A Roman ship scuttled near Salona in the Gulf of Kaštela, Croatia

David Ruff, Irena Radić Rossi, Cemal Pulak and Nili Liphschitz

Abstract
In 2002, the recovery of a 1000-litre perforated *dolium* in the Trstenik section of Kaštel Sućurac, near Split, Croatia, attracted the attention of archaeologists to significant Roman remains submerged near the shore. A return visit to the site in 2006 identified the outline of a wooden ship scuttled alongside a submerged wooden wall: in 2015, the ship was uncovered and labelled, recorded via photogrammetry and extensively sampled, then preserved *in situ*. Reconstruction determined the ship to be a flat-floored, mortise-and-tenon constructed ship, dated to approximately the late 1st century AD, suitable for the transport of heavy cargo.

Keywords
Dolium, flat floor, mortise-and-tenon, Roman Dalmatia

Résumé
En 2002, la récupération d'un *dolium* perforé d'une capacité de 1000 litres à Trstenik, Kaštel Sućurac près de Split en Croatie, a attiré l'attention des archéologues sur d'importants vestiges romains immergés près du rivage. Une expertise sur le site en 2006 a permis d'identifier les contours d'un navire coulé volontairement le long d'une paroi en bois. C'est finalement en 2015 que le navire a fait l'objet d'un dégagement et d'un marquage avant d'être enregistré par photogrammétrie et largement échantillonné, puis conservé *in situ*. Le travail de reconstruction a permis de déterminer que ce navire assemblé à tenons et mortaises, daté approximativement de la fin du Ier siècle apr. J.-C., possédait un fond plat et était adapté au transport d'une cargaison pondéreuse.

Mots clés
Dolium, membrure plate, assemblage à tenon et mortaise, Dalmatie romaine

The geographical region of modern Dalmatia, one of four major regions of modern Croatia, is significantly smaller than the Imperial province of Roman Dalmatia, which was formed in approximately 9 AD by the division of Illyricum into two provinces: Pannonia and Dalmatia (Wilkes 1969, p. 78-80). While the border of Roman Dalmatia is not precisely known, figure 1 overlays the approximate ancient boundary upon a modern map of the Balkan countries. The capital of Roman Dalmatia, Salona (near present-day Split, Croatia), was originally an Illyrian city with Greek presence, taken over by the Delmatae as they pushed westward in approximately the 3rd century BCE, and ultimately conquered by Republican Rome in 76 BCE (Stipčević 1977, p. 55-59). Salona, with its central location in Roman Dalmatia coupled with a protected harbour in the eastern Gulf of Kaštela and a connection to the hinterlands through the mountain pass of Klis, was the natural choice for the location of the provincial capital.

Roman underwater archaeological remains have been known in the Gulf of Kaštela since the late 19th century, when Roman sarcophagi were located along the Vranjic peninsula, southwest of Salona (fig. 2) (Bulić 1900). Other underwater finds include an accumulation of Dressel 20 and North African cylindrical amphorae discovered near Split in 1958 (Cambi 1975; Radić Rossi 2008), and extensive coastal excavations of the Hellenistic/Roman site of Siculi in the Resnik area of Kaštel Štafilić, in the western part of the Gulf of Kaštela towards Trogir (Kamenjarin, Šuta 2011).

Archaeological attention was attracted to Trstenik, a section of Kaštel Sućurac adjacent to ancient Salona, with the report of "large jars" just off the coast in the muddy bottom of the sea. In October 2002, a seven-day underwater campaign recovered a 1000-liter perforated *dolium* (to date the only complete/unfragmented perforated *dolium* known in the Mediterranean) and identified an accumulation of Dressel 20 amphorae, as well as a 50 m length of ancient wooden sea wall (Radić Rossi 2003). In 2006, during the recovery of Dressel 20 amphorae, the outline of a wooden ship approximately 12 m in length was noted alongside the wooden wall, filled with rocks and scuttled at a depth of about 1,5 m (Radić Rossi 2006, 2007). In 2012, after partial excavation (Radić Rossi, Lete 2012), the hull was found to be in excellent condition, and a complete uncovering with hull photogrammetry was planned for 2015.

