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NOVI PODACI ANALIZE DRVA PRAPOVIJESNOG ŠIVANOG BRODA IZ ZAMBRATIJE, ISTRA, HRVATSKA

NEW DATA FROM THE ANALYSIS OF THE WOOD OF THE PREHISTORIC SEWN BOAT OF ZAMBRATIJA, ISTRIA, CROATIA

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Ovaj rad predstavlja nove podatke dobivene nakon podizanja i rastavljanja prapovijesne brodske konstrukcije iz uvale Zambratija (Hrvatska) 2023. godine. Rezultati analize novih elemenata, posebice grančica korištenih u vodonepropusnom sustavu, nadopunit će ranije objavljene rezultate identifikacije vrsta drva. Također, mogućnost proučavanja poprečnih presjeka svake platice oplate omogućuje preciznu analizu morfologije te donosi podatke o izvornom stablu i tehnologiji obrade drva.

KLJUČNE RIJEČI: *dendrokronologija; dendromorfologija; šivani brod; drvo; Zambratija*

This contribution aims to present new data obtained following the recovery and dismantling of the prehistoric boat of Zambratija (Croatia) in 2023. The results of the analysis of new elements, in particular rods used in the waterproofing system, will be added to the results of the identification of wood species already published. The possibility of observing cross-sections of each planking strake allows for a detailed study of the morphology, providing information about the parent tree and wood technology.

KEY WORDS: *dendrochronology; dendromorphology; sewn boat; wood; Zambratija*

UVOD

Brodska konstrukcija iz Zambratije (Istra, Hrvatska) datirana je u kasno brončano/rano željezno doba (Koncani Uhač *et al*. 2019, s literaturom) i predstavlja najstariji primjer u potpunosti šivanog broda otkrivenog u Sredozemlju. Ovaj primjerak ujedno je i prvi dokaz tradicije šivanih brodova koja se razvila na sjevernom Jadranu, a čiji je kontinuitet potvrđen sve do kraja antike (Pomey, Boetto 2019, 8-12; Boetto 2024).

Obrada drvenih elemenata započela je već nakon posljednje akcije iskapanja prapovijesnog plovila 2013. godine. Analizirano je 28 uzoraka s ostataka brodske konstrukcije te identificirano pet taksona (Ferreira Domínguez *et al.* 2019). Dendromorfološka analiza i opažanja tragova alata nisu provedeni na terenu, već su naknadno obavljeni na temelju fotografske dokumentacije, što je predstavljalo značajno ograničenje (Eeckman 2019). Također, dendrokronološka analiza bila je provedena samo na dva nepovezana komada drva iz oplate (PRL11 i PRL19), koji su imali ograničen broj godova (manje od 50) (Ferreira Domínguez 2021, 94-95).

Budući da nije bilo moguće uspostaviti korelaciju s referentnim kronologijama, provedeno je precizno 14C datiranje metodom AMS radiokarbonskog *wiggle matchinga* (Pearson 1986; Bronk Ramsey i dr. 2001) na četiri uzorka prikupljena iz serije godova PRL11. Rezultati nisu omogućili visoku kronološku rezoluciju zbog tzv. Halštatskog koljena, platoa u radiokarbonskoj kalibracijskoj krivulji koji utječe na datume iz razdoblja 1210. - 1140. g. pr. Kr. Ti su rezultati stoga, zajedno s onima koji su prethodno dobiveni s Instituta Ruđer Bošković (Zagreb) i Beta Analytic Inc. (Miami), smjestili dataciju izgradnje broda u period vrlo širokog raspona, između 1288. i 930. g. pr. Kr. (Guibal *et al.* 2019, 121, Sl. III.2).

1. METODE I MATERIJAL ISTRAŽIVANJA

Podizanje ostataka trupa broda iz Zambratije 2023. godine omogućilo je izravno proučavanje morfologije svakog sačuvanog elementa brodske konstrukcije[1]. Zahvaljujući rastavljanju same konstrukcije u cilju podizanja, prikupljeni su poprečni presjeci svih platica oplate. Ne bi li granice godova bile jasno vidljive, poprečne su plohe zaglađene žiletom. Širine godova mjerene su s preciznošću od 0,01 mm uporabom fotografija i programa *CooRecorder* (Maxwell, Larsson 2021). Radi lakšeg opažanja, pribadače su postavljane na mjesta gdje

[1] Za proces podizanja, metode i nove podatke o strukturi broda vidi članak Koncani Uhač et al., u ovoj publikaciji.

INTRODUCTION

The Zambratija boat (Istria, Croatia) has been dated to the Late Bronze / Early Iron Age (Koncani Uhač *et al*. 2019 with bibliography) and is the oldest example of an entirely sewn boat discovered in the Mediterranean. This wreck is also the first evidence of a sewn-boat tradition that developed in the northern Adriatic, and whose survival is attested until the end of antiquity (Pomey, Boetto 2019, 8-12; Boetto 2024).

