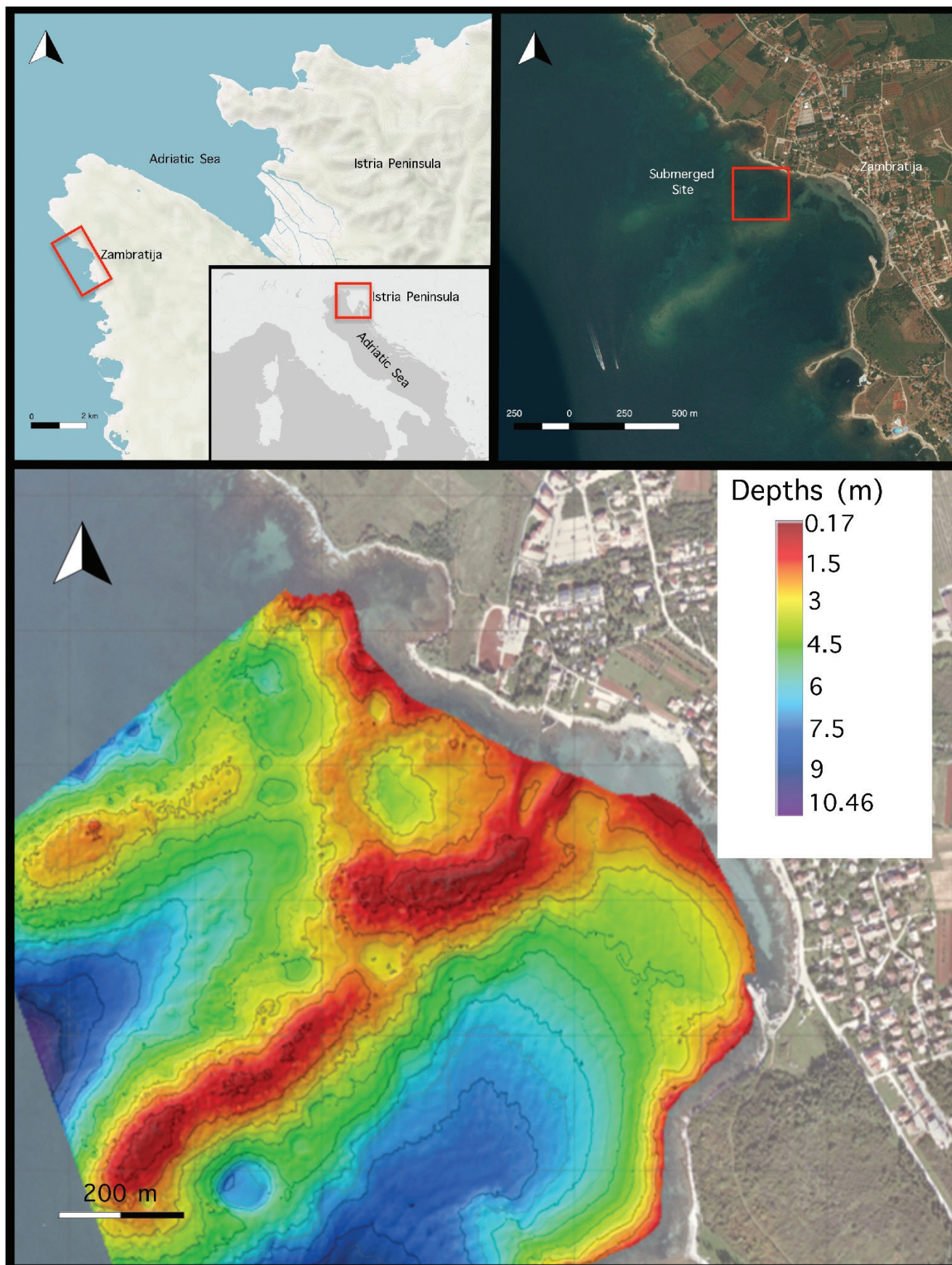
Zambratija se razlikuje od ostalih suvremenih naselja na Jadranu – naime, za neolitik i bakreno doba na tom su području tipične pećine i lokaliteti na otvorenom, a u brončanom dobu gradinska naselja (Buršić-Matijašić 2012). U vrijeme otkrića nalazište u Zambratiji bilo je jedinstveno i po morskom kontekstu. Među brončanodobnim nalazištima na istarskom poluotoku nalazimo megalitičke utvrđene građevine smještene na vrhovima brežuljaka, s grobljima u blizini, što ukazuje na složeni društveni ustroj (Buršić-Matijašić 1998; Buršić-Matijašić i Žerić 2013). Od prapovijesnih utvrda, Zambratiji je najbliža Romanija; gradinsko naselje branjeno trima redovima suhozidnih bedema, s nalazima keramike i brončanog koplja koji su tipološki pripisani brončanom i željeznom dobu. Radiokarbonskih podataka nema jer je nalazište uništeno 1936. godine zbog gradnje vodospreme. Položaj je korišten kao utvrđeno mjesto za vrijeme Drugog svjetskog rata, a godine 1970. tu je izgrađena druga vodosprema (Buršić-Matijašić 2007; Marchesetti 1903).

Prisutnost značajne količine ostataka drvenih arhitektonskih elemenata pružila je priliku za daljnje istraživanje veza s alpskim jezerskim naseljima i prikupljanje uzoraka drva za preliminarnu dendrokronološku procjenu. U tu svrhu je u Zambratiji 2017. proveden mali projekt prikupljanja uzoraka drva s ciljem procjene je li lokacija prikladna za mjerenje godina. Rezultati i interpretacije proizašle iz tog projekta, predstavljeni u ovom radu, predstavljaju jedinstvenu i novu priliku za ciljanu dendrokronološku procjenu kakvih je do sada bilo vrlo malo na arheološkim nalazištima u Hrvatskoj (Durman i sur. 2009; Ferreira

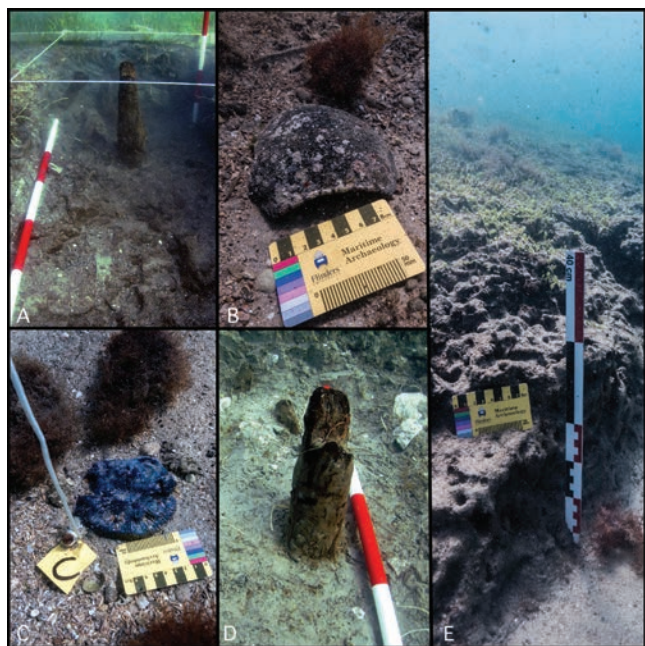
nevertheless be considered. Five fragments of perforated funnels were found in stratigraphical layers. These types of vessels, which are usually associated with production of dairy products and therefore considered indicators of settlements, are found in Bronze Age layers along the Eastern Adriatic Coast (Zlatunić 2019; Komšo 2008). These fragments indicate direct or indirect evidence of cultural continuity in Zambratija, which can also be supported with the aforementioned discovery of a Bronze Age sewn boat, some 50 metres from the settlement. Samples taken from the boat yielded a radiocarbon date range between 1120–930 cal BC (Koncani Uhač and Uhač 2012; Boetto et al. 2015, Koncani Uhač et al. 2017a). The abundance of brushed surface pottery, considered to be a pottery feature which was used within the wider prehistoric timeframe from the Neolithic to the Bronze Age (Čović 1983; Petrić 1979; Buršić-Matijašić 1994), also indicates a chronological continuity.

Traditionally, the occupational sites from the Neolithic and Copper Ages in the Adriatic are represented by caves and open-air sites, and hillforts during the Bronze Age (Buršić-Matijašić 2012), distinguishing Zambratija from other contemporary settlement sites in the Adriatic. The site at Zambratija was also, at the time of discovery, unique for its maritime context. On the Istrian Peninsula, Bronze Age settlements included megalithic fortified structures on hilltops, with nearby graveyards that indicate complex social structures (Buršić-Matijašić 1998; Buršić-Matijašić and Žerić 2013). The nearest prehistoric fortification to Zambratija is Romanija, a hillfort protected by three layers of drywall, with findings of pottery and a bronze spear typologically attributed to Bronze and Iron Ages. There are no radiocarbon determinations due to it being destroyed in 1936 for construction of a water reservoir. The hillfort was also later used as a fortification during WW2 and finally in 1970 a second water reservoir was built there (Buršić-Matijašić 2007; Marchesetti 1903).

The presence of a significant number of examples of wooden architectural remains provided an opportunity to further investigate connections with Alpine lake-dwelling settlements and collect wooden samples for a preliminary dendrochronological assessment. A small-scale wooden sample collection campaign was performed in Zambratija in 2017 with the aim to assess whether the site is suitable for an in-depth tree-ring study. Results and interpretations derived from the campaign represent a unique and novel opportunity for a targeted dendrochronological assessment, which there have been very few on archaeological sites in Croatia thus far (Durman et al. 2009; Ferreira Domínguez et al. 2018; Čufar et al. 2014; Čufar et al. 2008a), are



Sl. 1 Gore: položaj uvala Zambratija u Jadranskom moru. Dolje: grafički prikaz pregleda multi-beamom. Izradio: E. Aragón Núñez.
Fig. 1 Above: The position of Zambratija Bay in the Adriatic Sea. Below: the multi beam survey imagery. Figure by: E. Aragón Núñez.



Sl. 2 A: Podvodna sonda istražena 2008. godine. B: Prapovijesna keramika na morskom dnu. C: Drveni pilot viri iz morskog dna. D: Drveni pilot u sondi. E: Tresetna platforma. Fotografije: I. Koncani Uhač i J. Benjamin.

