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PRAPOVIJESNI ŠIVANI BROD ZAMBRATIJA - PODIZANJE IZ PODMORJA I NOVA ZAPAŽANJA O BRODSKOJ KONSTRUKCIJI

THE ZAMBRATIJA PREHISTORIC SEWN BOAT: RECOVERY AND NEW OBSERVATIONS CONCERNING THE BOAT'S STRUCTURE

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Tijekom lipnja i srpnja 2023. hrvatsko-francuski tim arheologa, restauratora, tehničara i ronilaca, okupljen oko Arheološkog muzeja Istre, Ministarstva kulture i medija RH i Centra Camille Jullian (CNRS, Sveučilište Aix Marseille), iz podmorja uvale Zambratija podigao je ostatke istoimenog prapovijesnog šivanog broda. Brodska konstrukcija je cjelovito istražena 2013. godine, a prezentirana je kroz brojne izložbe s pratećim katalogom te stručno-znanstvenom monografijom u kojoj su izneseni svi dotad poznati podaci o plovilu. Demontiranje i podizanje plovila pružili su izvanrednu priliku za dovršetak analize ovog unikatnog nalaza. Novi podaci o načinu izgradnje, popravcima te brtvljenju trupa dobiveni su zahvaljujući rastavljanju brodske konstrukcije te pažljivom dokumentiranju i analizi svakog pojedinog elementa. Cjelovita brodska konstrukcija je dokumentirana, fotografirana i skenirana uz pomoć prijenosnog 3D skenera. Cilj ovog članka je prikaz postupka odnosno metodologije primijenjene za podizanje nalaza iz podmorja, ali i uvid u nove podatke, iako su analize i 3D rekonstrukcija još u tijeku.

KLJUČNE RIJEČI: *Sjeverni Jadran; Istra; Zambratija; podvodna arheologija; šivani brod; kasno brončano doba, rano željezno doba*

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A team of Croatian and French archaeologists, restorers, technicians, and divers gathered around the Archaeological Museum of Istria, the Culture and Media Ministry of the Republic of Croatia, and the Centre Camille Jullian (CNRS, Aix Marseille Université), raised the remains of the Zambratija Late Bronze Age / Early Iron Age sewn boat from the seabed of Zambratija cove in June and July of 2023. The shipwreck was comprehensively investigated in 2013 with the results presented at many exhibitions, accompanied by a catalogue, and in a specialist monograph presenting the data known at the time of publication. The recovery of the boat provided a unique opportunity to complete the analysis of this unique find. New data concerning the building methods, repairs, and the waterproofing system of the hull have been obtained as a result of the dismantling of the boat and the meticulous documentation and analysis of each timber. The entirety of the surviving structure was documented, photographed, and scanned with a portable 3D scanning device. This paper discusses the procedures used, i.e., the methods employed, to raise the find from the seabed, to document it underwater and on land, and the newly obtained data, notwithstanding the still ongoing analysis and 3D reconstruction.

KEY WORDS: *North Adriatic; Istria; Zambratija; underwater archaeology; sewn boat; Late Bronze Age; Early Iron Age*

Brodska konstrukcija Zambratija otkrivena je 2008. godine u istoimenoj uvali na sjeverozapadnom dijelu istarske obale. Djelomično je istražena 2011. godine, a u potpunosti 2013. (Sl. 1) kada je dokumentirana unutrašnja strana trupa broda. Nakon istraživanja, brod je prekriven pijeskom i osiguran željeznim mrežištem (Koncani Uhač, Uhač 2019, 18-49). Metodom AMS radiokarbonskog datiranja uzorci platica broda datirani su u kasno brončano / rano željezno doba Istre (između posljednje četvrtine 12. stoljeća i posljednje četvrtine 10. stoljeća pr. Kr.). Unutar i uokolo brodske konstrukcije nisu pronađeni pokretni arheološki nalazi koji bi pružili preciznu kronologiju, a ujedno nije bilo moguće utvrditi ni je li brod napušten ili je nastradao u brodolomu.

Povijest otkrića i istraživanja, rezultati proučavanja brodske konstrukcije, prve rekonstrukcije forme i dimenzija plovila, identifikacija vrsta drveta, prve spoznaje o morfologiji te tragovima alata korištenih za izradu, kao i razmatranja o brodu u povijesnom kontekstu brončanodobne Istre odnosno lokalne brodograđevne tradicije, detaljno su obrađeni u monografiji *Zambratija. Prapovijesni šivani brod. Rezultati arheološkog istraživanja, analiza i studija* (Koncani Uhač *et al.* 2019.).

U ovom se radu donosi osvrt na primijenjenu metodologiju vađenja broda iz podmorja te novi uvid u strukturu brodske konstrukcije, kojim će se pokušati odgovoriti na istraživačka pitanja koja su ostavila nedoumice nakon terenskog istraživanja u 2013. godini, kao i na naknadne laboratorijske analize. Riječ je o

The Zambratija boat was discovered in 2008 in the Zambratija cove, located on northwestern coast of the Istrian peninsula. It was partially investigated in 2011, and comprehensively investigated in 2013 (Fig. 1), with the latter campaign involving the documentation of the inboard side of the boat's hull. Following the investigative work, the boat was covered with sand and secured with iron mesh (Koncani Uhač, Uhač 2019, 18-49). The AMS radiocarbon method was used to date samples taken from the boat's planks, yielding results that placed the boat in the Late Bronze / Early Iron Age in Istria (last quarter of the 12th to last quarter of the 10th c. BCE). No artefacts were identified within or around the boat's structure that would provide for a narrower dating window, and there were no indications as to whether the boat was abandoned or wrecked.

The discovery and investigation, the results of the examination of the boat's structure, the initial reconstruction of the boat's form and dimensions, the identification of the wood species, the first insights into the morphology and traces of the tools used to build the boat, and the boat's place in the historical context of Bronze Age Istria, i.e., in the local shipbuilding tradition, are all treated in detail in the monograph *Zambratija Prehistoric Sewn Boat: Results of the Archaeological Research, Analysis and Study* (Koncani Uhač et al. 2019).