The study of wooden elements had already been addressed following the last excavation campaign on the wreck in 2013. Twenty-eight samples from the structure were analysed and five taxa were identified (Ferreira Domínguez *et al.* 2019). The dendromorphological analysis and observations of tool marks were not carried out in the field during excavation; this was achieved later on the basis of photographic documentation, which was a significant limitation (Eeckman 2019). Furthermore, dendrochronological analysis had only focused on two disjointed pieces of wood from the planking (PRL11 and PRL19) which offered a limited number of rings (less than 50) (Ferreira Domínguez 2021, 94-95).

Since no correlation could be established with master chronologies, accurate 14C dating by AMS radiocarbon wiggle matching (Pearson 1986; Bronk Ramsey *et al.* 2001) was attempted on four samples collected from PRL11 tree-ring series. Results did not provide a high chronological resolution because of a plateau in the radiocarbon calibration curve that affects dates in the period 1210-1140 BCE. Therefore, these four results combined with those previously carried out by the Ruđer Bošković Institute (Zagreb) and Beta Analytic Inc. (Miami) offered a very large date range, spanning 1288-930 BCE for the boat construction (Guibal *et al.* 2019, 121, fig. III.2).

1. METHODS AND MATERIAL OF STUDY

The recovery of the Zambratija wreck in 2023 allowed direct observation of the morphology of each preserved element of the boat structure[1]. As the wreck was dismantled cross-sections were collected for all the strakes. In order to make the ring limits clearly visible, transverse planes were surfaced by using razor blades. Ring widths were measured to a 0.01 mm resolution using photography and the CooRecorder program (Maxwell, Larsson 2021). Sewing pins were placed to identify where the tree

[1] For the process of recovery, methods and new information on the boat structure, see the article by Koncani Uhač et al. in this volume.



Sl. 1 Priprema poprečnog presjeka za dendrokronološku analizu uz pomoć žileta, u cilju jasnije vidljivosti godova (L. Damelet, CCJ/CNRS).
Fig. 1 Preparation of sections for dendrochronological analysis using razor blades to enhance the readability of growth rings (L. Damelet, CCJ/CNRS).

su se godovi nastavljali preko slomljenih fragmenata, čime je pojednostavljena analiza poprečnih ploha (Sl. 1).

Fotografska dokumentacija osigurala je trajni digitalni zapis i omogućila dostupnost podataka za kasnije analize. Također, to omogućava da se izbjegne prikupljanje velikih uzoraka drva i njihov transport u laboratorij. Uz to, 3D skeniranje konstrukcije iz Zambratije pružilo je neprocjenjivu dokumentaciju za proučavanje drva, posebice za rekonstrukciju izvornog stabla.

2. REZULTATI

2.1. Identifikacija drva i tehnologije obrade

2.1.1. Uzdužni osni element (P2) i oplata

Uzdužni osni element P2 izrađen je iz jednog komada drva brijesta (*Ulmus* sp.) najmanjeg promjera oko 70 cm te starosti barem 77 godina. Vjerojatno je izdubljen iz polovine debla uz pomoć sjekire, na što ukazuju brojni tragovi alata vidljivi na unutarnjoj površini (Sl. 2 a). Ova tehnika vjerojatno je pridonijela značajnoj strukturnoj slabosti, što potvrđuju popravljene pukotine na dnu duž središnje osi (Sl. 3). Pukotine su mogle nastati zbog mehaničkog stresa prilikom obrade svježeg drva, kao i zbog prirodnih svojstava materijala.

Metoda proširivanja elementa P2 (parom i vatrom) još nije utvrđena. Na najširem dijelu presjeka uočena je izražena deformacija godova (Sl. 4). Ova deformacija mogla bi biti povezana s tehnikom proširivanja, ali može se pripisati i unutarnjim anatomskim obrascima drvnog tkiva[2]. S druge strane, spaljeno područje na unutarnjoj

[2] *Ulmus laevis* ima ukrštena drvna vlakna, što otežava obradu i uzrokuje nedostatke (Caudullo, de Rigo 2016).

ring continued across the broken fragments, making the analysis easier (Fig. 1).

Photographic documentation provides a permanent digital record, ensuring that data are accessible for later analyses. It also avoids the collection of large samples of wood and the transportation of it to the laboratory. In addition, the 3D scanning of the Zambratija wreck provided invaluable documentation for the study of wood, particularly for the reconstruction of the parent trees.

2. RESULTS

2.1 Wood identification and woodworking technology

2.1.1 The longitudinal axial element (P2) and the planking

The longitudinal axial element P2 was carved from a single timber from an elm trunk (*Ulmus* sp.) with a minimal diameter of *circa* 70 cm and at least 77 years old. It was likely hollowed out from a half-trunk using an axe, as shown by the numerous tool marks on the inner surface (Fig. 2 a). This technique may have contributed to significant structural weakness, as evidenced by the repaired cracks on the bottom along its central axis (Fig. 3) The cracks could have resulted from both the mechanical stress of working the fresh wood and the natural properties of the material.