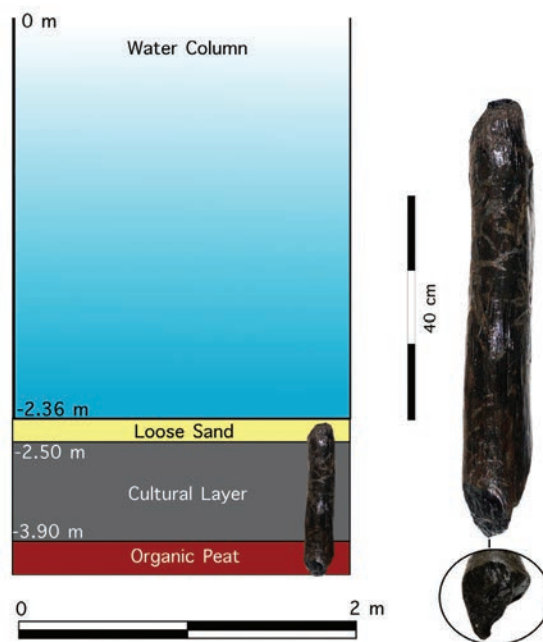
Fig. 2 A: An underwater trench from 2008. B: Prehistoric pottery on the seabed. C: A pile protruding from the seabed. D: A pile in a trench. E: The peat platform. Photos by: I. Koncani Uhač and J. Benjamin.

Domínguez i sur. 2018; Čufar i sur. 2014; Čufar i sur. 2008a). Kako bismo kontekstualizirali raspravu i nova otkrića u Zambratiji, najprije ćemo ukratko predstaviti fenomen *Pfahlbautena* i time dati povijesnu pozadinu.

FENOMEN PRAPOVIJESNIH ALPSKIH SOJENICA: DVJESTO GODINA RASPRAVE

Fenomen srednjoeuropskih sojenica izvor je gotovo dvostoljetne akademske rasprave. Drveni piloti (zabijeni stupovi) primijećeni su 1854. godine kako vire iz dna švicarskog jezera Zürich kada se razina vode spustila uslijed ekstremne zime. Ubrzo se pokazalo da se radi o ostacima prapovijesnog naselja (Koncani Uhač i Čuka 2015; Benjamin i sur. 2011) što je izazvalo međunarodnu senzaciju. Bilo je to nadahnuće mnogim suvremenim proučavateljima starina u susjednim alpskim zemljama, koji su s vremenom otkrili stotine slično očuvanih nastambi iz vremenskog raspona od neolitika do željeznog doba. Ta je lančana reakcija proizvela takozvani *Pfahlbaufieber* fenomen, koji se može smatrati prvom teoretskom raspravom u europskoj arheologiji (Menotti 2001).

Izvanrednu univerzalnu vrijednost prapovijesnih alpskih sojenica prepoznao je UNESCO, koji ih je



Sl. 3 Lijevo: shematski prikaz sonde 1, istražene 2008. godine. Kulturni sloj sadržavao je keramiku tipološki datiranu u razdoblje od kasnog neolitika do bronzanog doba te drveni pilot za koji je radiokarbonskom analizom dobiven datum u rasponu od 4230. do 3984. godine pr. Kr. Taj je datum prvi put objavljen 2015. godine (Koncani Uhač i Čuka 2015) kao 5260 ± 30 godine prije sadašnjosti, kalibrirano u rasponu od 4230. do 3980. godine pr. Kr. Autori su na ovaj radiokarbonski datum primijenili najnoviju inačicu kalibracijske krivulje OxCal 4.4 IntCal20 (<https://c14.arch.ox.ac.uk/oxcal/OxCal.html>) za sjevernu polutku (Reimer i sur. 2020).

Desno: Drveni pilot iz sonde 1. Pilot je konzervatorski obrađen u cilju izlaganja u Arheološkom muzeju Istre. Izradili: E. Aragón Núñez i K. Jerbić.

Fig. 3 Left: A schematic representation of Unit 1 excavated in 2008. The cultural layer contained pottery typologically dated from the late Neolithic to the Bronze Age, as well as a wooden pile which revealed a 4230-3984 cal BC radiocarbon date range. This date was first published in 2015 (Koncani Uhač and Čuka 2015) as 5260 ± 30 BP calibrated to 4230-3980 cal BC. Authors had run the Radiocarbon date through the most recent OxCal 4.4 IntCal20 calibration curve (<https://c14.arch.ox.ac.uk/oxcal/OxCal.html>) for the Northern Hemisphere (Reimer et al. 2020).

Right: The wooden pile from Unit 1. This was processed for conservation for the purposes of being displayed at the Archaeological Museum of Istria. Figure by: E. Aragón Núñez and K. Jerbić.

presented further in the article. To contextualise the discussion and the new findings at Zambratija, we will first briefly summarise the *Pfahlbauten* phenomenon to provide historical background.

THE PREHISTORIC ALPINE PILE-DWELLING PHENOMENON: TWO-HUNDRED YEARS OF DEBATE

The Central European pile-dwelling phenomenon has been a source of scholarly debate for nearly two centuries.

2011. uvrstio na na Popis svjetske baštine (Hafner 2014) (sl. 4, gore). Jedan od mnogih značajnih doprinosa proizašlih iz istraživanja sojenica jest razvoj europske dendrokronologije (Billamboz 2004). Do danas, uzorci drva iz potopljenih naselja u Alpama u južnoj Njemačkoj, Francuskoj i Švicarskoj pridonose s više od 100 tisuća pojedinačnih predmeta svjetskoj najdužoj postojećoj dendrokronološkoj sekvenci temeljenoj na hrastu, koja traje 12 500 godina, od 8480. godine pr. Kr. (Becker et al. 1985). Dendrokronološki sljedovi s ovih sjevernoalpskih nalazišta pokazuju da je fenomen obitavanja u sojenicama započeo u ranom neolitu, oko 4200. godine pr. Kr., a završio u željeznom dobu, oko 630. godine pr. Kr. Postojanje dugih sljedova godina rasta znači da ova kronologija ima apsolutnu kalendarsku točnost u rasponu od jedne godine (Königer 2015). Ova “isprekidana neprekidnost” boravka u sjevernoalpskim sojeničkim naseljima bilježi tri glavna razdoblja intenzivnog obitavanja, iza svakog od kojih je slijedilo potpuno napuštanje (Menotti 2004a). Još nema apsolutnih datuma

In 1854 at Lake Zürich, Switzerland, wooden piles were noticed protruding out of the lakebed which had been exposed when water levels lowered due to extreme winter conditions. It was soon discovered that these were the remains of a prehistoric settlement (Koncani Uhač and Čuka 2015; Benjamin et al. 2011). This discovery quickly avalanched into an international sensation, inspiring many contemporary antiquarians in neighbouring Alpine countries to eventually discover hundreds of similarly preserved dwellings, ranging from the Neolithic to the Iron Age. This chain reaction produced the so-called *Pfahlbaufieber*, which could be considered the first theoretical dispute in European archaeology (Menotti 2001).

The outstanding universal value of the prehistoric Alpine pile-dwellings was recognized by UNESCO when they were inscribed to the World Heritage list in 2011 (Hafner 2014) (Fig. 4, up). Amongst the many significant contributions of pile-dwelling research is the development of dendrochronology in Europe (Billamboz 2004). To date, wood samples from Alpine submerged settlements in Southern Germany, France and Switzerland contribute with more than 100 thousand individual items to the world's longest existing dendrochronological oak-based sequence of 12,500 years, an uninterrupted timeline from 8480 BC (Becker et al. 1985). Dendrochronological sequences from these northern Alpine sites show that the phenomenon of pile dwelling occupation started in the Early Neolithic, ca. 4200 BC and ended in the Iron Age ca. 630 BC. Because of the long tree-ring sequences, this chronology has an absolute calendrical one-year-accuracy (Königer 2015). This ‘discontinuous continuity’ in the northern Alpine pile-dwelling occupation is characterized by three main periods of intense occupation, all followed by total abandonment (Menotti 2004a). The chronologies of Southern Alpine dwellings in Eastern Austria and Northern Italy are not yet absolutely dated while some of Slovenia have been teleconnected and dated with the Northern dwellings (Čufar et al. 2015, 2023). Since the Alps are a natural (also climatic) boundary which affects the tree-ring signals, chronologies based on tree rings of oak trees growing on the opposite parts of the Alps are not always compatible for matching. The Southern Alpine floating tree-ring chronologies of the pile-dwellings there mostly rely on radiocarbon dates (Martinelli et al. 2011).

Although the Pfahlbauten phenomenon was originally considered predominantly an Alpine complex on the European continent, current research and subsequent re-evaluations suggest their cultural and architectural traits were represented more widely and new information has



Sl. 4 Gore: smještaj prapovijesnih sojeničkih naselja sjeverno (ljubičasto) i južno (žuto) od Alpa.

Dolje: uvala Zambratija u odnosu na druga poznata nalazišta sojeničkih naselja na istočnoj obali Jadrana. Izradio: E. Aragón Núñez.

Fig. 4 Up: The locations of the Prehistoric pile-dwellings north (purple) and south (yellow) of the Alps. Down: Zambratija Bay in relation to other known pile-dwelling sites on the eastern Adriatic coast. Figure by: E. Aragón Núñez.

u kronologiji južnoalpskih nastambi istočne Austrije i sjeverne Italije, dok su neki dijelovi Slovenije usklađeni uz pomoć *teleconnection* metode i datirani zajedno s naseljima na sjeveru (Čufar i sur. 2015, 2023). Budući da Alpe tvore prirodnu (i klimatsku) granicu koja utječe na signale godina, kronologije temeljene na godovima hrastova koji rastu na suprotnim stranama Alpa nisu uvijek prikladne za usporedbe podudarnosti. Južnoalpske plutajuće kronologije godina rasta tamošnjih sojenica uglavnom se oslanjaju na radiokarbonske datume (Martinelli i sur. 2011).

Iako se *Pfahlbauten* fenomen izvorno smatrao pretežno alpskim kompleksom unutar Europe, trenutna istraživanja i naknadne revizije upućuju na to da su te kulturne i arhitektonske značajke bile zastupljene šire, dok su nove informacije pokazale veliku koncentraciju sojenica na jugu Balkana i na europskom sjeveroistoku (Hafner i sur. 2021; Maczkowski i sur. 2021; Glagkoulis 2020; Hafner i sur. 2022; Flaux i sur. 2016; Marriner i sur. 2014; Prankenaitė i sur. 2021). Primjeri u središnjem i južnom Balkanu predstavljaju najnovija otkrića (Maczkowski i sur. 2021; Hafner i sur. 2021; Reich i sur. 2021). Europska prapovijesna sojenička naselja, uzevši u obzir prijašnja i novija otkrića, vidimo kao elemente prapovijesnih karata podložnih razvoju i stalnom ažuriranju, dok "praznine" između područja veće gustoće ovih naselja nisu nužno odraz prapovijesne stvarnosti (Mainberger i sur. 2022). Grupirani obrasci uzrokovani su relativnim manjkom istraživanja i ponekad istraživačkim pristranostima, arheološkim „potpisom“ i, najviše od svega, osjetljivošću očuvanja samog nalazišta, što je, kako se čini, slučaj i s istraživanjima prapovijesnih sojenica u Hrvatskoj, prikazanim u nastavku.