1. EXCAVATION AND PHOTOGRAMMETRY

Excavation was conducted in April and May of 2015 by a joint international team, co-directed by Irena Radić Rossi, archaeologist at University of Zadar and David Ruff, PhD candidate at Texas A&M University (Ruff, Radić Rossi 2015). The work was performed by scuba divers entering from shore, with an aluminium grid suspended over the wreck site to support the removal of rocks and overburden both manually and by dredge. Any small artefacts found (a total of 236, the vast majority of which were ceramic shards) were assigned a sequential artefact number, photographed, and described in an artefact log. Many times, removal of rock used to scuttle the ship resulted in 'floating wood,' damaged ship components that began to float away as soon as they were no longer weighed down. When possible, these pieces were reattached to support photogrammetry: if too damaged or the original location was

Fig. 1: *The boundary of Roman Dalmatia overlaid on the present-day Balkans. Modern Dalmatia is shown in orange (drawing V. Butorac).*

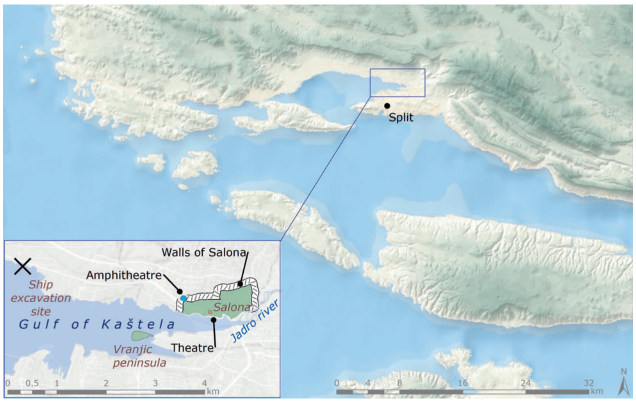

Fig. 2: *Salona in the Gulf of Kaštela. The excavation site is 3 km west of ancient Salona's city walls (drawing V. Butorac).*

unknown, they were removed to shore for study and consideration for sampling.

After the ship's hull was uncovered, major components were labelled to support detailed photogrammetry, and additional construction features were enhanced for photogrammetry purposes, including placing white thumbtacks on treenails, yellow thumbtacks on pegs in mortise-and-tenon joints, and white electrical wire into seams to enhance the visibility of planking joints. Photogrammetry was performed three separate times to record the progress of the excavation as different components were revealed, for example before and after the removal of stringers (ceiling planking). By placing metre sticks in the field of view, a scaled three-dimensional model could subsequently be generated using the Agisoft PhotoScan computer programme, allowing for extensive measurement and hull analysis during post-processing. To facilitate photogrammetry, the aluminium grid was lifted and removed from the site prior to taking pictures, then returned before the continuation of work.

Following photographic documentation, construction details of the hull were recorded by hand, and extensive sampling of hull components for wood species was undertaken (Liphschitz *et al*. 2018). The ship was then reburied and covered with geotextile, sand and rock to preserve it *in situ* for potential future investigation.

2. HULL REMAINS

The Trstenik ship was scuttled in an east-west orientation against a wooden sea wall, with its bow tentatively identified to the east based on two observations, the presence of a space between the frames on the western end that often is reserved for the bilge pump and the multiple notched frames to the east which would have supported the missing mast step. The wall preserved the curvature of the (port) hull to the north, while the weight of the rocks broke and flattened the (starboard) hull to the south, extending the total number of strakes preserved for analysis. The ship was built shell-first, the planking being assembled by pegged mortise-and-tenon joints. The keel-stem-sternpost assembly was made of three timbers securely scarfed together: the shell construction began with laying 11 strakes, then an alternating wale/strake/wale/strake/wale pattern. Limited remains prevent exact determination of the number of strakes installed above the third wale. The ship had a total of 69 preserved frames (numbered from 11 aft to 79 forward), most with a single limber hole over the keel, attached to the planking with treenails driven from the outside of the hull. No frames were attached to the keel/stem/sternpost timber assembly. Stringers were nailed and treenailed longitudinally across the frame tops for internal support. The mast step was not present in the remains: apparently it was removed prior to scuttling for possible repurposing.

2.1. KEEL-STEM-STERNPOST ASSEMBLY

The keel-stem-sternpost assembly of the Trstenik ship consisted of three timbers scarfed together: a 1.8 m section of sternpost made of ash (*Fraxinus excelsior*), an 8.7 m length of beech (*Fagus sylvatica*) that composed the keel, and a 1.7 m section of stem fashioned from elm (*Ulmus campestris*). It is likely that an additional timber was scarfed onto the surviving stem and sternpost pieces to complete the curvature and add the required height for hull construction, but no archaeological evidence for them has survived. The width of the assembly varied from 10 to 12 cm with the thickest section amidships: as the ship was not fully excavated and dismantled, the depth of the assembly and the details of the rabbet for the attachment of the garboard strakes could not be determined. While the two scarfs (one directly underneath frame 17, the other between frames 75 and 76) were not disassembled for study, there was no visual evidence for any bolt or vertical locking device or key. This lack of bolting a floor timber directly through the keel scarfs in the Trstenik ship is consistent with the ship predating the 2nd century AD "Western Roman Imperial" tradition, which is characterised by bolted frames often associated with a keel scarf to provide reinforcement (Pomey *et al*. 2012, p. 237, 306).