The expansion of P2 using steam and fire is not yet established. A prominent distortion of the annual rings is observed at the point towards the widest cross-section (Fig. 4). This distortion could be related to expansion



Sl. 2 a) Tragovi sjekire na unutarnjoj površini uzdužnog osnog elementa P2 (Ph. Soubias, CNRS/CCJ); b) Tragovi tesle na vanjskoj površini platice (L. Damelet, CNRS/CCJ).
Fig. 2 a) Axe tool marks on the inner face of the axial element P2 (Ph. Soubias, CNRS/CCJ); b) Adze tool marks on the outer surface of a strake (L. Damelet CNRS/CCJ).

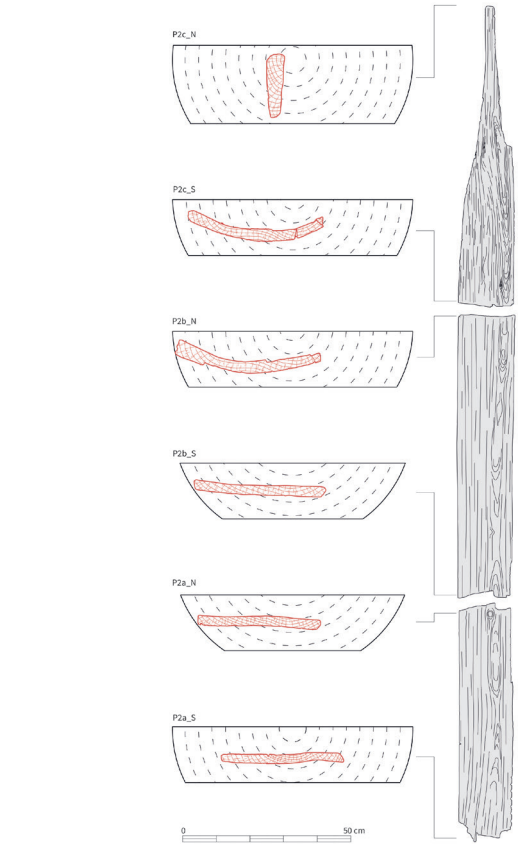


Sl. 3 Zakrpana pukotina na dnu, sredinom uzdužnog osnog elementa (P2) (Ph. Soubias, CNRS/CCJ).
Fig. 3 Repaired crack on the bottom along the central axis of the longitudinal axial element (P2) (Ph. Soubias, CNRS/CCJ).

strani elementa P2, blizu ekstremiteta, vjerojatnije je rezultat dubljenja debla, a ne njegova proširivanja.

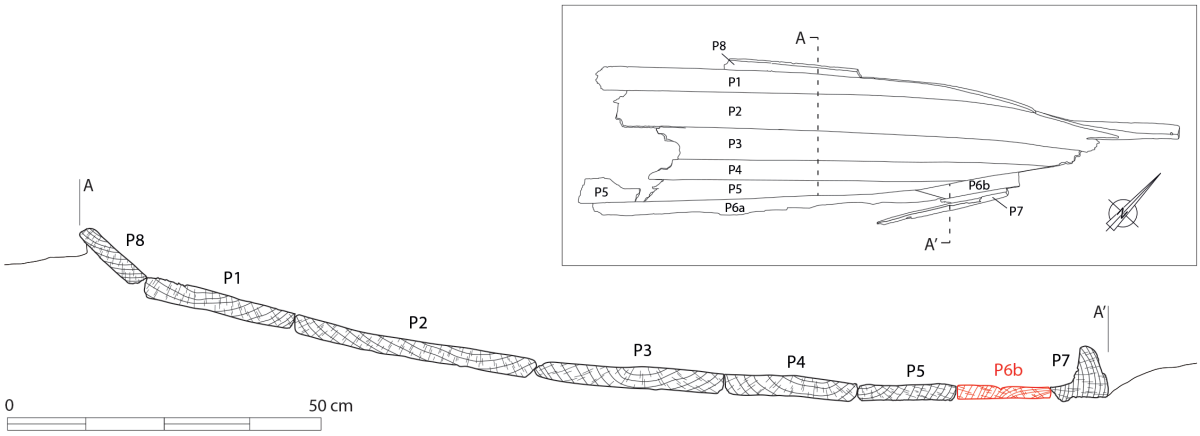
Sve platice oplate također su izrađene od drva brijesta, što upućuje na namjerni odabir određene vrste drveta za izradu oplate. Brodograditelji su koristili tangencijalne rezove (rascjep u smjeru godova), koje su oblikovali sjekirom i teslom (Sl. 2 b). Debla su imala približan promjer od 40 cm, a stabla su bila stara najmanje 67 godina.