PROUČAVANJE PRAPOVIJESNIH SOJENICA U HRVATSKOJ: KRATKA POVIJEST

U vrijeme njegova otkrića sojeničko naselje kod Zambratije bilo je posebno zbog morskog konteksta, no tri nedavna otkrića ukazuju na mogućnost da bi moglo biti dijelom jedinstvenog jadranskog fenomena (sl. 4, dolje) s rijetkim usporedivim povijesnim primjerima [vidi moguće crnomorske usporedbe (Flaux i sur. 2016; Filipova-Marinova i sur. 2011; Draganov 1995)].

Najstarije od ovih novih otkrića je prapovijesno naselje u podmorju blizu plaže Janice u Pakoštanima kod Zadra. Prema Bekiću i sur. (Bekić i sur. 2015) nalazište se nalazi na dubinama od 5 do 6 m ispod srednje razine mora. U iskopnim jedinicama pronađena su četiri okomita

demonstrated a large concentration of pile-dwellings in both the southern Balkans and north-eastern Europe (Hafner et al. 2021, Maczkowski et al. 2021, Glagkoulis 2020, Hafner et al. 2022, Flaux et al. 2016, Marriner et al. 2014, Prankenaitė et al. 2021). The central and southern Balkan examples are most recent discoveries (Maczkowski et al. 2021, Hafner et al. 2021, Reich et al. 2021). With previous and new discoveries, European Prehistoric pile-dwellings are seen as a developing and constantly updated feature on prehistoric maps, and the 'empty spaces' between settlement clusters are not necessarily a reflection of prehistoric reality (Mainberger et al. 2022). The clustered patterns are caused by a relative lack of research and sometimes research bias, archaeological signature and most of all preservation vulnerability, all of which seems to also be the case with prehistoric pile-dwelling research in Croatia, presented below.

PREHISTORIC PILE-DWELLING RESEARCH IN CROATIA: A BRIEF HISTORY

At the time of initial discovery, the Zambratija pile-dwelling settlement was unique for its maritime nature, however three recent discoveries suggest that this site could be a part of a unique Adriatic phenomenon (Fig. 4, down) with rare comparable prehistoric examples [see possible comparisons from the Black Sea (Flaux et al. 2016, Filipova-Marinova et al. 2011, Draganov 1995)].

The oldest of these new discoveries includes a prehistoric settlement on the seabed of Janice Beach in Pakoštane near Zadar. According to Bekić et al. (Bekić et al. 2015), the site is located at a depth of 5–6 m below MSL and five wooden elements, four vertical piles and one horizontal plank, were found in the excavation units. An abundance of pottery and chert tools, three obsidian tools as well as one radiocarbon date from a wooden pile with an age range of 4681–4539 cal BC show that the site was in use during the Neolithic and Copper Age periods (Bekić et al. 2015).

Similarly, underwater investigations of the Šimuni harbour revealed what might be an in situ submerged Bronze Age settlement. At a depth of around 2–3 m below MSL, archaeologists found 40 wooden piles protruding out of the seabed, 10–30 cm in diameter and organised in a linear formation. A large number of prehistoric pottery sherds typologically attributed to the Urnfield Culture Complex (Late Bronze Age), which is dated from the 14th to the 12th century BC, were found scattered on the seabed surface (Bekić 2017).

drvena pilota i jedna vodoravna daska. Obilje keramike i rožnjačkih alatki, tri alatke od opsidijana te jedan radiokarbonski datum dobiven analizom drvenog pilota s rasponom starosti od 4681. do 4539. godine pr. Kr. pokazuju da je naselje bilo u uporabi tijekom neolitika i bakrenog doba (Bekić i sur. 2015).

Podvodno istraživanje kod luke Šimuni otkrilo je moguće *in situ* potopljeno brončanodobno naselje. Na dubinama od oko 2 do 3 m ispod srednje razine mora arheolozi su našli 40 drvenih pilota s promjerima od 10 do 30 cm, koji su u pravocrtnom rasporedu izvirivali iz morskog dna. Veliki broj ulomaka prapovijesne keramike tipološki pripisanih kulturnom kompleksu polja sa žarama (kasno brončano doba), koji se datira od 14. do 12. stoljeća pr. Kr., pronađen je razasut po površini morskog dna (Bekić 2017).

Posljednji primjer s juga je potopljeno nalazište smješteno između otočića Ričul i obale kod mjesta Turanj. Nalazište je spojeno s obalom potopljenim nasipom i okruženo razbacanim ulomcima prapovijesne keramike. Nedavna arheološka istraživanja pokazuju da potopljeni 125 m dugački kameni nasip leži na morskom dnu na dubini od 3 do 4 metra, a podupiru ga drveni piloti. Na umjetno proširenoj obali otočića Ričul vidljivi su ostaci prapovijesnog naselja. Iskopani sediment sadržavao je keramiku srednjeg brončanog doba, kosti i rogove kopnenih životinja, koštice i sjemenke. Tri objavljena radiokarbonska datuma otkrila su starost između 1500. i 1300. godine pr. Kr., tj. srednje brončano doba (Čelhar i sur. 2017).

Sojenice na obali Jadrana predmet su najnovijih istraživanja sojenica u Hrvatskoj, no prapovijesne sojenice u nas su poznate još od konca 19. stoljeća. Otkrivene su u isto vrijeme kao i bolje poznata nalazišta u Italiji i Švicarskoj te su s njima tada i uspoređivane. Arheolog Š. Ljubić iz Arheološkog muzeja u Zagrebu otkrio je 1885. godine zašiljene drvene pilote u močvarnom tlu blizu sela Budinščina u sjeverozapadnoj Hrvatskoj. Po njegovim izvješćima, piloti su bili pravilno raspoređeni i identificirani su kao ostaci nastambe. Ljubić je to nalazište usporedio sa suvremenim *Terramare* nalazima u talijanskoj pokrajini Emiliji (Ljubić 1885; Ljubić 1887). Od tada je ta sojenica zapostavljena, no bilo je i mnogih kasnijih prapovijesnih nalaza u Budinščini, većinom pripisanih kasnom brončanom dobu te kompleksu kulture polja sa žarama (Vinski-Gasparini 1973). Arheolog J. Brunšmid je 1884. godine također izvještavao o postojanju sojenica blizu sela Andrijevcu na lijevoj obali rijeke Save, u sjeveroistočnoj Hrvatskoj (Brunšmid 1900). Spominje i nalazišta u područjima

The final southern example is a submerged site situated between the islet of Ričul near Turanj and the nearby shore. The site is connected to the shore with a submerged embankment, surrounded by scattered prehistoric pottery. Recent archaeological investigations show that the submerged 125-metre-long stone embankment structure lies on a 3–4 metre deep seabed and is supported by wooden piles. Remains of the prehistoric settlement are seen on the Ričul islet shoreline, which was artificially expanded towards the sea. Excavated sediments contained Middle Bronze Age pottery, land animal bones and antler, as well as pits and seeds. Three published radiocarbon dates revealed an age between 1500 and 1300 years BC, or Middle Bronze Age (Čelhar et al. 2017).

The Adriatic coastal pile-dwellings represent the most recent pile-dwelling research in Croatia, however, prehistoric pile-dwellings were known there since the end of the 19th century and their discovery was contemporary and even compared to the famous Italian and Swiss sites. In 1885, Š. Ljubić, an archaeologist at the Archaeological Museum of Zagreb, found sharpened wooden piles in a marshy ground near the village of Budinščina in today's north-western Croatia. According to his reports, the piles were placed in regular formations in the ground and were identified as remains of a dwelling. Ljubić compared the site to the then-contemporary *Terramare* findings in the Italian province of Emilia (Ljubić 1885, Ljubić 1887). No work has been done since on the pile-dwelling but since that time numerous prehistoric finds were found in Budinščina, most of them assigned to Late Bronze Age and the Urnfield Culture complex (Vinski-Gasparini 1973). In 1884, near the village of Andrijevcu on the left bank of the Sava River in north-eastern Croatia, archaeologist J. Brunšmid also reported pile-dwellings (Brunšmid 1900). He mentions waterlogged sites in Donja Bebrina on Sava River and the Retfala village near Osijek (Brunšmid 1900) and in 1977 an excavation in Andrijevcu supported his reports when a wooden platform placed on short piles was recorded along with prehistoric cultural material (Majnarić-Pandžić 2000). Even with these northern Croatian sites, which lie much closer to the Slovenian border, it was not until 2002 when the sites recorded by Brunšmid more than a hundred years earlier, were mentioned by Marović (2002) in the same context as the prehistoric pile-dwellings in the Ljubljansko Barje in Slovenia.

Before the recent discoveries in the Balkan lakes, the most well-known prehistoric pile-dwelling sites were the fluvial settlements in Donja Dolina on river Sava (Truhelka 1901, Truhelka 1902, Truhelka 1903,

mokrih tla kod Donje Bebrine na rijeci Savi te kod sela Retfala blizu Osijeka (Brunšmid 1900). Iskop proveden 1977. godine u Andrijevcima govori u prilog njegovih izvještaja; zabilježena je drvena platforma postavljena na kratkim pilotima, uz prapovijesni kulturni materijal (Majnarić-Pandžić 2000). Unatoč postojanju tih nalazišta u sjevernoj Hrvatskoj, blizu Slovenije, o kojima je Brunšmid izvijestio stotinu godina ranije, tek ih je 2002. godine spomenuo Marović (2002), u kontekstu usporedbe s prapovijesnim sojenicama u Ljubljanskom barju u Sloveniji.

Najpoznatija prapovijesna sojenička nalazišta na ovom području, prije nedavnih otkrića na balkanskim jezerima, riječna su naselja otkrivena i istražena koncem 19. stoljeća kod Donje Doline blizu rijeke Save (Truhelka 1901; Truhelka 1902; Truhelka 1903; Truhelka 1906a; Truhelka 1906b) te kod Ripača na rijeci Uni (Radimsky 1895; Radimsky 1897) u današnjoj Bosni i Hercegovini. Većina poznatih nalazišta riječnih sojenica u Hrvatskoj smještena su uz rijeku Cetinu u zaleđu Dalmacije. Za vrijeme građevinskih radova na otočiću Dugišu blizu Sinja 1955. i 1956. godine lokalni je arheolog primijetio arheološki materijal, uključujući drvenu arhitekturu, te nedugo zatim proveo iskop probnih sonde (Marović 2002; Gabričević i Marović 22. 10. 1956; Gabričević 9. 10. 1956). Brojne izradevine i ostaci struktura ukazivali su na prisutnost prapovijesnog naselja. Ta su istraživanja objavljena gotovo 50 godina kasnije te su uspoređivana s prapovijesnim sojenicama u Italiji i Sloveniji. Još je jedno sojeničko naselje otkriveno blizu sela Vratnice, tipološki pripisano brončanom dobu (Marović 1981). Oba su nalazišta zabilježili podvodni arheolozi devedesetih godina prošlog stoljeća, koji su provodili arheološki pregled korita rijeke Cetine. Primijetili su skupinu drvenih pilota koji vire iz riječnog korita, pokrivajući područje dugo 400 metara, s velikom količinom arheoloških nalaza razasutih oko njih. Još su dva sojenička naselja zabilježena za vrijeme tog pregleda; jedan blizu otočića Okruglo te drugi na mjestu gdje se rijeka Ruda ulijeva u Cetinu (Milošević 1999; Milošević 1992; Milošević, 1998). Osim na Cetini, dolazano je postojanje prapovijesnih sojenica na rijeci Neretvi u zaleđu Dalmacije, gdje su 1978. zabilježeni drveni piloti te ulomci keramike blizu sela Bijeli Vir (Marović 1980).