This paper reviews the recovery and documentation methods and new insights into the boat's structure, aimed at attempting to answer the open questions remaining after



Sl. 1 Položaj lokaliteta te prapovijesni brod Zambratija tijekom istraživanja u 2013. godini (fotografija: Ph. Groscaux, CNRS/CCJ).
Fig. 1 The position of the site / the prehistoric Zambratija boat during 2013 investigative work (photo: Ph. Groscaux, CNRS/CCJ).

neodgovorenim pitanjima koja su djelomično odredila način i postupak izvedenog podizanja brodskih elementa u 2023. godini iz podmorja[1].

BRODSKA KONSTRUKCIJA

Ostaci brodskog trupa sačuvani su u dužini 6,7 m te u širini 1,6 m. Brod se sastoji od uzdužnog osnog elementa (P2), dva voja platica na zapadnoj strani (P1 i P8), pet vojeva na istočnoj strani (P3 do P7) i tri rebrenice (R1 do R3). Peti, gornji voj (P7) ima presjek u obliku slova L te predstavlja završni voj. Uzdužno šivanje platice izvedeno je jednostavnim rubnim šavom. Vanjski rubovi platica su zakošeni radi upuštanja ligature unutar sljubnica platica, dok su rupe za šivanje izbušene ukoso, dijagonalno prema sljubnicama platica. Nakon što su platice bile opšivene, ligatura više nije bila vidljiva na vanjskoj strani oplate, što upućuje da je takav način utjecao na njenu trajnost. Preko sljubnica platica prije šivanja su se stavljale letvice širine 3 do 4 cm. Iako ligatura nije sačuvana, na letvicama su vidljivi njezini tragovi u negativu. Istim načinom šivanja popravljene su i neke pukotine na oplati. Šavovi su zaptiveni drvenim konusnim i zašiljenim čavlićima. Rebrenice su bile privezane za oplatu, razmaknute na prosječnoj udaljenosti od oko 83 cm.

Najistaknutiji element trupa je uzdužni osni element P2, čiji sjeverni kraj ima specifičan suženi oblik (23 cm visok i 6 cm širok) dok je središnji dio širine 39 cm i debljine 3 cm. Pitanje je li izvorno drvo izdubljeno teslom ili izdubljeno i prošireno bilo je jedno od glavnih neriješenih pitanja nakon istraživanja iz 2013. godine.

Ostala neodgovorena pitanja odnosila su se na vrstu ligature korištene za šivanje i vezivanje, budući da šavovi

[1] Na projektu vađenja broda sudjelovali su dr. sc. Ida Koncani Uhač, muzejska savjetnica iz Arheološkog muzeja Istre; Marko Uhač, viši stručni savjetnik iz Područne konzervatorske službe Pula; dr. sc. Pierre Poveda de Chabert Ostland, znanstveni inženjer-nautički arheolog iz Centra Camille Jullian (Fr); dr. sc. Giulia Boetto, istraživačica-nautička arheologinja iz Centra Camille Jullian (Fr); Andrea Dugandžić, viša konzervatorica-restauratorica iz Arheološkog muzeja Istre; Vincent Dumas, znanstveni inženjer-topograf iz Centra Camille Jullian; Loïc Damelet, pomoćni inženjer-fotograf iz Centra Camille Jullian; Phillipe Soubias, podvodni arheolog-fotograf iz Centra Camille Jullian; Kato Nees, doktorandica sa Sveučilišta u Marseilleu i Nera Janković, studentica MoMarcha na Sveučilištu u Marseilleu. Restauratori koji su radili na prihvatu brodskih elemenata, njihovom čišćenju te pripremi za desalinizaciju bili su Henri Bernard Maugiron, viši restaurator iz Arc Nuclearta (Grenoble) i Monika Petrović, viša konzervatorica-restauratorica iz Arheološkog muzeja Istre. Dendrološko proučavanje i uzorkovanje brodskih elemenata provela je dr. sc. Alba Ferreira Dominguez, dendroarheologinja iz firme Ipso Facto (Fr). Ronioci na istraživanju i demontaži broda su bili Anton Prekalj, Moreno Almassi, Ivan Pisak, Neven Kelemen i Daniele Kolec.

the 2013 fieldwork and subsequent laboratory analyses. These were unresolved questions that in part informed the methods and procedures used to raise the boat timbers from the seabed in 2023.[1]

THE BOAT'S STRUCTURE

The surviving part of the hull measures 6.7 metres in length and 1.6 metres in width. This includes a longitudinal axial timber (P2), or dugout base, two strakes of planking to the west side (P1 and P8), five strakes to the east side (P3 to P7), and three floor timbers (R1 to R3). The fifth, upper strake (P7) is L-shaped in section, and is the sheer strake (the topmost strake). The longitudinal sewing of the planks was done following a simple over-edge stitching pattern. The outboard edges of the plank are chamfered to allow ligatures to sit recessed in the seams where the planks meet, with the stitching holes bored obliquely, diagonal to the plank seams. Once sewn, the ligatures were no longer visible at the outboard face of the planking, indicating that the carpenters were aware that the stiches needed to be protected in order to ensure the effectiveness and durability of the assemblies. Laths measuring three to four centimetres in width were laid over the seams between planks prior to sewing. Although the ligatures have not survived, we do see their negative traces on the laths. Cracks in the planking were repaired applying the same sewing method. The stitching holes were plugged with conical pegs, thus locking the stitching in place. The floor timbers, on average spaced about 83 centimetres apart, were lashed to the planking.