Prilikom analize orijentacije godova platica važno je napomenuti da je srž stabla dosljedno bila okrenuta prema unutrašnjosti broda. Ovakva orijentacija, vidljiva i na kutovima presjeka, sugerira da su brodograditelji koristili prirodnu zakrivljenost debla kako bi oblikovali trup. Iznimka je uočena kod jedne platice (P6b), gdje je srž orijentirana prema van (Sl. 5).



Sl. 4 Orijentacija godova na uzdužnom osnom elementu P2, s vidljivim deformacijama (K. Nees, AMU/CCJ).
Fig. 4 Growth ring orientation on the axial piece P2 showing the distortions (K. Nees AMU/CCJ).

technology, but could also be attributed to internal anatomical patterns of the tissue[2]. On the other hand, the burnt area on the inner side of P2, near the extremity,



Sl. 5 Tragovi sječe i položaj srži na platicama (K. Nees, AMU, CCJ).
Fig. 5 Felling cuts and pith orientation on the strakes (K. Nees, AMU, CCJ).

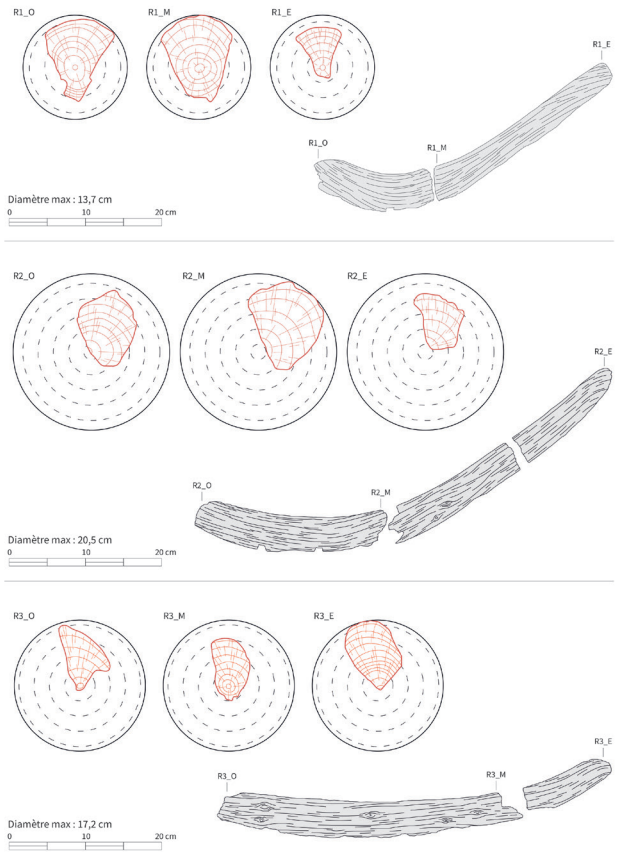
[2] *Ulmus laevis* has cross-grained wood, which causes difficulty in woodworking and defects (Caudullo, de Rigo 2016).

2.1.2. Rebrenice

Rebrenice potječu od dviju vrsta tvrdog drva: dvije su od johe (*Alnus* sp.) i jedna od divlje kruške (*Rosaceae maloïdeae cf. Pirus*). Ovi elementi izrađeni su od debala promjera približno 20 cm i starosti oko 15 godina, blago could be related to the carving of the trunk rather than to the expansion.

All the strakes were also crafted from elm wood, indicating the deliberate choice of a specific species for the planking. The shipbuilders employed tangential cuts (rift splits), which were shaped using an axe and an adze (Fig. 2 b). The trunks had an approximate diameter of 40 cm and the trees were at least 67 years old.

When examining the tree-ring orientations of the strakes, it is noteworthy that the pith of the trees is consistently oriented towards the interior of the boat. This alignment, which also appears at the corners of the sections, suggests that the shipbuilders exploited the natural curvature of the trunks to aid in the shaping of the hull. An exception to this pattern is observed in one plank (P6b), where the pith is oriented outward (Fig. 5).



Sl. 6 Orijentacija godova na trima rebrima (R1, R2 i R3), s vidljivom blizinom srži (K. Nees, AMU, CCJ).
Fig. 6 Growth ring orientation on the three frames (R1, R2 and R3) showing the proximity of the pith (K. Nees, AMU, CCJ).



Sl. 7 Tragovi sjekire i tesle na rebru R2 (Ph. Soubias, CNRS/CCJ).
Fig. 7 Axe and adze tool marks on frame R2 (Ph. Soubias, CNRS/CCJ).