Iz ovog kratkog pregleda vidimo da se ta nalazišta uklapaju u ukupni fenomen europskih prapovijesnih sojenica te da su nedovoljno istraživana. Rezultati iz Zambratije značajno će pridonijeti široj raspravi te ponuditi temelj i poticaj za stvaranje hrvatske baze podataka o prapovijesnim sojenicama i dendrokronologiji.

Truhelka 1906a, Truhelka 1906b) and Ripač on river Una (Radimsky 1895, Radimsky 1897) in today's Bosnia and Herzegovina, discovered and researched at the end of the 19th century. The majority of known fluvial pile-dwellings in modern day Croatia are located along the river Cetina in the Dalmatian hinterland. In 1955 and 1956, during construction works on the islet of Dugiš near Sinj, findings of archaeological material, including wooden architecture were noticed by a local archaeologist who soon thereafter performed an excavation of test trenches (Marović 2002, Gabričević and Marović, October 22 1956, Gabričević, October 9 1956). Numerous artefacts and structural remains indicated that this was a prehistoric settlement. Nearly 50 years later, the excavations were published and compared to the prehistoric pile-dwellings in Italy and Slovenia. One more pile-dwelling was discovered near the village of Vratnice and was typologically assigned to the Bronze Age (Marović 1981). Both sites were also recorded in the 1990s by underwater archaeologists who were performing archaeological surveys of the Cetina riverbed. They noticed a 400-metre long conglomerate of wooden piles protruding from the riverbed with large amounts of archaeological finds scattered around them. Two more pile-dwellings were recorded during this survey, one near Okruglo islet and one at the confluence of the Ruda and Cetina rivers (Milošević 1999, Milošević 1992, Milošević 1998). Other than Cetina, evidence of a prehistoric pile-dwelling is also known from the Neretva river in the Dalmatian hinterland where in 1978 wooden piles and pottery fragments were recorded near the village of Bijeli Vir (Marović 1980).

This summary overview suggests that these sites are a part of the overall European prehistoric pile-dwelling phenomenon and are under-researched. The results from Zambratija will evidently add significant value to the wider discussion and provide a foundation for a call to action to create a Croatian database for prehistoric pile-dwellings and dendrochronology.

RECENT INVESTIGATIONS AT ZAMBRATIJA: FIELDWORK AND LABORATORY METHODS

Data were collected through aerial and underwater acquisition methods to record landscape context and collect wooden samples, embedded vertically into what is now the seabed, for dendrochronological analysis. The sampling location was determined near the submerged peat platform and the two units that had produced material culture. The peat is well preserved due to its protected

NEDAVNA ISTRAŽIVANJA NALAZIŠTA ZAMBRATIJA: TERENSKI RAD I LABORATORIJSKE METODE

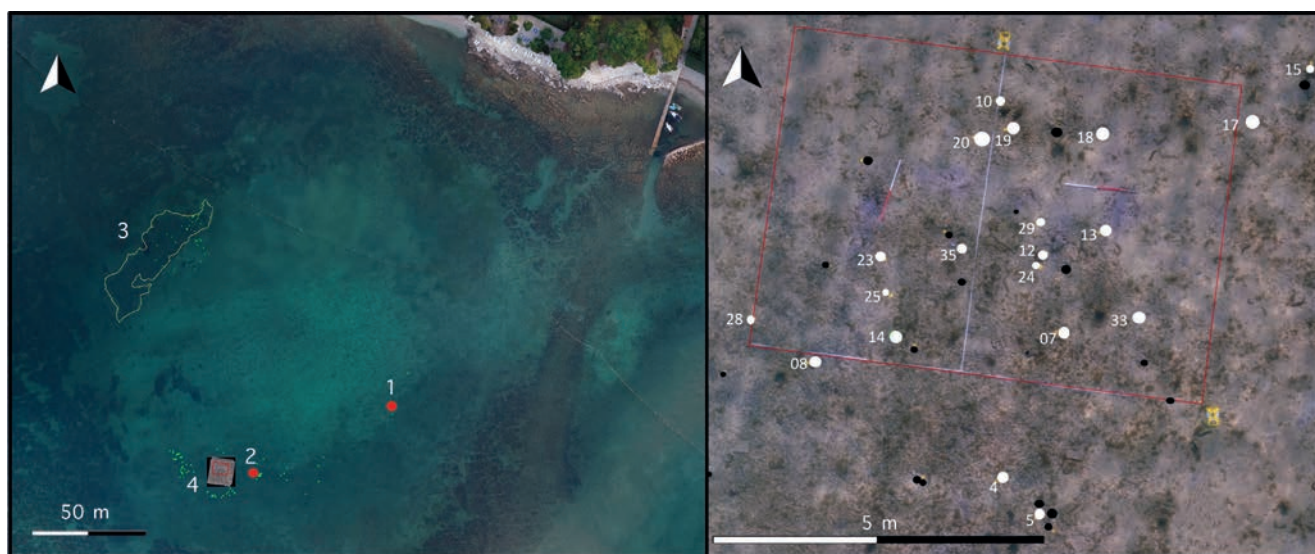
Podaci za dendrokronološku analizu prikupljeni su zračnim i podvodnim metodama, ne bi li se zabilježio kontekst krajolika i prikupili drveni uzorci, okomito ugrađeni u sadašnje morsko dno. Mjesto uzorkovanja određeno je u blizini potopljene tresetne platforme i dviju jedinica u kojima je pronađena materijalna kultura. Treset je dobro očuvan zbog svog položaja u kraškoj vrtači: zaštićen je višim terenom, koji je bio prirodni valobran. Treset također ukazuje na to da je vrtača vjerojatno nekoć bila slatkovodno jezerce ili močvara, prije no što je na kraju bila potopljena tijekom podizanja razine mora u srednjem holocenu. Terensko istraživanje 2017. bilo je provedeno na području koje do sada nije bilo iskapano niti istraženo.

Izrada fotomosaika potopljene vrtače i snimanje strukture pod vodom obavljani su zračnim putem, uz pomoć bespilotnih letjelica, te ronilačkim pregledom podmorja. Zračno snimanje provedeno je 2015. godine bespilotnom letjelicom DJI Phantom 2V+, pri čemu je korišten kružni polarizacijski filter za smanjenje odsjaja i snimanje kroz vodu. Podvodne fotografije snimljene su kamerama Lumix TS5 GPS i Sony RX100. Slike su uvezene u Agisoft Metashape za 3D rekonstrukciju i generiranje 2D ortofoto snimke.

setting in the karstic sinkhole, sheltered by higher ground around the sinkhole which formed a natural breakwater. The peat also indicates that the sinkhole was probably once a freshwater pond or marsh before it was eventually transgressed during the mid-Holocene sea-level highstand. The 2017 field campaign focused on an area that had not been previously excavated or investigated.

Aerial drone and diver-based surveys were used to produce a photomosaic of the submerged sinkhole and record underwater features. The aerial survey was performed in 2015 with a DJI Phantom 2V+ flown with circular polarising filter to reduce glare and cut through the water. Underwater photographs were taken with a Lumix TS5 GPS and Sony RX100 cameras. Images were imported into Agisoft Metashape for 3D reconstruction and 2D orthophoto generation.

Snorkelling and diving surveys were performed in 2017 to record a new 5 x 7 m excavation trench. The dives took place on the south-western ridge of the submerged karstic sinkhole at depths between -3.2 m and -3.5 m MSL (Fig. 5, left). After the selection of the trench location, all visible piles were marked and recorded with numbered tags (Fig. 5, right). The trench and piles were photographed with a GoPro Hero3 camera to produce a 3D model of the site. A hand-drawn site plan was produced as a reference for processing digital data as well and to analyse the site for architectural building patterns. The original site plan was



Sl. 5 Lijevo: položaj područja koje se istraživalo 2017. godine (4) u odnosu na ranije poznate nalaze i istražene jedinice (1, 2, 3). Područje 3 označava ugrubo pravokutnu potopljenu tresetnu platformu. Desno: položaji svih označenih drvenih pilota u području istraženom 2017. godine, označeni su crno i bijelo. Piloti označeni bijelo uzeti su za dendrokronološku analizu. Ortofoto snimili: J. Benjamin i E. Aragón Núñez.

Fig. 5 Left: The position of the 2017 investigation area (4) in relation to previously known features and excavation units (1, 2, 3). Area (3) represents the sub-rectangular submerged peat platform. Right: The positions of all the marked piles in the 2017 investigation area are marked in black and white. The piles marked with white have been taken for dendrochronological analyses. Ortophotos by: J. Benjamin and E. Aragón Núñez.

Tijekom 2017. provedeni su ronilački pregledi u apneji i sa SCUBA opremom, a u cilju obilježavanja nove sonde dimenzija 5 x 7 m. Ronilo se na jugozapadnom grebenu potopljene vrtače, na dubinama između -3,2 m i -3,5 m (sl. 5, lijevo). Nakon odabira mjesta iskapanja sonde, svi su vidljivi drveni piloti zabilježeni brojevima (sl. 5, desno). Sonda i drveni piloti fotografirani su kamerom GoPro Hero3 ne bi li se izradio 3D model lokacije. Rukom crtan plan lokacije izrađen je kao referenca za obradu digitalnih podataka te da se utvrdi postoji li pravilnost u rasporedu koja bi upućivala na kakvu građevinu. Izvorni plan lokacije napravljen je pod vodom, potom je ponovno nacrtan na kopnu te naposljetku digitaliziran. Usporedno s tim, podvodni arheolozi identificirali su 35 dotad nezabilježenih drvenih pilota, smještenih unutar i neposredno uz sondu. Piloti koji su označeni izvan sonde zabilježeni su u cilju prostorne analize.