[1] Participating in the boat recovery project were museum advisor Ida Koncani Uhač PhD of the Archaeological Museum of Istria, senior expert advisor Marko Uhač of the Conservation Department in Pula, research engineer and nautical archaeologist Pierre Poveda de Chabert Ostland PhD of the Centre Camille Jullian (CCJ), investigator and nautical archaeologist Giulia Boetto PhD of the CCJ, senior conservator and restorer Andrea Dugandžić of the Archaeological Museum of Istria, research engineer and archaeologist specialized in topography Vincent Dumas of the CCJ, engineers and photographers Loïc Damelet and Philippe Soubias of the CCJ, nautical archaeologist Kato Nees MA of Aix Marseille University, and student of Aix Marseille University Master of Maritime and Coastal Archaeology programme Nera Janković. The restorers that worked on the reception and cleaning of the boat timbers, and preparation for their desalination, were senior restorer Henri Bernard Maugiron of the ARC-Nucléart laboratory (Grenoble, Fr), and senior conservator and restorer Monika Petrović of the Archaeological Museum of Istria. Dendrological analysis and sampling of the boat's timbers was performed by dendroarchaeologist Alba Ferreira Dominguez PhD of the Ipso Facto company (Fr). Divers Anton Prekalj, Moreno Almassi, Ivan Pisak, Neven Kelemen, and Daniele Kolec made up the investigation and dismantling dive team.

nisu sačuvani, kao i na pitanje zašto jednu rupu kroz koju je bilo obavljeno šivanje čine dva ili tri utora te nadalje pitanje učinkovitosti sustava vodonepropusnosti broda koji je bio učvršćen biljnim vlaknima, prekriven letvicama i premazan paklinom s unutarnje strane trupa[2].

ODLUKA O PODIZANJU BRODSKE KONSTRUKCIJE

Reambulacije lokaliteta prapovijesnog broda u uvali Zambratija pokazale su da se, unatoč zaštiti s mrežištem postavljenim na kraju istraživanja u 2013. godini, brodska konstrukcija nalazi u opasnosti. Naime, sve učestalije ekstremne meteorološke nepogode uzrokovale su ubrzanu eroziju morskog dna, a stihijsko sidrenje u uvali dovelo je do ugroze lokaliteta (Sl. 2).



Sl. 2 Zračni snimak lokacije broda u uvali Zambratija tijekom istraživanja u 2023. godini (fotografija: Ph. Soubias).
Fig. 2 Aerial image of the boat site in Zambratija cove taken during the 2023 investigation (photo: Ph. Soubias).

S obzirom na važnost broda Zambratija, koji je do danas najstariji primjer šivanog plovila na Mediteranu, zaključeno je da bi rizik od njegova oštećenja rezultirao nemjerljivim materijalnim i znanstvenim gubitkom za buduće generacije. Stoga se počelo intenzivno razmišljati o njegovu podizanju s morskog dna, što je zahtijevalo adekvatnu pripremu cjelokupnog projekta. Također je razmatran način manipulacije i konsolidacije drvenih ostataka nakon vađenja, njihova detaljna analiza

[2] Priroda vlakana zahtijeva daljnja istraživanja. Početne analize identificirale su mahovinu kao i ovojnice, listove i korijenje biljke *Cymodocea nodosa*. Međutim, treba napomenuti da se čini kako se prisutnost ove morske cvjetnice dogodila nakon što je konstrukcija broda bila prekrivena sedimentima. Korijenje se razvilo u svim međuprostorima drvenih struktura, pridonoseći njihovoj degradaciji.

Longitudinal axial timber P2 is certainly the most conspicuous of the hull timbers, with its north terminal having a specific tapered form (standing 23 centimetres and six centimetres thick) while its central part is 39 centimetres wide and three centimetres thick. The question of whether the wood had been carved into its shape with an adze, or had been carved and then expanded into the desired form, was one of the primary unanswered questions following the 2013 investigative campaign, which can only be answered by studying the cross sections of the timber.

Other open questions pertained to the type of ligature material used for sewing and lashing (since the stitching has not survived), why a stitching hole is comprised of two or three channels, and the effectiveness of the system used to render the boat watertight, using plant fibres fixed in place by laths and coated with pitch on the inboard side of the hull.[2]

THE DECISION TO RAISE THE BOAT STRUCTURE

Reconnaissance of the prehistoric boat site at the Zambratija cove showed that, notwithstanding the protective mesh installed at the close of the 2013 investigative campaign, the boat's structure remained under threat. Increasingly frequent extreme weather events were causing accelerated erosion of the seabed, while uncontrolled anchoring activity posed a direct threat to the site (Fig. 2).

Mindful of the importance of the Zambratija boat, the oldest known example of a sewn boat in the Mediterranean, the conclusion was that any damage, which would cause immeasurable material and scientific loss for future generation, was an unwarranted risk. This opened intensive consideration as to raising the boat from the seabed, which would entail adequate preparation of a comprehensive project. This included considering the manner in which the find would be handled and the consolidation of the wooden remains post-extraction, detailed analysis of the material, and, finally, appropriate museum exhibition.

In 2013, prior to the investigation of the Zambratija boat, the Archaeological Museum of Istria had undertaken

[2] The nature of the fibers requires further investigation. Initial analyses identified moss and the sheaths, leaves and roots of *Cymodocea nodosa*. The presence of this seagrass, however, appears to be related to the period after the boat was covered with marine sediment. The roots of the seagrass developed in all the interstices of the wooden structures, contributing to their degradation.

te naposljetku izlaganje u odgovarajućem muzejsko-galerijskom prostoru.

Arheološki muzej Istre je u 2013. godini, prije istraživanja ovog broda, na području današnje Flaciusove ulice u Puli prethodno proveo zahtjevno arheološko istraživanje i vađenje dviju šivanih brodskih konstrukcija datiranih u drugu polovicu 2. st., otkrivenih prilikom komunalnih radova. Ostaci oba rimska broda *Pula 1* i *Pula 2* izvađeni su iz arheološkog iskopa, a brodovi su bili podvrgnuti konzervaciji u laboratoriju ARC-Nucléart u Grenobleu. Prvotno su konzervirani ostaci broda Pula 2 (Koncani Uhač *et al.* 2018, 178-182), a zatim i broda Pula 1 (Boetto *et al.* 2017, 192-196)[3]. Na užem i okolnom području rive u Puli, u okviru istih zaštitnih arheoloških radova utvrđene su i rimske lučke instalacije koje su zajedno s brodovima pripadale kontekstu gradske luke kolonije *Pola* (Koncani Uhač 2023, 169-171).