2.1.2 Floor timbers

The floor timbers were crafted from two hardwood species: two from alder *(Alnus* sp.*)* and one from wild pear *(Rosaceae maloïdeae cf. Pirus)*. These timbers were derived from trunks with an approximate diameter of 20 cm and an age of *circa* 15 years, slightly curved, likely from a forked branch curving out from the tree.

The analyses of cross-sections reveal that these timbers were taken from parts of the trunk close to the pith,



Sl. 8 Tragovi dlijeta u slivnici na rebru R2 (Ph. Soubias, CNRS/CCJ).
Fig. 8 Chisel tool marks in a limber hole of the frame R2 (Ph. Soubias, CNRS/CCJ).

zakrivljenih, vjerojatno iz račvastih grana koje su se odvajale od stabla.

Analize poprečnih presjeka pokazuju da su rebrenice uzete iz dijelova debla blizu srži, što upućuje na selektivan pristup pri odabiru materijala (Sl. 6). Oblikovane su teslom, a kora je uklonjena ne bi li se dobile glatke površine (Sl. 7) te su dlijetom izdubljene slivnice (Sl. 8).

2.1.3. Letvice

Letvice, uključujući i one korištene za popravke, sustavno su izrađene od jelovine (*Abies* sp.) i dobivene su radijalnim cijepanjem trupca (Sl. 9). Ova metoda posebno je prikladna za vrste s ravnim vlaknima, poput jele, jer omogućuje dobivanje dugih, ravnih komada drva (Lieutaghi 1969, 1173; Rival 1991, 40-41). Tehnika radijalnog cijepanja omogućuje da se očuva poravnanje vlakana, čime se povećava vodootpornost (Renard 1921, 11).

Radijalno cijepanje također omogućuje proizvodnju iznimno tankih komada poput ovih, maksimalne debljine 0,5 cm. Odabir jele i način sječe svjedoče o pomnom poznavanju drva i načina kako najbolje iskoristiti njegova svojstva. To bi također moglo objasniti i namjerni odabir vrste koja raste u planinskim područjima te ju je trebalo transportirati do brodogradilišta.

indicating a selective approach to the material (Fig. 6). Timbers were shaped using an adze, with the bark removed to ensure smooth surfaces (Fig. 7). Additionally, a chisel was employed to cut the limber holes (Fig. 8).

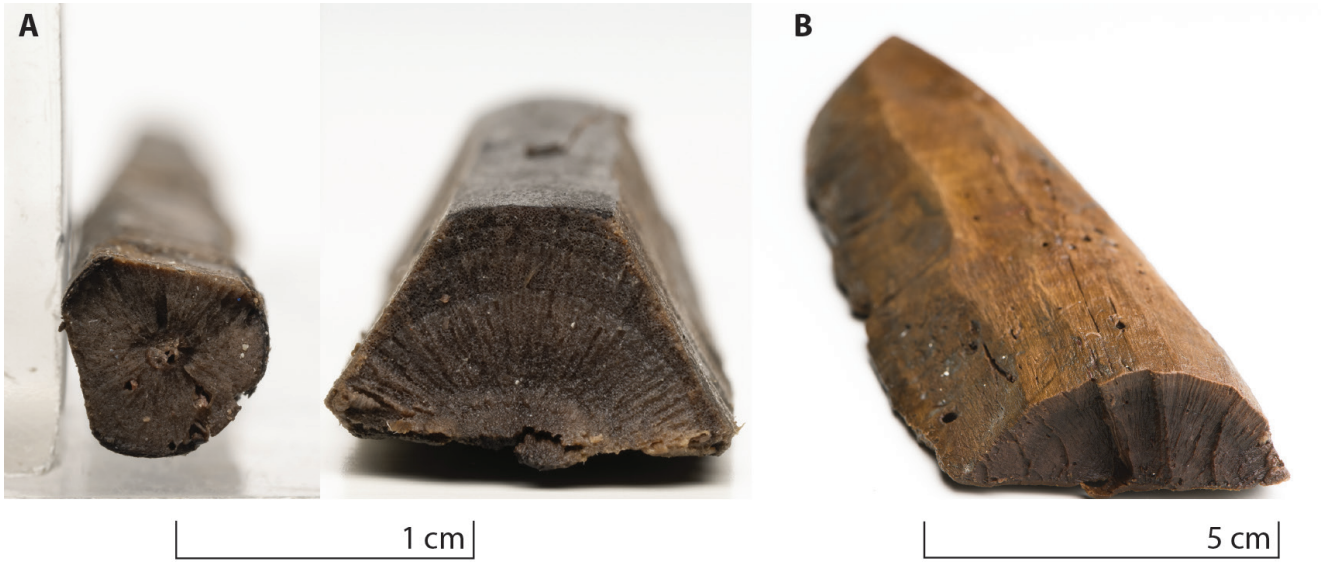
2.1.3 Laths

The laths, including those used for repairs, were systematically made from fir wood (*Abies* sp.). They were crafted by splitting the log radially (Fig. 9). This method seems particularly suited for species with straight grains, such as fir, producing long, straight pieces of wood (Lieutaghi 1969, 1173; Rival 1991, 40-41). The splitting technique preserves the alignment of the fibres, enhancing water resistance (Renard 1921, 11).