Na dendrokronološku analizu poslano je 20 uzoraka drvenih pilota, od kojih su dva naknadno poslana na radiokarbonsko datiranje. Odabir pilota od strane tima podvodnih arheologa i dendrokronoloških stručnjaka temeljio se na *in situ* procjeni njihove očuvanosti kao i na njihovu položaju na morskom dnu u smislu dostupnosti i prikladnosti za datiranje. Uzorkovanje je obavljeno ručnim piljenjem dijela pilota koji je virio iz dna, ostavljajući preostali materijal *in situ* ispod razine morskog dna. Svakom je uzorku dodijeljen broj te je prebačen u terensku bazu na obali za preliminarni pregled i pripremu za transport. Drveni su uzorci potom očišćeni u slatkoj vodi, izmjereni i pakirani za transport do dendrokronološkog laboratorija u Centru Camille Jullian, Sveučilište Aix-Marseille, Francuska. Nalazište je snimljeno s obale ručnom totalnom stanicom Leica FlexLine TS06, korištenjem GIS koordinatnog sustava MGI 1901/Balkan zone 5 kako bi se omogućilo georeferenciranje ortofoto snimke i tehničkog crteža.

Određivanje vrsta drva provedeno je rezanjem tri uzorka tankog presjeka (poprečno, tangencijalno i radijalno) iz svakog pilota čistom oštricom britve. Vrsta je određena promatranjem strukturnih karakteristika drva i usporednim istraživanjima (Schweingruber 1978), analizom mikroskopskih varijeteta svakog od presjeka uzoraka. Uzorci su analizirani uz pomoć elektronskog mikroskopa marke Olympus.

Širine godova izmjerene su uz pomoć LINTAB inkrementalnog mjernog stola s točnošću od 0,01 mm. Mjerenja su automatski digitalno prebačena u računalnu aplikaciju TSAP-Win (tvrtka Rinntech, Heidelberg, Njemačka). Sirovi i logaritamski indeksi nizova godova zatim su podvrgnuti testovima korelacije (koeficijenti

recorded under water, re-drawn on land and digitalised. During this time, underwater archaeologists identified 35 previously unrecorded wooden piles, situated inside and immediately adjacent to the excavation trench. Piles that were marked outside the trench were recorded for spatial analysis.

Twenty of these newly identified wooden piles were sampled for dendrochronology and two of those were later sent for radiocarbon dating. Selection of the piles by the team of underwater archaeologists and dendrochronological specialists, was based on an *in situ* evaluation of their quality of preservation as well as on their position in the seabed regarding availability for a safe suitability for dating. Sampling was performed by hand sawing the visible protruding pile, leaving the remaining material *in situ* below the level of the seabed. Each sample was designated a number and transported to the field coastal base for preliminary inspection and preparations for transport. The wooden samples were then cleaned in fresh water, measured, and packed for transport to the dendrochronological laboratory at the Centre Camille Jullian, Aix-Marseille University, France. The site was recorded from shore with a Leica FlexLine TS06 manual total station, using the MGI 1901/Balkan zone 5 GIS coordinate system to enable georeferencing of the orthophoto and technical drawing.

Wood species determination was performed by slicing three thin sample sections (transversal, tangential and radial) from each pile with a clean razor blade. The species was determined through observation of wood anatomical features and comparative research (Schweingruber 1978), by analysing microscopic varieties of each section of the samples. The samples were analysed through an Olympus Electron microscope.

Ring widths were measured using the incremental table LINTAB with 0.01 mm accuracy. The measurements were automatically digitally transferred into the TSAP-Win software (Rinntech Company, Heidelberg, Germany). The raw and logarithmic indexations of the tree ring series were then run through correlation tests (correlation coefficients, Student t test and seven years moving windows) with the DENDRON IV software, developed with RunRev LiveCode, Edinburgh, Scotland (Lambert, 2006). All resulting tree-ring series and the cross-datings were visually examined and verified for accuracy.

Radiocarbon dating was undertaken on two wooden samples: one from the beginning and one from the end of the established dendrochronological sequence (chronology). Radiometric determinations were

korelacije, Studentov t-test i sedmogodišnji pomični prozori) koristeći računalnu aplikaciju DENDRON IV, razvijenu s RunRev LiveCode, Edinburgh, Škotska (Lambert 2006). Svi su tako dobiveni nizovi godova i unakrsna datiranja podvrgnuti vizualnom pregledu i provjeri točnosti.

Radiokarbonsko datiranje provedeno je na dva uzorka drva: jednom s početka i jednom s kraja utvrđenog dendrokronološkog slijeda (kronologije). Radiometrijska određivanja proveo je je Scottish Universities Environmental Research Centre (SUERC) (Bronk Ramsey 2017; Dunbar i sur. 2016). Radiokarbonski datumi kalibrirani su na kalendarski vremenski okvir uz pomoć kalibracijskog programa OxCal 4.4.2 Oxford Radiocarbon Accelerator Unit, te dalje kalibrirani uz pomoć IntCal20 kalibracijske krivulje starosti radiokarbonsa za sjevernu polutku (Reimer i sur. 2020).

Wiggle-matching proveden je s dva radiokarbonska datuma putem Oxford Radiocarbon Accelerator Unit programa za kalibraciju OxCal 4.4.4 pokretanjem sljedećeg koda:

```
Options()
{
  Resolution=1;
};
Plot()
{
  D_Sequence ("Zambratija chronology")
  {
    R_Date("SUERC-77772", 5310 , 32);
    Gap(55);
    R_Date("SUERC-77773", 5129 , 34);
    Gap(4);
  }
  Date("end-date Zambratija chronology")
};
};
```

Rezultati

Svih dvadeset uzoraka drva identificirano je kao listopadni hrast (*Quercus* sp.) s karakteristikama drva tipičnim za hrast (sl. 6). Iako se crno obojena srž arheološkog hrasta može razlikovati od smeđe obojene bjeljike, također smo uočili tiloze koje su bile očuvane u uzorcima u različitim količinama, što nam je dodatno pomoglo da razlikujemo srž (s tilozama) od bjelike (bez tiloza ili s manje tiloza) (Dufraisse i sur. 2018). Boja drva i prisutnost tiloza upućuju na to da većina uzoraka drva ne sadrži bjeljiku (sl. 7). Devetnaest uzoraka bilo je dovoljno očuvano, s godovima pogodnim za provedbu

performed by the Scottish Universities Environmental Research Centre (SUERC) (Bronk Ramsey 2017, Dunbar et al. 2016). The radiocarbon dates were calibrated to the calendar timescale using the Oxford Radiocarbon Accelerator Unit calibration program OxCal 4.4.2 and calibrated using the IntCal20 Northern Hemisphere radiocarbon age calibration curve (Reimer et al. 2020).

Wiggle-matching was performed with the two radiocarbon dates through the Oxford Radiocarbon Accelerator Unit calibration program OxCal 4.4.4 by running the following code:

```
Options()
{
  Resolution=1;
};
Plot()
{
  D_Sequence ("Zambratija chronology")
  {
    R_Date("SUERC-77772", 5310 , 32);
    Gap(55);
    R_Date("SUERC-77773", 5129 , 34);
    Gap(4);
  }
  Date("end-date Zambratija chronology")
};
};
```

Results

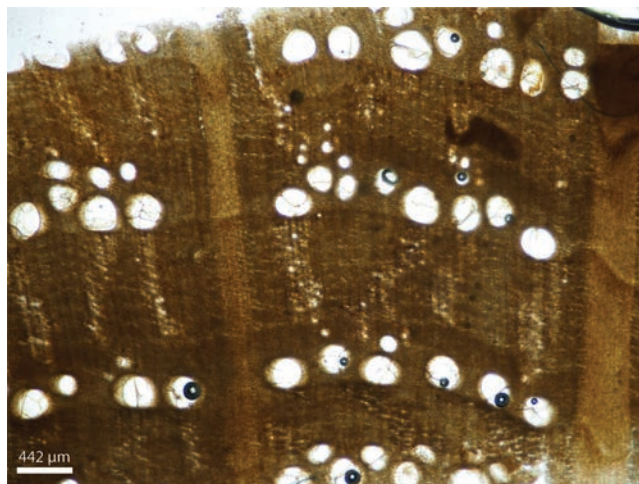
All twenty wooden samples were shown to be deciduous oak (*Quercus* sp.) with wood anatomy features typical for oaks (Fig. 6). Although black coloured heartwood of archaeological oak can be distinguished from brown coloured sapwood, we also observed tyloses which were preserved throughout the samples in varying amounts which additionally helped us to distinguish heartwood (with tyloses) from sapwood (without or less abundant tyloses) (Dufraisse et al. 2018). The colour of wood and the presence of tyloses indicated that most samples of the wood did not contain the sapwood (Fig. 7). Nineteen samples were sufficiently preserved with tree rings suitable to perform a dendrochronological analysis. Eleven of the nineteen tree-ring series were cross-dated (see Student's t test and correlation coefficients in the square matrices in Figure 8). These series were rather short, having only 15 to 56 growth rings (Fig. 7). Even with these low numbers, visual correlations supported by the statistical parameters were sufficient to average the raw and standardised tree-ring series in a 62 year-long tree-ring chronology (Fig. 8). The remaining eight samples did not correlate either to the 62-year chronology, or to one another.

dendrokronološke analize. Jedanaest od devetnaest nizova godova unakrsno je datirano (vidi Studentov t-test i koeficijente korelacije u kvadratnim matricama na slici 8). Ti su nizovi prilično kratki, sa samo 15 do 56 godina rasta (sl. 7). Čak i s ovim niskim brojevima, vizualne korelacije potkrijepljene statističkim parametrima bile su dovoljne za izračunavanje prosjeka neobrađenih i standardiziranih nizova godova u kronologiji godova koja pokriva 62 godine (sl. 8). Preostalih osam uzoraka nije u korelaciji ni sa 62-godišnjom kronologijom, ni međusobno.

Unakrsno datirani nizovi i kronologija poslani su Arheološkoj službi Ureda za baštinu i arheologiju (Office du patrimoine et de l'archéologie, OPAN) u švicarskoj pokrajini Neuchâtel, talijanskoj tvrtki Dendrodata s.a.s. te Odsjeku za znanost i tehnologiju drva na Biotehničkom fakultetu Sveučilišta u Ljubljani za moguće korelacije s njihovim dugim prapovijesnim kronologijama godova hrasta. Međutim, nisu odgovarale nijednoj drugoj datiranoj referentnoj kronologiji, vjerojatno zato što kronologija iz uvale Zambratija ne potječe iz sličnog kronološkog razdoblja ili zato što su korištene referentne kronologije predaleko od Zambratije da bi dale značajne korelacije.