Pronalazak i vađenje rimskih šivanih brodova iz iskopa te s druge strane nedostatak prostora za njihovo izlaganje u matičnoj zgradi muzeja doveli su do ideje o potrebi izgradnje objekta za njihovu prezentaciju. Prethodno navedeni razlozi potrebe vađenja prapovijesnog broda Zambratija, a zajedno s brodovima iz Pule, te predmeti bogate podmorske baštine antičke Istre iznjedrili su projekt budućeg Paviljona šivanih brodova u Puli u kojem bi ti nalazi trebali biti muzealizirani.

PROJEKT PODIZANJA BRODA - DIZAJNIRANJE NOSAČA I HODOGRAM RADOVA

Nakon donošenja odluke o podizanju brodske konstrukcije, sljedeći je korak bio izbor metodologije vađenja te razrada tehnika i materijala kao i načina manipuliranja nalazom. S obzirom na krhkost drva te na činjenicu da tri rebrenice nisu bile pričvršćene za oplatu, kao i na nedostatak ligatura koje su spajale vojeve[4], odlučeno je da se trup rastavi te podignu pojedinačni elementi. Na osnovu fotogrametrijskog modela iz 2013.,

[3] U 2020. godini na području grada Poreča pronađeni su ostaci trećeg rimskog šivanog broda u Istri koji datira u početak 1. stoljeća. U istraživanju koje je proveo Zavičajni muzej Poreštine sudjelovali su Arheološki muzej Istre, Konzervatorski odjel u Puli (Ministarstvo kulture i medija RH) i Centar Camille Jullian (CNRS, Sveučilište u Marseilleu). Brodski ostaci su iz iskopa podignuti prokušanom metodologijom s pulskih brodova te su podvrgnuti konzervaciji, a u budućnosti se planira i prezentacija u Zavičajnom muzeju Poreštine; Boetto et al. 2024.

[4] Na trupu nisu bili sačuvani šavovi koji su povezivali rebrenice s oplatom. Šavovi koji su međusobno spajali platice također nisu sačuvani, a nije bila ni poznata prisutnost drvenih čavala ili tipli koje bi spajale platice prije opšivanja.

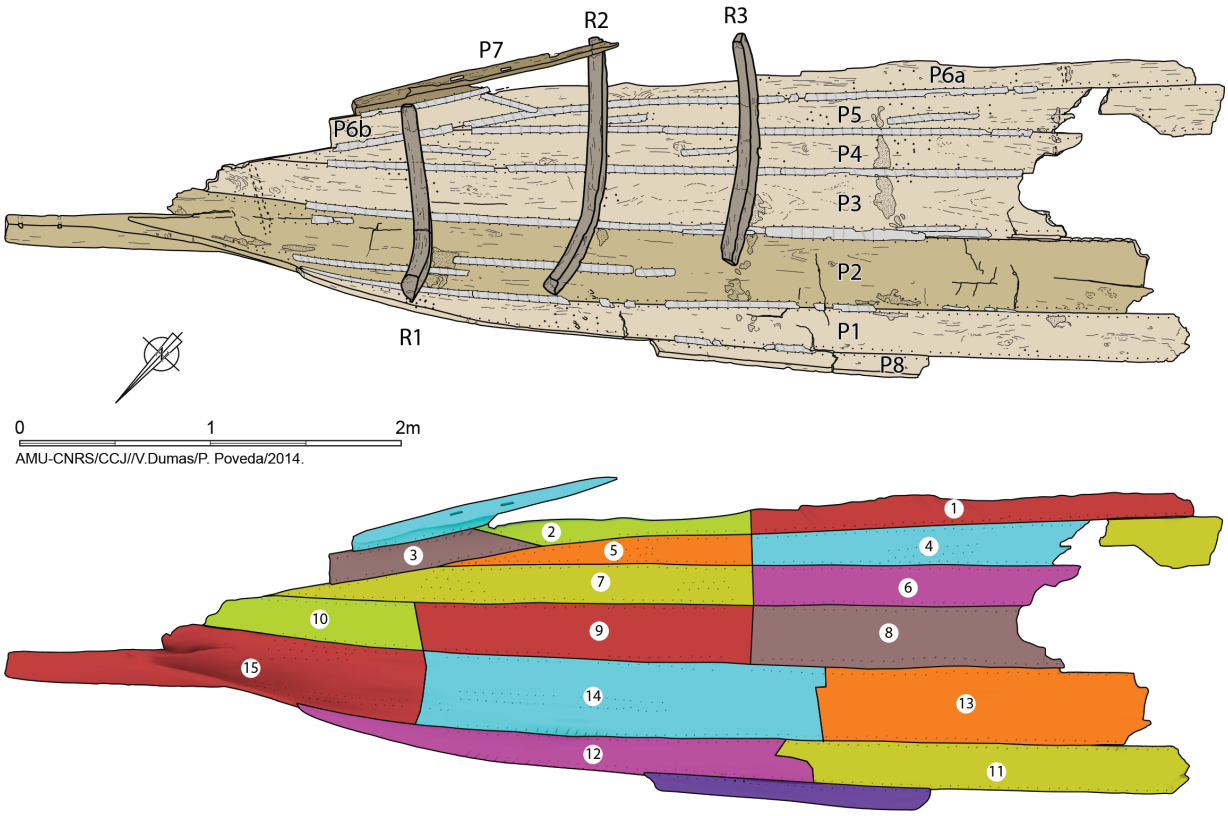
the demanding archaeological investigation and extraction of two sewn boats dated to the second half of the 2nd c. at a site at present-day Flaciusova street in Pula, discovered in the course of municipal infrastructure works. The remains of the Roman period boats, named Pula 1 and Pula 2, were removed from the archaeological excavation site and transported to the ARC-Nucléart laboratory in Grenoble for conservation. The remains of the Pula 2 boat were the first to be conserved (Koncani Uhač et al. 2018, 178-182), followed by the Pula 1 boat (Boetto et al. 2017, 192-196).[3] The archaeological rescue investigation identified Roman period port installations in the immediate and surrounding area of the Pula waterfront; these and the boats were part of a context comprising the municipal port of the Roman colony of Pola (Koncani Uhač 2023, 169-171).

