

***Condura Croatica* – a revision of the structural drawings**

Anita Jelić – Mladen Pešić

Abstract: Since 1994, two wooden boats known as *Condurae Croaticae* have been exhibited in the small Museum of Nin Antiquities. Over time, significant degradation has been observed on the wooden elements. This led to a comprehensive conservation-restoration procedure launched in 2017. During these works, a gap was noticed between the frames and planking measuring up to 5 cm, which led to a revision of the structural drawings of these vessels. With the help of new digital technologies and the creation of ship lines based on images, efforts were made to determine whether their current condition aligns with its first interpretation presented in the Museum.

Keywords: 3D scanning, 3D modelling, Nin, *Condura Croatica*, revision of drawings

1. Introduction

While extracting sand from the seabed, which was usually used as a building material, a sand miner from Privlaka extracted stones and traces of timber. He reported this unusual situation to the curator of the Archaeological Collection in Nin, underwater archaeologist Zdenko Brusić, who found a wooden boat at the very entrance to the port of Nin in his survey in 1966 (Brusić 1969: 443). Two years later, a wider search of the area near the first boat resulted in the discovery of another boat. The boats were situated at a depth of only 1.5 to 2 m under a pile of stones on the sandy seabed. Furthermore, they were found without the remains of cargo and equipment (Brusić 1969: 444). This pointed to the assumption that the boats were purposely scuttled to protect the entrance of the port of Nin from enemies in that period. The absence of any remains of cargo or gear made it impossible to ascertain the time of its use, and for this purpose a radiocarbon (^{14}C) dating of wood samples was performed. The completed analysis dated the boats to the middle of the 11th and beginning of the 12th century, i.e., to the High Middle Ages during the era of the native Croatian rulers (Brusić 1969: 443; Brusić 1978: 10–12).

In the 10th century, Byzantine Emperor Constantine VII Porphyrogenitus wrote that the Croatian navy at the time consisted of smaller *condura* ships and larger *sagena* ships (Kozličić 1991: 18). The *condura* ships had narrow hulls that were 7–9 m long and 1.5–2 m wide, and built with frames connected to the planks by treenails and iron nails. Over the course of history, they were known as the smallest but also very deadly warships. Apart from warfare and defence, they were also used for other purposes, such as fishing and the transport of people and goods. They were fast row boats and could be propelled by a sail when favourable winds blew. A specific feature of the hull's construction is the lack of a classic keel, replaced instead by a thicker keel plank. Instead of a classic keel, the boats had two parallel longitudinal beams on each side that ran along the outer part of the hull. These beams were used to stabilize it and maintain the boat's line while sailing, while also making the boats fast and agile. Moreover, due to the shallow stern, it is assumed that they were also used to pull them ashore (Brusić 1969; 1978: 8–10). Many similarities between the *condura* vessels and the boats found in Nin, such as a similar period of use, as well as length, width, specific hull construction and the presence of treenails, iron nails, and parallel beams, led the scholars to presume that those boats were the *condura* type. The boats were, therefore, named *Condura Croatica* and today they represent a unique example of the maritime tradition of the medieval Croatian rulers, which makes them exceptional and very valuable components of Croatia's cultural heritage.

2. Background

The boats were extracted from their marine environment in 1974 (Brusić 1978). The process of desalination, conservation, restoration and reconstruction of one of the boats followed (Jurić, Oguić, Vilhar 1991; Kozličić, Brusić 1991; Jurić, Sutlović, Vilhar 1997), after which both boats were exhibited in the Museum of Nin Antiquities, a department of the Archaeological Museum in Zadar (Fig. 1). However, due to the timber's sensitivity to the adverse microclimatic conditions to which the boats were exposed very soon after the conservation procedure, degradation was observed on the timber. This prompted the University of Zadar to conduct a collaborative analysis of wood samples with the University of Tel Aviv in 2008 and Texas A&M University in 2010. This analysis showed that the boats were made of oak (Radić Rossi, Liphshitz 2010: 263–264). Further analysis showed the impact of a number of chemical and physical processes due to the inadequate conditions to which the boats were exposed that degraded the structure of the wood (Šimičić, Vrgoč 2016). Based on these results, a comprehensive conservation and restoration procedure was initiated in 2017. The project receives funding through the Ministry of Culture and Media, and is implemented by experts from the International Centre for Underwater Archaeology in Zadar.