Dva uzorka, jedan s najstarijim godovima dendrokronološkog niza (ZAMB_18) i drugi s najmlađim godovima (ZAMB_29), uzorkovana su za radiokarbonsko datiranje (Tablica 1). S obzirom na to da su ta dva uzorka drva uvrštena u kronologiju unakrsnim datiranjem, stvarna udaljenost u godinama između godova uzorkovanih za radiokarbonsko datiranje mogla bi se koristiti u *wiggle-matching* modelu (Galimberti i Bronk Ramsey 2004; Reimer i sur. 2020). Srednja godina u svakom od uzorkovanih blokova godova (relativne godine 3 i 58) korištena je kao prosječna godina goda za radiokarbonske uzorke. Krajnji datum zambratijske kronologije, dobiven *wiggle-matching* metodom, jest 4041. do 3934. pr. Kr. (sa stupnjem vjerojatnosti od 95,4%). Uzorak ZAMB_18 uzet je iz neposredne blizine srčike, što implicira kronološki najstarije godove stabla. Uzorak ZAMB_29 uzet je iz posljednjih sačuvanih godova uzoraka, objektivno bliže datumu sječe. Ovaj je datum stoga najpouzdaniji za kronološke interpretacije arheoloških struktura. Količina uzorkovanog materijala odgovara pet godova uzorka ZAMB_18 i deset godova uzorka ZAMB_29 (sl. 9).

Jedna od manjkavosti prikazanih rezultata su kratki rasponi sljedova godova, a dio s >2 uzorka i/ili t-vrijednostima $\approx 3,5$ ili korelacijom $\approx 0,4$ je ispod 50 godina. Promjeri uzoraka mogli bi ukazivati na to da



Sl. 6 Poprečni presjek uzet od pilota 15 s prepoznatljivim godovima i strukturom drva tipičnom za listopadne hrastove (*Quercus* sp.). Fotografija: A. Ferreira Domínguez.

Fig. 6 Cross-section from Pile 15 with distinguishable tree-rings and wood anatomy typical of deciduous oaks (*Quercus* sp.). Photo by: A. Ferreira Domínguez.

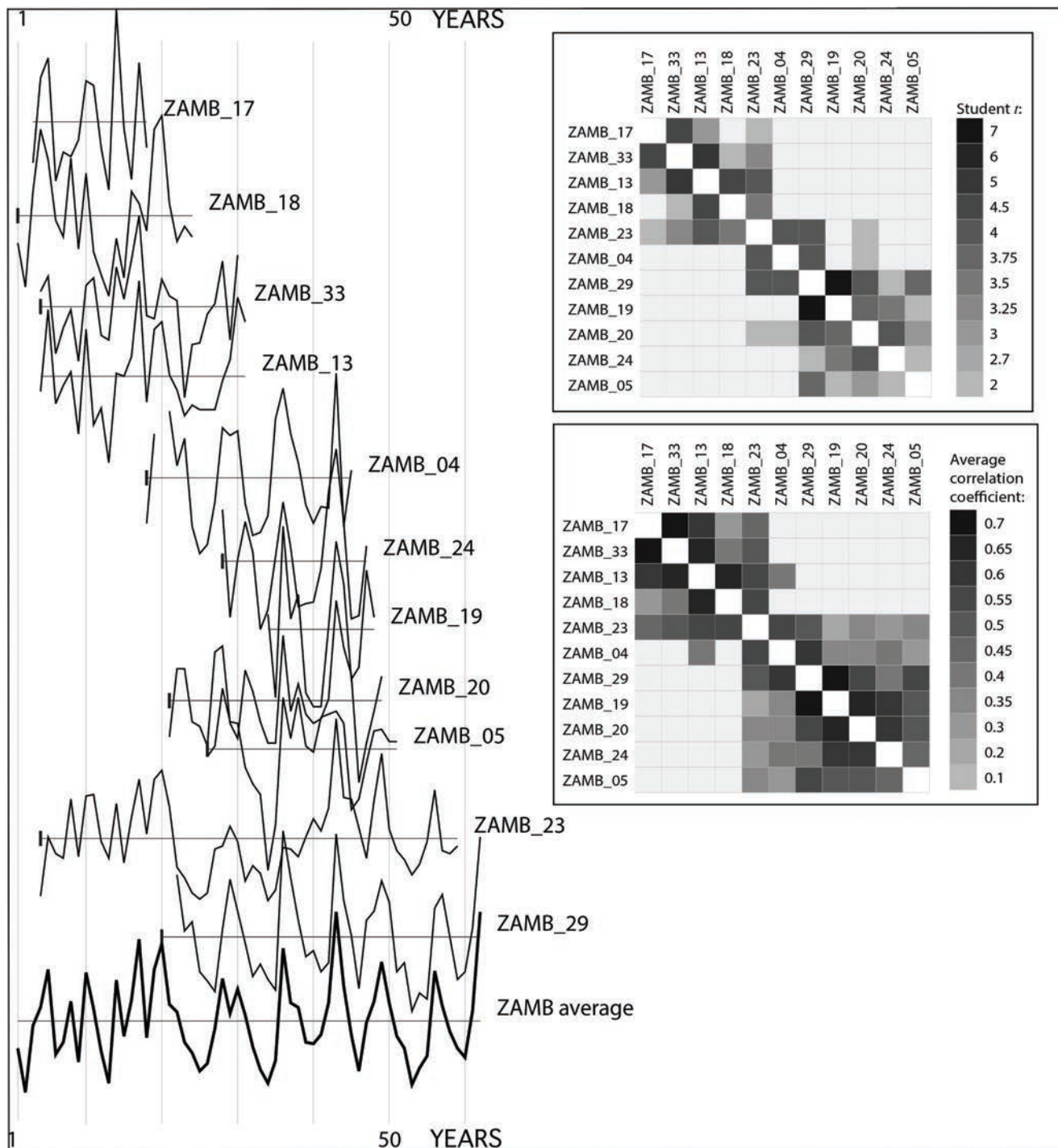
The cross-dated series and the chronology were sent to *Service de l'Archéologie de l'Office du Patrimoine du Canton de Neuchâtel* (OPAN) in Switzerland, Dendrodata s.a.s. in Italy and the Department of Wood Science and Technology at the Biotechnical Faculty of the University of Ljubljana in Slovenia for possible correlations with their long prehistoric oak tree-ring chronologies. However, they did not match any other dated referenced chronology, likely because the Zambratija Bay chronology does not come from a similar chronological period or because the reference chronologies used are too far away from Zambratija to yield significant correlations.

Two samples, one of them with the oldest rings of the dendrochronological series (ZAMB_18) and the other with the most recent rings (ZAMB_29) were sampled for radiocarbon dating (Table 1). Given that the two wood samples are cross-dated into a chronology, the actual distance in years between the rings sampled for radiocarbon dating could be used in a wiggle-matching model (Galimberti and Bronk Ramsey 2004, Reimer et al. 2020). The mid-point year in each of the sampled tree-ring blocks (relative years 3 and 58) was used as the average tree-ring year of the radiocarbon samples. The wiggle-matched end-date of the Zambratija chronology is 4041–3934 cal BC (95.4% probability). Sample ZAMB_18 was taken from the immediate vicinity of the pith, which implies the chronologically oldest rings of the tree. Sample ZAMB_29 was taken from the last preserved rings of the sample, which is objectively closer to the felling date. This date is therefore the most reliable for making chronological



Sl. 7 Jedanaest uzoraka drva korištenih za dendrokronološku analizu i slaganje plutajuće kronologije godova. Fotografija: K. Jerbić.

Fig. 7 Eleven wooden samples which were used for dendrochronological analyses and construction of the floating tree-ring chronology. Photos by: K. Jerbić.



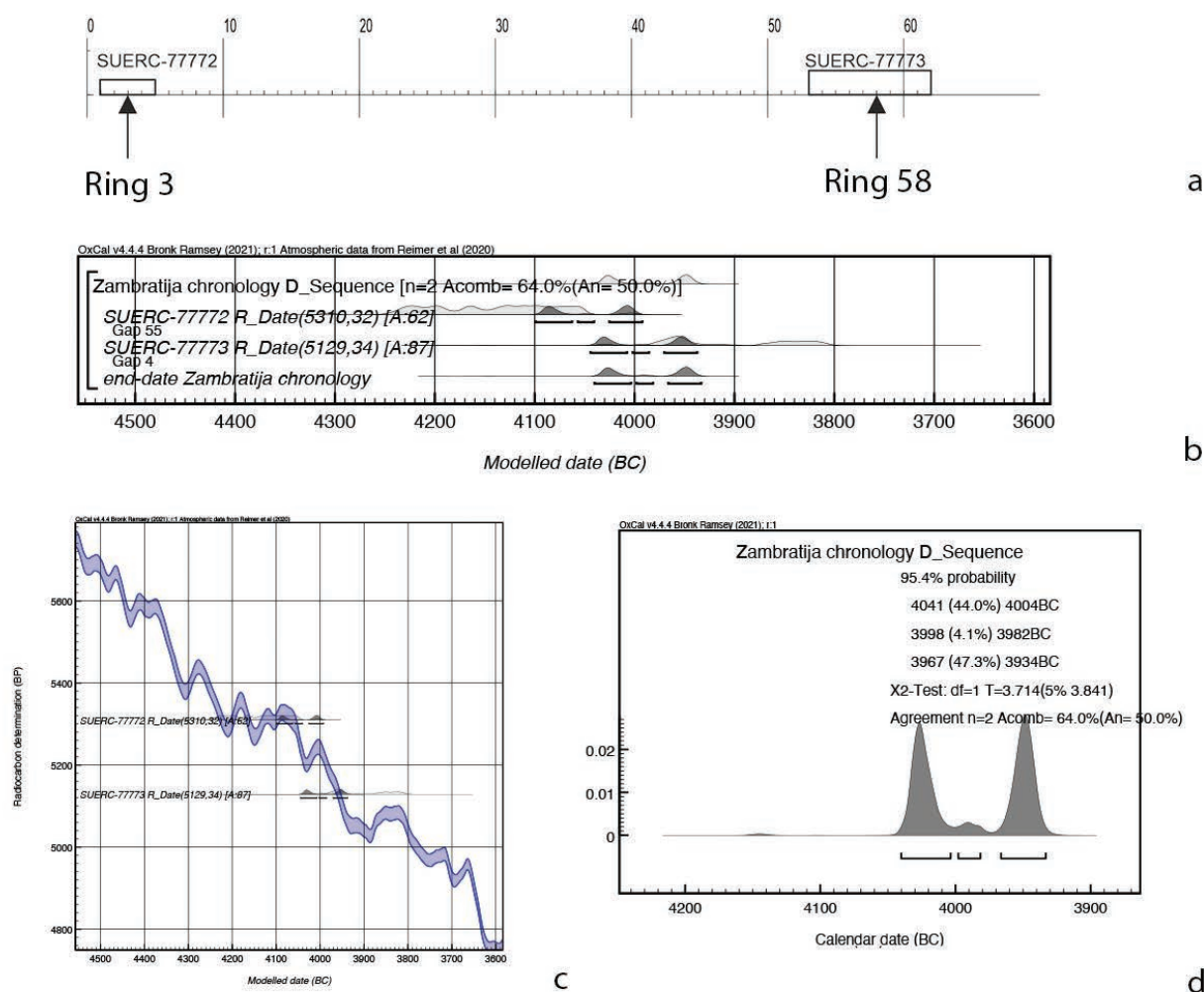
Sl. 8 Lijevo: jedanaest nizova širine godova hrasta u sinkroniziranim (križno datiranim) položajima. Okomite crte označavaju desetogodišnje intervale. Prosjek na dnu predstavlja plutajuću (nedatiranu) kronologiju hrasta iz zaljeva Zambratija. Desno: kvadratne matrice predstavljaju Studentove t-vrijednosti i prosječne korelacijske koeficijente jedanaest unakrsno datiranih nizova. Ove tablice dvostrukog unosa pokazuju poklapanja između nizova. Što je polje tamnije, to je veća vrijednost statističkog parametra, a time i sličnost dvaju uspoređivanih nizova godova (matrica generirana softverom Dendron IV Lambert, 2006). Svi podaci o širini godova dostupni su od autora na zahtjev. Grafikoni: L. Shindo.