2.2. STRAKES AND WALES

The hull of the ship was formed by planks scarfed together with mortise-and-tenon joinery. Strake widths vary, with typical

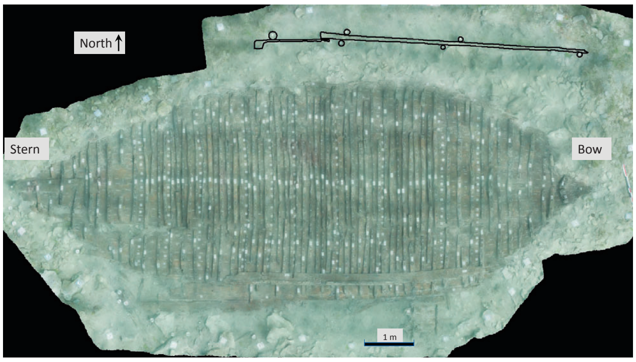

Fig. 3: *The Trstenik ship with stringers removed except for stringer S23. The ship was scuttled on an east-west axis. North is to the top, as is the shoreline (50 m distant today) and the ancient wooden wall (black lines at top): bow to right (orthophotograph D. Ruff).*

widths between 16 and 18 cm: some narrow sections are as thin as 13 cm and the widest section measured 23 cm. Strake thickness measured at the ship's edges was 4-5 cm, although this requires confirmation by disassembling and measuring the planking in multiple zones of the ship. Samples taken for tree species identification determined that the majority of the hull was constructed from Aleppo pine (*Pinus halepensis*) and black pine (*Pinus nigra*), with a lesser contribution from cypress (*Cupressus sempervirens*): one sample each of Scots pine (*Pinus sylvestris*) and stone pine (*Pinus pinea*) were also noted. There was no obvious pattern to the selection of wood for use in planking, and the choice of wood for stringers was very similar to that of the strakes. Due to dense framing and an internal coating of pitch obscuring strake joinery, evaluation of the mortise spacing pattern and consistency requires additional study following hull disassembly, measurements, and statistical analysis. Two hull repairs were noted, one in the after section of the second strake and one amidships in the third strake, both on the port side. Additional repairs are likely to be noted in the future upon re-examining the hull after the dense framing amidships and the pitch coating the interior of the planking are removed.

The Trstenik hull displays three surviving wales on the starboard and two on the port sides, with varying degrees of completeness. The cross sections of the five wales appear to be fairly regular and consistent, measuring approximately 10 cm wide, and roughly 5 cm in thickness where measurements could be taken. The wales are flush mounted with the planking inside the ship but protrude beyond the hull planking externally. Each of the five surviving wales was sampled, and all are made of stone pine (*Pinus pinea*). This is a noteworthy result, as only one frame component and one strake length were made of stone pine. Thus, this particular tree species was preferred for the long run of wales, yet it was not a commonly used species elsewhere in the ship. No scarfs were observed in any of the wales.

2.3. FRAMES

The Trstenik ship had a total of 69 surviving frames, and 214 frame components were individually labelled with unique numbers (fig. 3). These 214 frame components were all 'stand-alone' pieces. Although some frame components were physically touching one another, in no case was a frame component scarfed or connected to an adjacent frame component. Lengths of the frame components varied widely, with the shortest at 20 cm and the longest over 2 m. While frame height above the hull planking was typically 6-8 cm (moulded), frame widths varied more widely, from 4-10 cm (sided). The frames numbered from 15 to 74, for a total of 60 consecutive frames, all consist of floor timbers: 11 of these floor timbers have notches cut over the keel, some of which must have keyed into the ship's mast step. The frames are attached to the hull by treenails: no iron nails were noted attaching frames, and no frames are attached to the keel. Of 27 treenails sampled, 19 were made of sycamore (*Acer pseudoplatanus*). With few exceptions, the centreline floor frames have a semicircular limber hole notched directly over the keel, typically 4-6 cm in width.