The discovery and extraction of the Roman period sewn boats from the dig site, and the lack of adequate space for their exhibition in the museum building, birthed the idea of building premises to be used for their public presentation. The above noted reasons necessitating the extraction of the Zambratija boat, the recovered Pula boats, and the rich maritime heritage that has come to us from Istria's antique period, are the drivers behind a project to create a sewn boat pavilion in Pula in which these artefacts would be exhibited.

THE BOAT RECOVERY PROJECT: DESIGNING THE SUPPORTING CRADLES AND WORKFLOW

The decision to move forward with a recovery of the boat structure was followed by the selection of a recovery method, an elaboration of the techniques and materials, and the manner in which the find would be manipulated. Given the fragility of the wood, the fact that the three floor timbers are no longer attached to the planking, and the absence of the ligatures that previously joined the

[3] The remains of a third Roman period sewn boat were discovered in the Poreč area in 2020 and dated to the early 1st c. Participating in the investigation led by the Poreč Heritage Museum were the Archaeological Museum of Istria, the Conservation Department in Pula (Croatian Ministry of Culture and Media), and the Centre Camille Jullian (CNRS, Aix -Marseille University). The remains of the boat were recovered from the archaeological dig site applying the method tested and proven with the Pula boats, and were conserved, with future plans to present them in the frame of the Poreč Heritage Museum; Boetto et al. 2024.



Sl. 3 Plan brodske konstrukcije Zambratija iz 2013. (izrada: V. Dumas) po kojem je napravljen plan demontaže od 15 elemenata po kronološkom redu izvlačenja (izrada: P. Poveda).
Fig. 3 Plan view of the Zambratija boat developed in 2013 (by: V. Dumas) used as the basis for the development of the dismantling plan to raise fifteen elements in chronological order (by: P. Poveda).

za svaki je element isprojektiran specifični nosač u 3D formatu. Podizanje brodske oplate isplanirano je u 15 zasebnih nosača te razrađen hodogram njihova podizanja (Sl. 3).

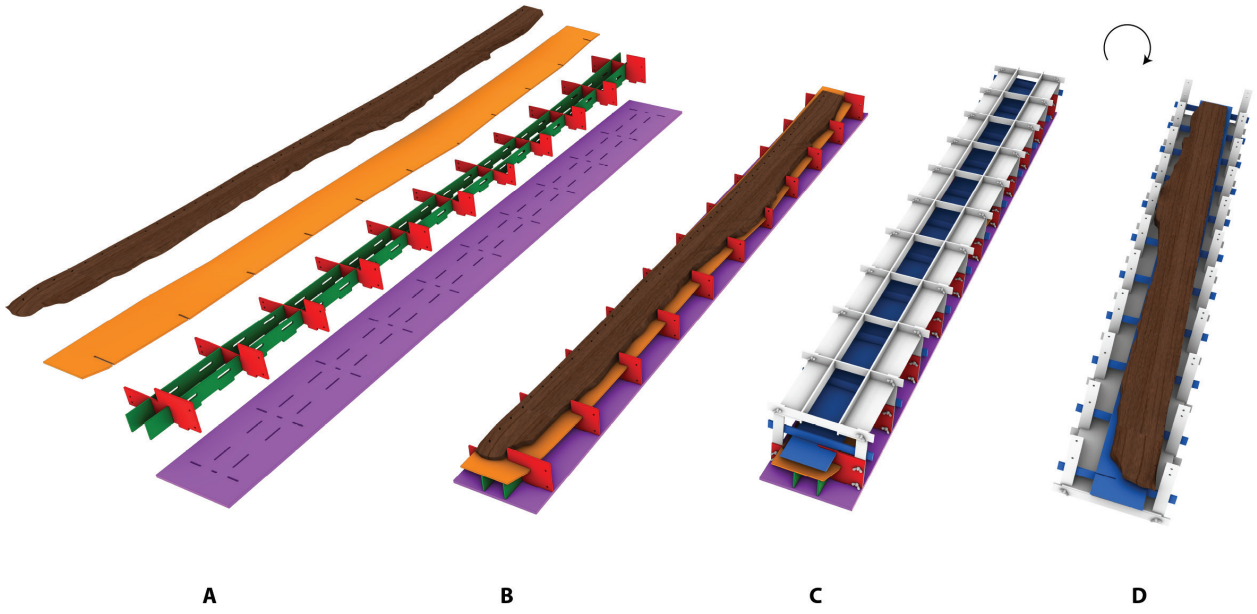
Ideja i princip vađenja broda iz podmorja bili su inspirirani metodologijom korištenom pri podizanju brodskih konstrukcija pronađenih u kontekstu luke, kao što je u Place Jules-Verne u Marseilleu (Pomey, Hesnard 2007) i u Yenikapı u Istanbulu (Kokabaş, Yılmaz 2012, 81). Odlučeno je da se za svaki element izradi prilagođeni nosač kako bi se sačuvao oblik pojedine platice pronađene u izvornom stanju na nalazištu.

Projekt izrade nosača za brodske elemente napravljen je prema dostupnom 3D modelu broda, dobivenom fotogrametrijskom izmjerom 2013. godine. Nosači su dizajnirani na način da savršeno odgovaraju obliku svakog pojedinog elementa. Izbor materijala za izradu nosača bio je također uvjetovan konzervatorski prihvatljivim materijalima na način da prati formu platica tijekom transporta, impregnacije PEG-om i sušenja smrzavanjem.

strakes,[4] it was decided that the hull should be dismantled and the individual elements recovered. Three-dimensional element-specific cradles were designed for each timber based on the 2013 photogrammetric model. The raising of the boat's planking was planned as a recovery involving fifteen separate cradles based on a developed recovery workflow (Fig. 3).