Sl. 9 Radijalni rez na presjeku letvice (L. Damelet, CNRS/CCJ).
Fig. 9 View of the radial cut in the section of a lath (L. Damelet, CNRS/CCJ).

Radial splitting also enables the production of exceptionally thin pieces like these, with a maximum thickness of 0.5 cm. The selection of fir and the felling technique evidence a thorough knowledge of the wood



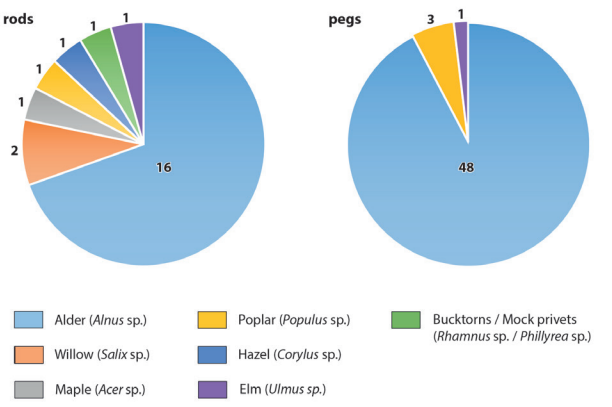
Sl. 10 a) Dvije grančice korištene u sustavu vodonepropusnosti, trapezoidnog presjeka (L. Damelet, CNRS/CCJ); b) Jedna od dviju zakrpa s polumjesečastim presjekom (Ph. Soubias, CNRS/CCJ).
Fig. 10 a) Views of two sealing rods, trapezoidal in section (L. Damelet, CNRS/CCJ); b) One of the two patches with half-moon section (Ph. Soubias, CNRS/CCJ).

2.1.4. Grančice (štapići)

Tanke grančice (štapići), promjera od 0,5 do 2 cm, korištene su za vodonepropusnost broda. Ove su grančice, cijele ili prepolovljene, pažljivo oblikovane kako bi se osiguralo njihovo precizno uklapanje u spojeve između platica (Sl. 10 a).

Analizirane su 23 grančice te je među njima identificirano šest različitih vrsta tvrdog drva. Većina je izrađena od johe (*Alnus* sp.), a u manjoj mjeri od vrbe (*Salix* sp.), javora (*Acer* sp.), topole (*Populus* sp.), lijeske (*Corylus* sp.), brijesta (*Ulmus* sp.) te krkavine/šmrijeka (*Rhamnus* sp./*Phillyrea* sp.)[3] (Sl. 11).

Zanimljivo je da mnoge grančice i dalje imaju dijelove kore, što je omogućilo da se utvrdi vrijeme sječe - ona je obavljena zimi, tijekom razdoblja mirovanja stabla. Ovaj podatak sugerira da je brod konstruiran ili popravljen tijekom zimskog razdoblja.



Sl. 11 Udio vrsta korištenih za izradu brtvenih grančica i malih drvenih klinova za učvršćivanje šavova.
Fig. 11 Percentage of taxa in the sealing rods and stitching pegs.

2.1.5. Mali drveni klinovi za učvršćivanje šavova

Pedeset i dva mala drvena klina korištena za učvršćivanje šavova izrađena su od tri vrste drva: uglavnom od johe (*Alnus* sp.), ali i od topole (*Populus* sp.) te brijesta (*Ulmus* sp.) (Sl. 11).

Nijedan od klinova nema elemente srži, što ukazuje da za njihovu izradu nisu korištene male grane. Umjesto toga, vjerojatno su izrađeni od drvnih ivera ili otpadaka nastalih tijekom obrade glavnih elemenata, poput johinih grana korištenih za izradu rebara.

[3] Teškoća u anatomskoj razlikovnosti između krkavine (*Rhamnus* sp.) i šmrijeka (*Phillyrea* sp.) navela nas je na uporabu binoma (Schweingruber 1990, 575, 607).

material and how to get the most from its properties. This could also explain the deliberate selection of fir, a species that grows in mountain areas and that must be transported to the shipyard.

2.1.4 Rods

Thin rods, with a diameter of 0.5 to 2 cm, were used for the waterproofing of the boat. These rods are either whole-cut or half-cut, and they are carefully shaped to ensure a precise fit within the joins between the planks (Fig. 10 a).

Six different hardwood species have been identified on the 23 rods analysed. They are in the majority cut from alder (*Alnus* sp.) and, to a lesser extent, from willow (*Salix* sp.), maple (*Acer* sp.), poplar (*Populus* sp.), hazel (*Corylus* sp.), elm (*Ulmus* sp.) and buckthorn/mock privet (*Rhamnus* sp./*Phillyrea* sp.)[3] (Fig. 11).