There are two distinct patterns of frame density visible in the Trstenik ship. The central section of the ship based on frame density stretches from frame 21 to frame 67. These 47 frames span over a length of 5.9 m, with an average centre-to-centre spacing of 12.8 cm. With the average width of frames approximately 6.5 cm (sided), visually and mathematically half of the central portion of the ship's hull is covered by these frame components. The gaps between frames in the central section of the hull vary, from as little as 2.5 cm to over 7 cm. In contrast, the stern of the ship, stretching 2.25 m between frames 11 and 21, has an average frame spacing of 22.5 cm, and the bow, stretching 2.6 m between frames 67 and 79, has an average spacing of 21.7 cm. This wider spacing forward and aft produces much wider gaps: for example, the gap between the edges of frame components F69 and F70 is 20 cm. The forward-most frame (frame 79) is a robust cant frame, with two sections sawn from the same piece of ash (*Fraxinus excelsior*): visible staining on the hull interior aft of the after-most frame would indicate a similarly large frame that did not survive.

The selection of tree species from which the Trstenik ship's frames were fashioned is by no means homogeneous, consistent, or repetitive. Of the 214 surviving frame components, 182 were sampled for tree species identification (resulting in 13 different species of wood), of which 100 are softwoods (conifers) and 82 are hardwoods. Aleppo pine was clearly the workhorse frame material selected when building the Trstenik ship, comprising 46% of the total frame components sampled. Among those sampled, there are more Aleppo pine frame components (84) than from all deciduous tree sources combined (82). The most common hardwood is sweet chestnut (*Castanea sativa,* 23 samples), followed by ash (*Fraxinus excelsior*), sessile oak (*Quercus petraea*) and Turkey oak (*Quercus cerris*) each with 14 samples. A total of 17 different tree species were identified on the Trstenik ship. This large diversity may hint at a timber acquisition or supply problem, lesser construction care, or a combination of both factors (Guibal, Pomey 2003, p. 38, 41).

2.4. STRINGERS

Multiple lengths of timber were nailed longitudinally across the tops of frames. This internal planking, termed stringers here but also known as ceiling, or ceiling planking, protected the hull from direct contact with cargo, and also likely provided attachment points for the fastening of ship's equipment, such as deck support stanchions or a bilge pump. These stringers provided some amount of longitudinal stiffening as well as internal support structure to protect the frames from the cargo. The stringers were attached to the frames with both treenails and nails, some of which may have been of iron based on rust stains. The wood species used are very similar for both strakes and stringers, suggesting that the lumber supplied for both strakes and stringers came from a common source.

2.5. RADIOCARBON DATING

Two samples submitted to the University of Georgia Center for Applied Isotope Studies for radiocarbon dating resulted in a date range of 24-134 AD, at 2σ (95.4%) confidence level. Additional radiocarbon samples, coupled with tree-ring analysis, are required to narrow down the Trstenik ship's construction and operational life span beyond mid-1st to early 2nd century AD.

3. SHIP RECONSTRUCTION

To support a computer reconstruction of the ship's hull, 20 ancient mortise-and-tenon assembled ships were reviewed based on their sharing one or more characteristics with the Trstenik ship, including age, multiple consecutive flat-floored frames, two or more wales, or a set of reconstructed ship's lines (table 1). The reconstruction was undertaken by importing the photogrammetry model of the Trstenik ship's hull into the Rhinoceros 3D modelling program. Cross sections of the model were taken, including notation of strake seam locations. As the port side of the ship had better preserved its original hull curvature by resting against the wooden sea wall, the starboard hull remains were mirrored on the port side and angled upwards to match the preserved curvature. Strake seams were then connected vertically to create a reconstructed cross section for each location, which were then connected longitudinally to define a reconstructed hull. The hull was then smoothed and extended to the height of a hypothetical caprail. Calculation of the hull displacement was based on the draught of the reconstructed hull, and the results are shown in figure 4. The computer model resulted in a hull that displaced 25.1 metric tons at a draft of 0.9 m.

4. CONCLUSION

The wooden remains found at Trstenik are from a mortise-and-tenon constructed ship that operated in the mid to late 1st or early 2nd century AD. Its heavy frame construction was suitable for the transport of heavy cargo at sea, which may have