Fig. 8 Left: 11 oak tree-ring width series in synchronised (cross-dated) positions. The vertical lines mark ten-year intervals. The average at the bottom represents the floating (undated) oak chronology from Zambratija Bay. Right: Square matrices represent the Student t values and average correlation coefficients of the eleven cross-dated series. These double-entry tables show the agreement between the series. The darker the box, the higher the value of the statistical parameter and thus the similarity of the two compared tree-ring series (matrix generated by Dendron IV software Lambert 2006). All the tree-ring width data is available upon request from the authors. Graphs by: L. Shindo.

Laboratorijska referenca / Lab Reference	Nekalibrirana ¹⁴ C starost [BP=prije sadašnjosti] / Uncalibrated ¹⁴ C Age	Kalibrirani datum [cal BC=kalibrirani datum pr. Kr.] / Calibrated Age	Stupanj vjerojatnosti / Probability	Položaj / Location	Godina / Year	Opis uzorka / Sample description
Beta-296187	5260 ± 30 BP	4230-3984 cal BC	95.4%	Sonda 1 / Unit 1 Sloj 2 / Layer 2	2008	Drvo (hrast) / Wood (Oak)
SUERC-77772	5310 ± 32 BP	4248-4003 cal BC	95.4%	ZAMB_18 (prvih pet godina / five first rings)	2017	Drvo (hrast) / Wood (Oak)
SUERC-77773	5129 ± 34 BP	4039-3801 cal BC	95.4%	ZAMB_29 (zadnjih deset godina / last ten rings)	2017	Drvo (hrast) / Wood (Oak)

Tabla 1 Radiokarbonski datumi dobiveni od uzoraka hrasta iz uvala Zambratija (Beta-296187, preuzeto od Koncani Uhač i Čuka (2015), dok su dvije SUERC determinacije izvorni podaci). Svi datumi kalibrirani su uz pomoć OxCal 4.4, s atmosferskim podacima iz IntCal20 kalibracijske krivulje starosti radiokarbena za sjevernu polutku (Reimer i sur. 2020).

Table 1 Radiocarbon dates from oak samples in Zambratija Bay (Beta-296187 from Koncani Uhač and Čuka 2015, while the two SUERC determinations are original data). All dates were calibrated using OxCal 4.4, with atmospheric data from IntCal20 Northern Hemisphere radiocarbon age calibration curve (Reimer et al. 2020).



Sl. 9 Dijagrami za uvalu Zambratija dobiveni wiggle-matching metodom: višestruki dijagram (a), dijagram krivulje (b), položaji radiokarbonskih srednjih godina (c) te pojedinačni dijagram (d).

Fig. 9 Zambratija Bay wiggle-matching multiple plot (a), curve plot (b), radiocarbon mid-year positions (c) and single plot (d).

drveni piloti potječu od stabala panjača (iz izdanačke šume), što bi vjerojatno otežalo unakrsno datiranje izvan nalazišta i dodatno utjecalo na neuspješno podudaranje s drugim kronologijama. Unatoč tome, trenutni dendrokronološki slijed dobiven *wiggle-matching* metodom predstavlja polazišnu osnovu za stvaranje trenutno nepostojeće, ali potrebne dendrokronološke baze podataka hrasta u Hrvatskoj/u jugoistočnoj Europi (Čufar i sur. 2014; Ważny i sur. 2014).

DENDROKRONOLOŠKI POTENCIJAL ARHEOLOŠKOG DRVA IZ UVALE ZAMBRATIJA

Budući da je dendrokronologija južnoalpskih nastambi, u usporedbi s onima na sjeveru Alpa, nepotpuna uslijed nedostatka arheološkog drva s kojim bi se mogle stvarati duge referentne kronologije, kao i zbog različitih signala u godovima hrasta, novi podaci povezani s arheološkim razdobljima mogu značajno pridonijeti stvaranju apsolutnih kronologija. Po sadašnjim podacima, podizanje sojeničkih naselja oko jezera na alpskom jugu u Italiji počelo je u kasnom neolitiku, doseglo vrhunac u ranom brončanom dobu te je napušteno mnogo ranije nego na sjeveru – u kasnom brončanom dobu, oko 1200. godine pr. Kr. (Menotti 2015). Podizanje sojeničkih naselja kod Ljubljanskog barja u Sloveniji također je započelo u kasnom neolitiku (oko 4500. godine pr. Kr.), doživjelo je niz vrhunaca u bakrenom dobu te je napušteno oko 2400. godine pr. Kr. (npr. Čufar i sur. 2010, 2015, 2022; Velušček 2006; Velušček i sur. 2023). Kronologija potopljenog nalazišta u uvali Zambratija u skladu je s onima s drugih nalazišta južno od Alpa; dendrokronološki slijed iz Zambratije stoga predstavlja veliki potencijalni doprinos dendrokronologiji južnoalpskog hrasta.

Dendrokronološki sljedovi koji nisu datirani, odnosno povezani s datiranom referentnom kronologijom, određuju se kao plutajući sljedovi (Galimberti i Bronk Ramsey 2004; Schweingruber 1978). Šezdesetvodišnji slijed iz Zambratije trenutno se smatra plutajućim, no radiokarbonski *wiggle-matching* smješta njegov krajnji datum u razdoblje od 4041. do 3934. godine pr. Kr.

Metoda *teleconnection* poredbeno je metoda kojom bi se moglo datirati plutajuće kronologije godina iz Zambratije – tj. usporedba s datiranim kronologijama s drugih više ili manje udaljenih nalazišta, poput onih na Ljubljanskom barju u Sloveniji te sjevernih kao što su Palù di Livenza u Italiji (Čufar i Martinelli 2004; Čufar i sur. 2008a, b, 2015; Martinelli i sur. 2011).

interpretations of the archaeological features. The quantity of sampled material corresponds to five rings on sample ZAMB_18 and ten rings on sample ZAMB_29 (Fig. 9).

One of the limitations to the presented results are the short spans of the tree-ring sequences and the portion with >2 samples and/or t values ≥ 3.5 or correlation ≥ 0.4 is under 50 years. The diameters of the samples might indicate that the piles derive from coppiced trees which would likely make the cross-dating beyond the site more difficult and would additionally affect the failed matching with other chronologies. Nevertheless, the current wiggle-matched dendrochronological sequence represents a starting ground for a Croatian/Southeastern Europe Oak dendrochronological database, which is currently lacking (Čufar et al. 2014, Ważny et al. 2014).

THE DENDROCHRONOLOGICAL POTENTIAL OF ZAMBRATIJA BAY ARCHAEOLOGICAL WOOD

Since the dendrochronological record of Southern Alpine dwellings is incomplete due to lack of archaeological wood to construct long reference chronologies and different signals in oak tree-rings compared to those of the North of the Alps, new data associated with archaeological periods can add significant value to construct the absolute chronologies. The current records suggest that the pile dwelling occupation of the Southern Alpine lakes in Italy started in the Late Neolithic, reached a peak in the Early Bronze Age and was abandoned much earlier than in the North, in the Late Bronze Age around 1200 BC (Menotti 2015). The pile dwelling occupation in Ljubljansko barje, Slovenia, also started in the Late Neolithic (around 4500 BC), reached various peaks in the Copper Age and was abandoned around 2400 BC (e.g. Čufar et al. 2010, 2015, 2022, Velušček 2006, Velušček et al. 2023). The chronology of the submerged Zambratija site is consistent with the ones from other sites from the south of the Alps and the dendrochronological sequence from Zambratija therefore represents a great potential to contribute to Southern Alpine oak dendrochronology.

Dendrochronological sequences which are not dated, i.e. connected to a dated reference chronology are determined as floating (Galimberti and Bronk Ramsey 2004, Schweingruber 1978). For now, the 62-year-long sequence from Zambratija is floating but the radiocarbon wiggle-matching places its end-date in the period 4041–3934 cal BC.