Remarkably, many of the branches retain portions of bark tissue, which allowed us to assess that the felling occurred in winter during the tree's dormant period. This result suggests that the boat was constructed or, possibly, repaired during this season.

2.1.5 Pegs locking the stitches

Fifty-two small pegs used to lock the stitches are made from three wood species: in the majority alder (*Alnus* sp.), but also poplar (*Populus* sp.) and elm (*Ulmus* sp.) (Fig. 11).

None of the pegs retain the pith, which suggests that small branches were not used. Instead, it is probable that the pegs were crafted from wood chips or offcuts produced during the woodworking of principal pieces, such as the alder branches used for the frames.

1.1.6 Repair patches

The two patches inserted on the outer face of the boat between the strakes P2 and P3 are made from alder (Fig. 10 b).

1.2 Initial dendrochronological data

Several cross-sections of the axial element P2 and of the other strakes were analysed, allowing us to build up

[3] The difficulty in anatomically distinguishing between buckthorn (*Rhamnus* sp.) and mock privet (*Phillyrea* sp.) led us to use the binomial (Schweingruber 1990, 575 and 607).

2.1.6. Zakrpe

Dvije zakrpe umetnute na vanjskoj strani broda, između platica P2 i P3, izrađene su od johe (Sl. 10 b).

2.1. Polazni dendrokronološki podaci

Analizirano je nekoliko presjeka uzdužnog elementa P2 i ostalih platica, što je omogućilo sastavljanje prosječne kronologije duge 98 godina, reprezentativne za brijest[4]. U ovoj fazi dendrokronološka analiza još ne može odrediti točan broj stabala brijesta korištenih u gradnji brodske konstrukcije, zbog prisutnosti čvorova koji otežavaju izračun, ali radi se na rješavanju tog pitanja.

Jelove letvice, iako malih dimenzija (4 do 5 cm širine i 0,5 cm maksimalne debljine), pokazale su se pogodnima za dendrokronološku analizu: serije su sadržavale i do 90 godova.

Nažalost, prosječne kronologije za brijest i jelu zasad su neodređene te se moraju testirati u odnosu na referentne kronologije iz južne Europe i udaljenijih geografskih područja. Planirano je i prikupljanje uzoraka drva kako bi se provelo precizno 14C datiranje metodom AMS radiokarbonskog *wiggle-matchinga*.

3. RASPRAVA I ZAKLJUČAK

Analizama drva identificirano je ukupno devet vrsta, s prevladavajućim vrstama tvrdog drva (brijest, joha, divlja kruška, vrba, javor, topola, lijeska, krkavina/šmrijek) te jednom četinjačom (jela).

Trup broda iz Zambratije vrlo je homogeno izgrađen, s isključivom uporabom brijesta za oplatu, dobivenog iz trupaca, i najmanje dvjema različitim vrstama za rebra, izrađenima od grana odabranih zbog svoje prirodne zakrivljenosti. Mali drveni klinovi, grančice i zakrpe otkrivaju sklonost prema uporabi johe, vrste koja je izdržljiva pri korištenju pod vodom. Ove vrste vjerojatno su bile dostupne u vrijeme gradnje ili kao otpad nastao obradom trupa, budući da je joha korištena i za rebra. Uporaba malih grana za štapiće korištene u sustavu vodonepropusnosti također ukazuje na specifičnu potragu za prirodno pogodnom morfologijom. Isključiva uporaba jele za letvice može se objasniti preciznošću tehnike cijepanja, koja zahtijeva

[4] Rebrenice imaju manje od 20 godova i nisu bile prikladne za dendrokronološku analizu, budući da su za statistički pouzdane usporedbe potrebne serije od najmanje 60 godova (Baillie 1982). Isto vrijedi za male drvene klinove i grančice (štapiće).

a mean 98-year-long chronology, representative of elm[4]. At this stage, dendrochronological analysis cannot yet determine the exact number of elm trees used in the boat's construction, as the presence of knots complicates the calculation. Nevertheless, we are working to address this issue.

Despite their small dimensions (4 to 5 cm in width and 0.5 cm in maximal thickness), the fir laths proved suitable for dendrochronological analysis: series provided up to 90 rings.

Unfortunately, the elm and fir mean chronologies are currently floating and have to be tested against master chronologies from Southern Europe and remote geographical regions. It is also planned to collect samples of wood to perform accurate 14C dating by AMS radiocarbon wiggle matching.

3. DISCUSSION AND CONCLUSION

A total of nine species were identified, associating predominant hardwoods (elm, alder, wild pear, willow, maple, poplar, hazel, buckthorn/mock privet), and a single conifer species (fir).