Table 1: Trstenik ship reconstruction compendium

	Shipwreck	Contemporaneous with Trstenik +/- 100 years	Multiple consecutive flat-floored frames	Two or more wales	Reconstructed ship's lines	References
1	Laurons 2			X		Gassend et al. 1984
2	Baie de l'Amitié	X	X			Wicha 2002; Jézégou 2003
3	Balise de Rabiou	X				Joncheray, Joncheray 2009
4	Barthélemy B	X				Joncheray, Joncheray 2004a
5	Calanque de l'Âne	X				Ximénès, Moerman 1994, 1998
6	Cavalière	X			X	Charlin *et al*. 1978
7	Chrétienne C		X		X	Joncheray 1975a
8	Dramont E			X	X	Santamaria 1995; Poveda 2008, 2012
9	Dramont F		X			Joncheray 1975b, 1977
10	Dramont I	X		X		Joncheray, Joncheray 1997
11	Fiumicino 1				X	Boetto 2000, 2001, 2003, 2008
12	Grado	X				Beltrame, Gaddi 2007
13	La Bourse			X	X	Gassend 1982
14	La Giraglia	X	X			Marlier, Sibella 2002; Marlier, Sciallano 2008
15	Ladispoli A	X	X			Carre 1993
16	Lardier 4	X	X			Joncheray, Joncheray 2004b
17	Napoli A	X	X	X	X	Boetto 2005; Boetto, Poveda 2018
18	Pointe de Luque B			X		Clerc, Negrel 1973; Marlier, Sciallano 2008
19	Saint-Gervais 3	X		X	X	Liou *et al*. 1990
20	Sud-Lavezzi 2	X	X			Liou, Domergue 1990

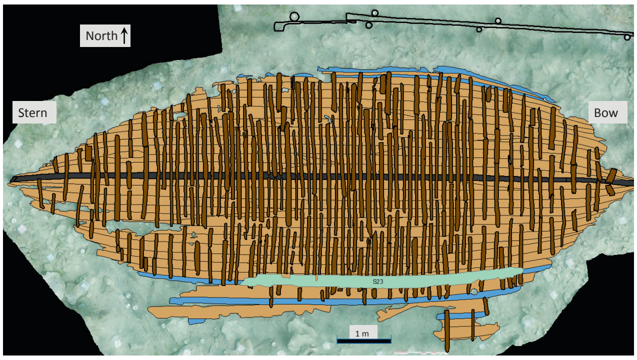

Fig. 4: *Frame site plan, showing doubled frame density in the centre of ship. Wales are shown in light blue: stringer S23 in light green. North is up: bow to right (drawing D. Ruff).*

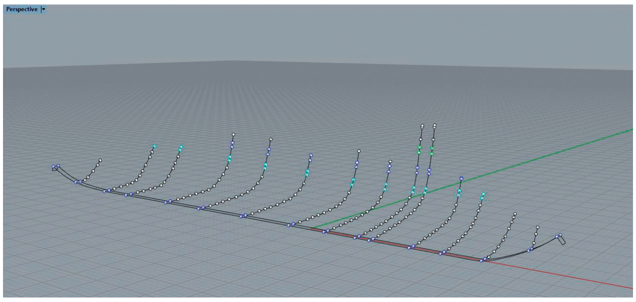

Fig. 5: *Reconstructed hull points and lines for each of the 14 sections cut from the photogrammetry model. Coloured section points indicate wales. Bow to right (elaboration D. Ruff).*

included raw materials such as construction stone or rough-hewn sarcophagi from the nearby quarries, as well as other heavy loads such as roof tiles or amphorae, into the shallow waters of the Gulf of Kaštela. Its flat-floored design is similar to other contemporary Roman-built ships used for transporting dense cargo such as *dolia* or metal ingots. Since most of the ship's usable components were removed prior to its scuttling and repurposing for use as a sea wall support, its operational

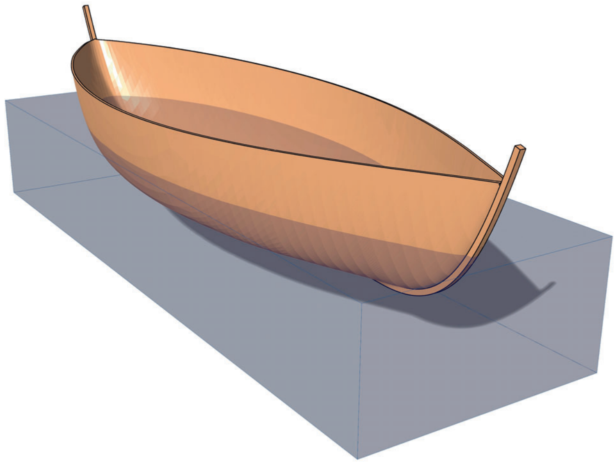

Fig. 6: *Computer generated reconstruction of hull shape. Displacement can be determined by specifying a draught for the ship and calculating the displaced volume in the computer ocean. Bow to right (elaboration A. Harrell).*

employment remains unknown. The 17 different species of wood identified in the remains indicate that its construction was likely performed using whatever wood happened to be available at the time: the exact construction location cannot be determined with certainty based on the tree species used. The vessel was repaired many times during its long operational life and was repurposed to support a wooden sea wall upon the end of its career afloat.

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