The concept and the principles guiding the extraction of the boat from the seabed were inspired by the methods used to raise boat structures found in port contexts, such as at the Place Jules-Verne in Marseille (Pomey & Hesnard 2007), and at the Yenikapı site in Istanbul (Kokabaş & Yılmaz 2012, 81). The plan foresaw the fabrication of a cradle specific to each timber with the aim of preserving the forms of the various planks in the condition in which they were found at the site.

[4] The stitches that joined the floor timbers to the planking have not survived. The stitches that joined one plank to another have also not survived, and there was no data as to the presence of either pegs or dowels that might have been used for plank-to-plank joining prior to sewing.



Sl. 4 Svaki nosač se sastoji od uzdužnih i poprečnih elemenata (zelenih i crvenih) koje zajedno drži osnovna ploča (ljubičasta). Gornja ploča (narančasta) postavlja se na vrh elementa i zatim se veže kako bi odgovarala pravom obliku prije lijepljenja (A). Nosač ima formu negativa platice koja se podiže iz mora (smeđa, B). Demontažni poklopac (bijeli i plavi, C) postavljen je i pričvršćen vijcima za nosač kako bi se omogućilo sigurno okretanje platice (D) (autor: P. Poveda).
Fig. 4 Each cradle consists of longitudinal and transverse elements (green and red) held together by a base panel (purple). An upper panel (orange) is placed on top of the element and then tied to fit the correct shape before gluing (A). The cradle takes the negative shape of the plank that is raised from the seabed (brown, B). A cover (white and blue, C) is placed and affixed to the cradle with screws to allow for safe rotation of the plank (D) (by: P. Poveda).



Sl. 5 Nosač s platicom P6a2 okrenut naopako zbog čišćenja i dokumentiranja vanjske oplate trupa (fotografija: L. Damelet).
Fig. 5 A cradle with plank P6a2 turned upside down for cleaning and documentation of the outboard side of the hull planking (photo: L. Damelet).

Također je bilo važno da materijal ima što manju plovnost kako bi se njime moglo manipulirati ispod mora.

Nosači su isprojektirani na principu modularnog sustava s gornjom pločom koja je bila namijenjena osiguravanju platica prilikom njihova kasnijeg okretanja, u cilju čišćenja i dokumentiranja s vanjske strane. Taj je princip omogućio okretanje brodskih elemenata bez gubitka forme (Sl. 4, Sl. 5). PVC ploče debljine 0,5 i 1 cm izrezane su numerički

The design of the cradles for the boat timbers was based on the available 3D model of the boat obtained from the photogrammetric survey performed in 2013. The cradles were designed to perfectly correspond to the form of each of the individual elements (timbers). The choice of cradle material was also contingent on suitability for the conservation process, ensuring that cradles follow the shape of planks during transport, PEG impregnation, and lyophilisation (freeze-drying). It was also important that the material had as little buoyancy as possible to allow for handling control when working underwater.

The cradles were designed following a modular system principle, with an upper panel intended to hold a plank in place when later turning it over during the cleaning and documentation of the outboard side. This system would allow for the rotation of the boat's timbers without compromising their form (Fig. 4, Fig. 5). Half-centimetre and one-centimetre-thick PVC panels were cut using a computer numerical control (CNC) machine prior to assembly and gluing into the desired form.

Some of the planks were cut in situ to facilitate raising them from the seabed and to reduce the risk of unwanted breakage during the recovery operation. Six cuts were made at points that will not be visible in museum

kontroliranim (CNC) strojem nakon čega su sastavljane i lijepljene.

Pojedine platice su izrezane *in situ* jer je takav pristup omogućavao lakše podizanje iz podmorja te ujedno smanjivao rizik od neželjenog loma prilikom vađenja. Dimenzije platica su također bile prilagođene dimenzijama liofilizatora za konzervaciju. Demontaža i rezovi na platicama omogućili su da se analiziraju ligature i morfologija svakog elementa te da se precizno odrede godovi vidljivi na poprečnim presjecima. Uvažavajući već postojeće pukotine na platicama, ukupno je napravljeno šest rezova na mjestima gdje oni tijekom prezentacije u muzeju neće biti vidljivi.

Prije spuštanja nosača u podmorje na gornjoj je njegovoj plohi nacrtan obris platice koju je trebalo izvaditi, kako bi ronioci unaprijed imali točno određeno mjesto za njeno postavljanje na nosač. Oko svakog nosača dodatno su fiksirane čičak trake kojima se pričvršćivala platica prije podizanja iz mora.

POSTUPAK PODIZANJA BRODSKE KONSTRUKCIJE

Ne bi li se izbjeglo otvaranje cijele brodske konstrukcije, zbog opasnosti od iznenadnih i snažnih zapadnih vjetrova koji bi imali katastrofalne posljedice na brod, otvarani su samo oni dijelovi broda koji su podizani isti dan. Iz podmorja su prvo izvađena tri brodska rebra (R1 – R3) koja su odvojena u unutrašnjosti trupa, gdje su bila pohranjena nakon istraživanja u 2013. godini. Nakon toga su vađene platice, zajedno s primarnim dislociranim letvicama koje su se nalazile iznad spojeva platica.

Prvo je pored platice napravljen rov u koji je umetnut

presentation and that take into account the existing cracks in the planks. The dimensions of the segments of planks were also thus adapted to the size of the lyophilisation chamber used during the conservation process. This process allowed for the analysis of the ligatures and the morphology of each of the timbers, and the precise identification of the tree rings visible in the cross-sections.

The outline of the plank to be extracted was drawn on the top panel of the cradle before it was lowered to the seabed so that the dive team would have a precise placement point. Hook and loop fastener (Velcro) straps were additionally placed around each cradle to be used to fix a plank in place prior to raising it from the seabed.