The hull of the Zambratija boat is very homogeneous, with elm used exclusively for the planking, sourced from trunks, and at least two different species for the frames, which were made from branches, selected for their naturally curved morphology. Pegs, rods and patches reveal a preference for the use of alder, a durable wood when kept under water. These species were probably available at the time of construction, or even from the offcuts of the hull work, as alder was used in the frames. The use of small branches for the rods also indicates a specific search for a natural morphology. The exclusive use of fir in the laths can be explained by the precision of the splitting technique, which requires woods with specific properties (straight and homogeneous grain, moderate hardness, low density, reduced tendency to splinter, and flexibility), thereby limiting the selection.

All the species used for the construction of the Zambratija sewn boat have today a very wide geographic distribution in the Adriatic region, including the Istria Peninsula. Nevertheless, given that this vessel is presumed to be of local origin and use, the selection of local timbers is probable. With the exception of fir, which

[4] The floor timbers have fewer than 20 rings and were not suitable for dendrochronological analysis, as series of at least 60 rings are required to guarantee statistically reliable matches (Baillie 1982). The same applies to pegs and rods.

vrste s posebnim svojstvima (ravna i homogena vlakna, umjerena tvrdoća, niska gustoća, smanjena sklonost rascjepljivanju i fleksibilnost), čime se sužava izbor.

Sve vrste korištene za izradu ovog šivanog broda danas imaju široku rasprostranjenost u jadranskoj regiji, uključujući istarski poluotok. Ipak, s obzirom na to da je pretpostavljeno lokalno podrijetlo i uporaba plovila, izbor lokalnog drva je vjerojatan. Osim jele, koja je planinska vrsta, sve su ostale vrste, koje rastu u poplavnim šumama, vjerojatno bile dostupne u neposrednoj blizini brodogradilišta. Jela je mogla stizati iz planinskih lanaca Učke i Ćićarije, odakle se drvo moglo spuštati do obale rijekama poput Mirne.

Preliminarni dendroarheološki rezultati brodske konstrukcije iz Zambratije pružaju uvid u tehnike gradnje brodova tijekom prijelaza s kasnog brončanog do ranog željeznog doba na sjeveroistočnom Jadranu. Oni tumače odnos između lokalnih prirodnih resursa i graditeljskih praksi, ukazujući da su brodograditelji svjesno i prilagodljivo koristili odabrane vrste drva.

Analiza je također otkrila vrlo selektivan odabir vrsta, koji odražava temeljito poznavanje svojstava drva i njihovu prikladnu primjenu kako bi se optimizirala čvrstoća i trajnost broda. Kad je riječ o tehnikama obrade, izuzetno je zanimljiva isključiva uporaba sjekira i tesli za oblikovanje trupaca i grana, umjesto pila. Tehnika cijepanja za dobivanje tankih letvica od jelovih trupaca također pokazuje dobro poznavanje svojstava ove četinjače i visoku razinu stručnosti.

Trenutna dendrokronološka istraživanja bit će ključna za preciznije datiranje gradnje broda te će doprinijeti proširenju dendrokronološke baze podataka za Sredozemlje. Dodatnu prednost predstavlja mogućnost uzimanja uzoraka nakon dendrokronoloških analiza, a prije početka konzervatorske obrade. Time se omogućava kalibracija AMS radiokarbonskog datiranja metodom *wiggle-matchinga*, što bi moglo odrediti vrijeme sječe stabala korištenih za gradnju broda te uspostaviti kronološki okvir za proučavanje razvoja tradicije šivanih brodova na Jadranu.

is a mountain species, all the other species, growing in riparian woodlands, were probably available within a short distance of the shipyard. Fir could have come from the Učka and Ćićarija mountain range, from where wood could be floated to the coast by rivers, such as the Mirna.

The preliminary dendroarchaeological results from the Zambratija boat provide insights into the shipbuilding techniques used during the transition from the Late Bronze Age to the Early Iron Age in the north-eastern Adriatic. They shed light on the relationship between local natural resources and construction practices, suggesting that the shipbuilders made a conscious and adaptive use of the selected wooden species.

The study has also revealed a highly selective use of wood species reflecting a thorough knowledge of wood properties and their adequate application to optimize the boat strength and durability. Regarding woodworking techniques, the exclusive use of axes and adzes for shaping the trunks and branches instead of saws is remarkable. The splitting technique to obtain thin laths from fir trunks also demonstrates a good knowledge of the qualities of this conifer and a high level of expertise.

The ongoing dendrochronological study will be crucial for dating the boat construction more precisely and will contribute to expanding the dendrochronological database for the Mediterranean. The possibility of taking samples after the dendrochronological analyses and before the start of the conservation treatment is also a plus. This would allow for AMS radiocarbon dating to be calibrated by wiggle matching, which may enable us to define the felling date of the trees used in the construction of the boat and to establish a chronological framework for the study of the development of the Adriatic sewn-boat tradition.

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