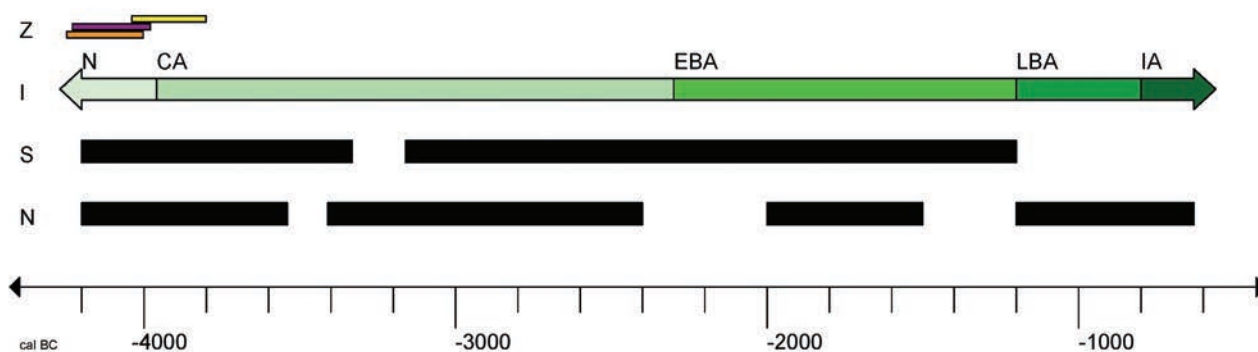
A comparative method which could be used to date a floating tree-ring chronology from Zambratija is

Kombinacija *wiggle-matching* metode (Bronk Ramsey i sur. 2001) i *teleconnectiona* plutajućih sljedova godova hrasta, i djelomično jasena (*Fraxinus* sp.), sa sojenica kod Ljubljanskog barja (Čufar i sur. 2008b, 2010, 2015) polako popunjava praznine u dendrokronološkoj bazi podataka za južnoalpsko područje. Slovenska kronologija sojenica trenutno se temelji na istraživanju više od 8800 uzoraka drva iz 16 nastambi od kojih je 26% bilo hrastovo (Čufar i sur. 2022). Kronologija, duga oko 500 godina i dobro replicirana, datirana je uz pomoć metode *teleconnection* kojom je usklađena s kronologijama sa sjevera Alpa (Čufar i sur. 2015). Apsolutno datirane kronologije hrasta u Sloveniji sada pokrivaju vremenski raspon od 3840. do 3330. godine pr. Kr., dok je za kronologije koje pokrivaju razdoblje od 3285. do 3108.±14 godine pr. Kr. te dijelove 3. tisućljeća pr. Kr., posebice razdoblje od 2659. do 2417.±18 godine pr. Kr., *wiggle-matching* metodom utvrđeno podudaranje s kalibriranim ¹⁴C datumima (Čufar i sur. 2022). Metoda *teleconnection* također je korištena za usporedbu dendrokronologije sojenica kod Hočevarice u Sloveniji i Palù di Livenza u Italiji, gdje su se sljedovi godova preklapali i potvrdili da su nalazišta bila suvremena te da se ondje živjelo u prvoj polovici 4. tisućljeća pr. Kr. (Čufar i Martinelli 2004).

Ovi primjeri pokazuju da je moguća uspješna usporedba plutajućih sljedova. Ne samo da upotpunjuju nepotpune sljedove novim vrijednim podacima, nego također pomažu u dobivanju točnije slike prapovijesnih društava.

teleconnection, i.e. comparison with dated chronologies from other more or less remote sites like the ones in Ljubljansko barje, Slovenia and northern for instance Palu di Livenza in Italy (Čufar and Martinelli 2004, Čufar et al. 2008a, b, 2015, Martinelli et al. 2011).

A combination of wiggle-matching (Bronk Ramsey et al. 2001) and teleconnection of floating oak and partly ash (*Fraxinus* sp.) tree-ring sequences from the Ljubljansko barje pile-dwellings (Čufar et al. 2008b, 2010, 2015) slowly started to fill in the missing gaps in the dendrochronological database of the Southern Alpine region. The Slovenian pile-dwelling chronology is currently based on investigation of more than 8800 wooden samples from 16 dwellings, of which 26 % was oak (Čufar et al. 2022). The chronology, which was around 500-years long and well replicated, was dated by using teleconnection, which matched it with the chronologies from the north of the Alps (Čufar et al. 2015). The absolutely dated oak chronologies in Slovenia currently cover the time span 3840–3330 BC, while the chronologies covering the periods 3285–3108±14 cal BC, and parts of the 3rd millennium BC, particularly the period 2659–2417±18 cal BC were wiggle-matched with calibrated ¹⁴C dates (Čufar et al. 2022). Teleconnection was also used to compare pile-dwelling dendrochronologies from Hočevarica in Slovenia and Palù di Livenza in Italy, where the tree-ring sequences overlapped and confirmed that the sites



Sl. 10 Vremenski rasponi poznatih kronologija sjevernih (N) i južnih (S) prapovijesnih alpskih sojenica i njihovih prekida prema dendrokronološkim i radiokarbonskim datumima. Podaci su uspoređeni s poznatim datumima (Čufar i sur. 2010; Čufar i Martinelli 2004; Čufar i sur. 2015; Forenbaher i sur. 2013; Hänsel i sur. 2005; Magny 2004; Magny 2015; Menotti 2002; Menotti 2004b; Menotti 2009; Mihovilić 2013) za istarski poluotok (I) iz neolitika (N), bakrenog doba (CA), ranog brončanog doba (EBA), kasnog brončanog doba (LBA) i željeznog doba (IA). Tri radiokarbonski datirana drvena pilota iz Zambratije (Z) su na vrhu, gdje je početni datum iz istraživanja provedenog od 2008. do 2014. godine u ljubičastoj boji, datum iz pilota ZAMB_18 je u narančastoj, a datum iz pilota ZAMB_29 u žutoj boji. Grafikon izradila: K. Jerbić.

Fig. 10 The time spans of the known chronologies of Northern (N) and Southern (S) prehistoric Alpine pile-dwellings and their hiatuses, according to dendrochronology and radiocarbon dates. The data were compared to known dates (Čufar et al. 2010, Čufar and Martinelli 2004, Čufar et al. 2015, Forenbaher et al. 2013, Hänsel et al. 2005, Magny 2004, Magny 2015, Menotti 2002, Menotti 2004b, Menotti 2009, Mihovilić 2013) for the Istrian Peninsula (I) from the Neolithic (N), Copper Age (CA), Early Bronze Age (EBA), Late Bronze Age (LBA) and Iron Age (IA). Three radiocarbon dated wooden piles from Zambratija (Z) are at the top, where the initial date from the 2008–2014 investigation is in purple, the date from pile ZAMB_18 is in orange and the date from pile ZAMB_29 is in yellow. Graph by: K. Jerbić.

Zambratija je zemljopisno južno od Alpa i između slovenskih i talijanskih nalazišta pa je treba promatrati unutar šireg južnoalpskog regionalnog konteksta. Nadalje, proširenje 62-godišnjeg dendrokronološkog slijeda izvedenog iz 11 drvenih pilota, zajedno s dosad zabilježenim podacima dobivenim iz više od 120 pilota (broj koji raste sa svakim novim istraživanjem nalazišta), povećat će vjerojatnost uspješnih podudaranja *wiggle-matching* metodom ili metodom *teleconnection* s nalazištima u Sloveniji i/ili Italiji. To bi pak pridonijelo izgradnji slijeda južnoalpskog hrasta, kao i razvoju lokalne baze podataka (sl. 10). Ovakvo dendrokronološko datiranje uz pomoć brojanja godina nije provedeno za istočnu obalu Jadrana, što ovu studiju čini dragocjenim doprinosom mediteranskoj arheologiji.

ZAKLJUČAK

Potopljeno naselje u uvali Zambratija značajno doprinosi postojećim spoznajama o obrascima naseljavanja istočnog Jadrana u prapovijesti. Dendrokronološki slijed predstavljen u ovom radu prvi je takve vrste u široj regiji i važan prvi korak u uspostavi prapovijesne dendrokronološke baze podataka u Hrvatskoj i jadranskom prostoru uopće. Kako je to očito ne samo iz radiokarbonskih dokaza i dendrokronoloških pokazatelja nego i iz rasporeda arhitekture i ostale materijalne kulture, potopljeno nalazište u uvali Zambratija možemo pouzdano tumačiti kao sojeničko naselje koje je bilo u uporabi tijekom kasnog neolitika i ranog bakrenog doba, oko 4041. do 3934. pr. Kr., kako je prikazano u ovoj studiji, te možda i u ranom brončanom dobu, na što posredno ukazuju nalazi keramike i obližnji nalaz broda. Ostaje otvoreno pitanje je li ovo naselje bilo kontinuirano naseljeno ili je bilo razdoblja kada je bilo i napušteno.

Donedavno se smatralo da je kontinentalni europski fenomen sojenica bio koncentriran oko alpskih jezera i močvarnih područja, no sada je očito da je prapovijest Europe obilježena s više suvremenih "sojeničkih zona". Zambratija se može promatrati kao nalazište koje popunjava prazninu između alpskih nalazišta i kulturnih tradicija na jugu, duž Balkanskog poluotoka. Smješteno na jadranskoj obali, ovo naselje možda ukazuje na neku mediteransku kulturu; iako nije bilo u moru u vrijeme kada je izgrađeno, blizina obali upućuje na sojeničku kulturu s mediteranskim atributima.

Terenski rad 2017. godine te naknadna analiza bili su skromnog opsega, ali ovdje predstavljeni rezultati su pionirski i daju naslutiti da ćemo budućim istraživanjima

were contemporary and in use in the first half of the 4th millennium BC (Čufar and Martinelli 2004).

These examples show how floating sequences can be successfully matched. Not only can they add valuable data to incomplete sequences, but they help to create a more accurate representation of prehistoric societies. Since Zambratija is geographically positioned south of the Alps and in between the Slovenian and Italian sites, it should be considered within the broader Southern Alpine regional context. Furthermore, the 62-year-old dendrochronological sequence derived from 11 piles, and with current records of more 120 piles (and growing with each new investigation on the site), expanding this sequence will increase the likelihood for successful wiggle-matching or teleconnection with Slovenian and/or Italian sites. This would in turn contribute to building up the Southern Alpine Oak sequence as well as a local database (Fig. 10). No such tree-ring dating has been undertaken on the Eastern Adriatic coast, making this study an invaluable contribution to Mediterranean archaeology.

CONCLUSION

The submerged settlement in Zambratija Bay significantly contributes to the existing knowledge of prehistoric settlement patterns on the Eastern Adriatic. The dendrochronological sequence presented in this paper is the first of its kind in the region and an important first step in establishing a prehistoric dendrochronological database in Croatia and the wider Adriatic. As it is evident not only in the radiocarbon evidence and the dendrochronology but also in the distribution of architecture and material culture, we confidently interpret the submerged site in Zambratija Bay as a pile-dwelling which was in use during the Late Neolithic and Early Copper Age, around 4041–3934 cal BC, as shown in this study, and potentially in Early Bronze Age periods as circumstantially indicated by the pottery finds and the nearby boat. Whether this settlement was continuously occupied or experienced periods of abandonment remains in question.

Until recently, the continental European pile-dwelling phenomenon has been thought to concentrate around the Alpine lakes and marshlands but it is now evident European prehistory contains several contemporary 'pile-dwelling zones'. Zambratija can be seen as filling in the gap between the Alpine sites and cultural traditions further south along the Balkan Peninsula. Situated on the Adriatic coast, the settlement site potentially implies a Mediterranean culture and although it would not have been built in the sea originally, its proximity to the coast

vjerojatno doći do visoko rezolutnih podataka koji će pomoći u rješavanju detaljnih pitanja o kasnom neolitiku i bakrenom dobu u srednjoj Europi.

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would suggest a pile-dwelling culture with Mediterranean attributes.

The 2017 fieldwork and subsequent analysis were modest in scale but the results presented here are groundbreaking and indicate that future research will likely yield high resolution data to help resolve current detailed questions on the central European Late Neolithic and Copper Ages.

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