THE PROCEDURE TO RAISE THE BOAT STRUCTURE

To avoid exposing the entirety of the boat structure at any given time, mindful of the danger of the sudden onset and power of the westerly wind, the action of which could have catastrophic consequences for the boat, the recovery work involved exposing only that part of the structure that would be extracted on a given day. The first to be raised from the seabed were the three frames (R1 to R3), which were isolated in the hull where they were set following the 2013 investigative work. The planks were recovered next, along with the primary dislocated laths set above the joints between the planks.

The first step involved excavating a ditch next to a plank to receive the recovery cradle (Fig. 6), whereupon the plank to be raised and a small part of the adjacent plank were cleaned. The laths that covered the plank stitching were assigned an alphanumerical code and, following



Sl. 6 Izvlačenje platice P1 (fotografija: L. Damelet).
Fig. 6 Extracting plank P1 (photo: L. Damelet).



Sl. 7 Numeriranje te premještanje letvice koja se nalazila iznad šavova (fotografija: Ph. Soubias).
Fig. 7 Numbering and moving a lath set above the stitching (photo: Ph. Soubias).



Sl. 8 Platica prebačena na nosač i učvršćena čičak trakama (fotografija: L. Damelet).
Fig. 8 A plank relocated to a cradle and fixed in place with Velcro straps (photo: L. Damelet).

nosač za podizanje (Sl. 6), nakon čega je platica očišćena zajedno s manjim dijelom susjedne. Letvice koje su prekrivale šavove na platici alfanumerički su označene, a nakon obavljene fotogrametrije premještene su i fiksirane na platicu koja se podiže (Sl. 7). Obavljena fotogrametrija omogućila je da se dobiju podaci o izvornom položaju

photogrammetric imaging, were moved and fixed to the plank that was to be raised (Fig. 7). This photogrammetric imaging provided data on the original position of a lath, which is critical to a later restoration of the boat. The plank was then moved onto the recovery cradle and the ensemble was secured in place using Velcro straps. The element was then fixed to an aluminium ladder to prevent the cradle from warping, i.e., to prevent the timber from cracking as it was raised from the seabed (Fig. 8). Once the cradle and the timber had been raised to the surface, the unit was transferred to land by boat.

A specific cradle was designed for the recovery of longitudinal axial timber P2. Given its complex shape and estimates of its weight, this recovery cradle comprises two elements, with regular insertions of support strips at its underside during excavation. The extraction of this timber was the most demanding part of the entire operation (Fig. 9 a-d).

Once all of the timbers had been recovered, an archaeological trench was excavated across the area over which the boat had lain. This excavation work yielded the find and collection of the remains of twigs, Bronze Age potsherds, and flint tools.



Sl. 9 a, b, c, d. Postupci vađenja uzdužnog osnog elementa P2 (fotografija: Ph. Soubias).
Fig. 9 a, b, c, d. The process of recovering longitudinal axial timber P2 (photo: Ph. Soubias).

letvice, važni za kasniju restauraciju broda. Platica je zatim prebačena na nosač te je sve učvršćeno čičak trakama. Element je potom fiksiran za aluminijske ljestve koje su sprječavale krivljenje nosača odnosno pucanje drveta pri podizanju iz mora (Sl. 8). Nakon što je nosač s elementom podignut na površinu, plovilom je prebačen na kopno.

Za uzdužni osni element P2 dizajniran je poseban nosač. S obzirom na složeni oblik osnog elementa te prethodnu pretpostavku o njegovoj težini, izrađeni nosač se sastojao od dva elementa, uz redovito umetanje potpornih traka tijekom iskopavanja s njegove donje strane. Vađenje ovog elementa bilo je ujedno i najteži dio cijele operacije (Sl. 9 a-d).

Nakon vađenja svih elemenata, na području gdje je ležala brodska konstrukcija provedeno je sondiranje prilikom kojeg su utvrđeni i izvađeni ostaci grane drveta te su pronađeni ulomci brončanodobne keramike i nalaz kremene alatke.

FAZE DOKUMENTIRANJA

Nakon što su dijelovi broda izvađeni iz mora, prevezeni su u halu Arheološkog muzeja Istre u Žminju u kojoj je prethodno bio izrađen bazen za desalinizaciju drveta, dimenzija 500 x 240 x 80 cm.

Rebrenice i platice su očišćene, fotografirane i skenirane prijenosnim skenerom Artec Leo. S obzirom da su nosači za elemente platica bili projektirani da se mogu okretati, i vanjska i unutarnja površina platica su dokumentirane u 3D (Sl. 10). Ne bi li se očuvala cjelovitost drva te smanjio učinak gravitacije, manevri okretanja elemenata su se ponekad izvodili u namjenskom bazenu s vodom (Sl. 11).

DOCUMENTATION PHASE

Once extracted from their marine environment the parts of the boat were transported to Archaeological Museum of Istria premises in Žminj, where a 500-by-240-by-80-centimetre wood desalination tank had been prepared.

The floor timbers and planks were cleaned, photographed, and scanned with an Artec Leo portable scanning device. As the plank cradles had been designed to allow the ensemble to be turned over, both the inboard and outboard surfaces of the planks were documented in 3D (Fig. 10). In order to ensure the integrity of the wooden timbers, and to mitigate the effect of gravity, rotation manoeuvres were at times performed in the purpose-built water tank (Fig. 11). The system proved to be very effective in the almost flawless digital composition of the inboard and outboard plank scans.

NEW OBSERVATIONS CONCERNING THE BOAT'S STRUCTURE

Dismantling of the planking provided answers to some of the open questions. Questions concerning the technological process used to create longitudinal axial timber P2, however, or concerning a date for the construction of the boat, require further investigative work and laboratory analysis.

The analysis of the individual boat timbers has clarified our insight into the system used to render the boat watertight. Small twigs (sticks with a 2.0-centimetre diameter) placed to the outboard side of the planking along the longitudinal recesses at the seams between strakes (Fig. 12) held in place sealant that was applied



Sl. 10 Skeniranje uzdužnog osnog elementa P2 (fotografija: L. Damelet). Fig. 10 Scanning longitudinal axial timber P2 (photo: L. Damelet).



Sl. 11 Na kraju svih faza dokumentiranja i uzorkovanja elementi broda uronjeni su u desalinizacijski bazen sa slatkom vodom (fotografija: L. Damelet). Fig. 11 Upon completion of all documentation and sampling phases the boat timbers were submerged in the freshwater desalination tank (photo: L. Damelet).

Sustav se pokazao vrlo učinkovitim u gotovo savršenom digitalnom sastavljanju gornje i donje skenirane platice.

NOVA ZAPAŽANJA O BRODSKOJ KONSTRUKCIJI

Rastavljanje oplate pružilo je odgovore na neka ranija pitanja, iako ona o tehnološkom procesu korištenom za dobivanje uzdužnog osnog elementa P2 ili datiranju gradnje broda zahtijevaju daljnja istraživanja i laboratorijsku analizu.

Nakon analize pojedinih elemenata broda jasnije su spoznaje o sustavu vodonepropusnosti plovila. Male drvene grančice (štapići promjera do 2 cm) postavljene s vanjske oplate u uzdužne utore sljubnica vojeva (Sl. 12) držale su brtvilo koje je bilo naneseno duž rubova platica[5]. Grančice na vanjskoj strani trupa i letvice s unutrašnje oplate bile su zajedno sašivene. Brod je bio premazan paklinom s unutarnje strane, ispod letvica te izvana.

Opservacijom rubova ustanovljeno je da većina platica na oplati ima višestruke utore koji čine rupe za šavove, što se može povezati s principom šivanja te popravcima. Treba napomenuti da je vanjski šav između uzdužnog osnog elementa P2 i platice P3 izrezan ne bi li se umetnule dvije zakrpe: jedna gotovo ravna, duga 76,5 cm, široka 2,9 cm i debela 1,5 cm, a druga lentikularnog oblika, duga 49 cm, široka 5 cm i debela 2,2 cm. Vanjska površina tih zakrpa također ima utore koji skrivaju ligature (Sl. 13).

Utori s istom funkcijom uočeni su i na drugim mjestima vanjske oplate za prolaz ligature koja je korištena za popravak pukotina u oplati i vezivanje rebrenice za oplatu.

Točna interpretacija funkcije rupa vidljivih na oplati bit će jasnija 3D modelima svake platice, što je jedan od sljedećih koraka u laboratorijskom radu. Ovaj je korak također ključan za rekonstrukciju izvornog oblika i strukture plovila Zambratija.

ZAKLJUČAK

Rastavljanje i podizanje prapovijesnog broda Zambratija pružilo je jedinstvenu priliku za istraživanje strukture gradnje i održavanja broda tijekom njegova korištenja. Proučavanje elemenata izvan vode omogućilo je uvid u morfologiju svakog pojedinog komada drva, kao i provedbu dendrokronološke analize koja će biti povezana s radiokarbonskim AMS datiranjem kalibriranim "wiggle matching" metodom, u pokušaju dobivanja preciznijeg

[5] Vidi prilog Albe Ferreire Dominguez i Frederica Guibala u ovom broju.



Sl. 12 Detalj oplate broda - pogled na vanjski rub platice P5b s ulomkom grančice (štapića) u utoru sa spojem (fotografija: L. Damelet).
Fig. 12 Detail of the boat's planking: view of the outer edge of plank P5b with a fragment of a twig (stick) in the recessed joint (photo: L. Damelet).

along the plank edges.[5] The twigs to the outboard side of the hull and the laths to the inboard side were all held in place by the stitching. The boat was coated with pitch on the inboard side, under the laths, and on the outboard side.

Our examination of the edges found that most of the hull planks have multiple channels that constitute the stitching holes, which can be associated with the original stitching assembly and later repairs. It should be noted here that the outer seam between longitudinal axial timber P2 and plank P3 was cut to allow for the insertion of two patches: one is almost flat, having a length of 76.5 centimetres, a width of 2.9 centimetres, and a thickness of 1.5 centimetres, while the other is lenticular, 49 centimetres long, five centimetres wide, and 2.2 centimetres thick. The outside surfaces of these patches also have recesses that conceal ligatures (Fig. 13).

[5] See the contribution by Alba Ferreira Domínguez and Frédéric Guibal in this issue.



Sl. 13 Zakrpe korištene za popravak šava između P2 i P3 (fotografija: Ph. Soubias).
Fig. 13 Patches used to repair the seam between timbers P2 and P3 (photo: Ph. Soubias).

datuma gradnje broda. Konačan cilj samog projekta je muzealizacija brodskih ostataka u novoplaniranom paviljonu, čemu prethode i pokušaji rekonstrukcije brodskih linija, kao i postupak konzervacije i restauracije drveta, što svakako predstavlja još jedan uzbudljivi korak u cjelokupnom projektu prije konačnog izlaganja.

Channels that served the same function have also been identified at other points on the outboard side of the planking, through which the ligatures used to repair cracks in the planking and to lash the floor timbers to the planking were threaded.

Our interpretation of the function of the holes in the planking will be clarified upon analysis of the 3D models of each of the planks, which is one of the following steps in our laboratory work. This step is also key to our reconstruction of the original form and structure of the Zambratija boat.

CONCLUSION

Dismantling and raising the prehistoric Zambratija boat has afforded us a unique opportunity to investigate both the structure of the boat and how maintenance was performed. Our study of the boat's elements following recovery from the marine environment has made it possible to gain insight into the morphology of the individual timbers, and to perform dendrochronological analyses that will be correlated with radiocarbon AMS dates, calibrated using the wiggle matching method, all aimed at obtaining a more precise date for the construction of the boat. The final objective of this project is to see the remains of this boat exhibited in a planned museum pavilion, which is to be preceded by an attempt to reconstruct the lines of the boat, and the conservation and restoration of the wooden material, certainly one more fascinating step in the overall project ahead of the exhibition of this find.

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