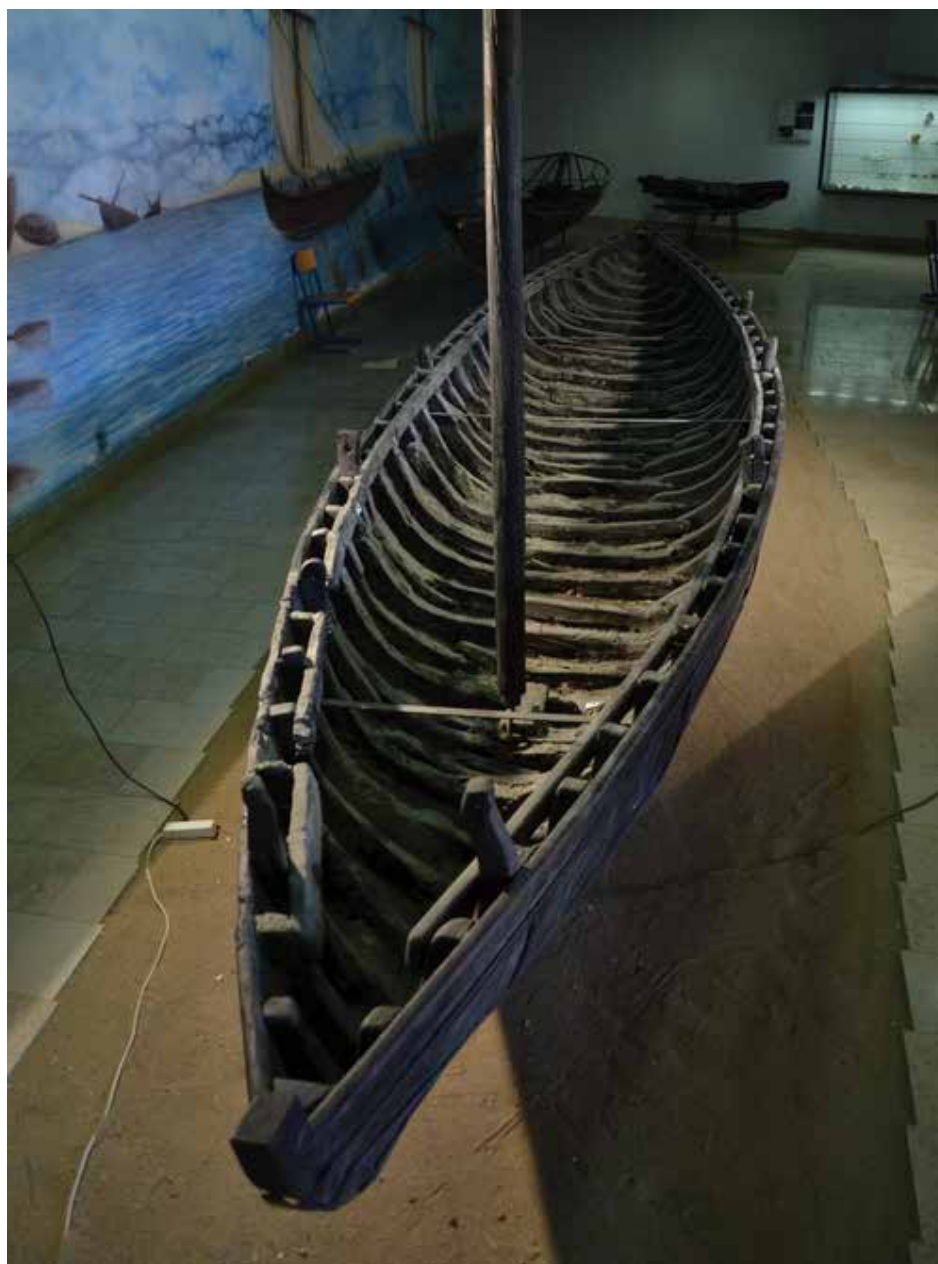


Fig. 1 The reconstructed boat (Nin MNS 2530), in the Museum of Nin Antiquities (photo: M. Ćurković Madiraca, ICUA)

A gap of 5 cm was observed between the planks and the frames during the process of conservation-restoration and cleaning of the boat structures. Since, so-called metal cradles in which the boats are exhibited were built according to measurements and designs made in 1974 (Jurić, Oguić, Vilhar 1991: 47–48), the possibility of the expansion of their wooden elements, which may have occurred when they sank, was most likely overlooked. The long-term impact of seawater on the structure of wood and the possible dimensional changes that occurred during the process of impregnation and drying of the wood also contributed to the aforementioned gap. Furthermore, the wood was irreversibly deformed by fluctuations in temperature and relative humidity in the exhibition room (Jelić 2023: 229) and mere force of gravity, especially on the wooden parts not supported by a metal cradle (Hauer *et al.* 2023: 50–51).

The need to revise the existing reconstruction was thus obvious, so digital documentation of the existing condition of the boats was done as part of the conservation and restoration process. With the help of new digital images and the construction of ship lines based on them, an attempt was made to determine whether the current condition of the *Condura Croatica* boats aligned with their original interpretation presented in the Museum.

3. Digital Documentation

The first step in digital documentation was a 3D scanning of the boats to obtain invaluable data about their length, dimensions and circumference, as well as their position points. The first 3D scan of the vessel structure was done prior to the start of PEG cleaning. The scanning and 3D model processing were done by Aero Photo 3D SLLC from Pula. After the initial scan, the wood remains underwent the complex conservation procedure. The main goal was to remove all PEG that was applied to the original wood and to get complete insight into the remains of the wooden elements, but also to understand the correlation between the original and reconstructed wooden elements that were added during first reconstructions. Upon completion of the cleaning process, new scans of the Nin boats were done. The 3D scanning was performed by a team from NITEH, Duga Resa, using a handheld scanner, i.e., a HandySCAN Black/Elite-Creaform scanner. Based on the data collected by the 3D scans, complete and detailed 2D technical documentation was compiled using existing ship lines as well as a complete 3D reconstruction with existing and missing parts of one of the boats i.e., the reconstructed boat (Nin MNS 2530)¹. The model was made by ViaKornel – an experienced studio involved in 3D modelling, prototype development and shipwreck reconstruction.

3.1. 3D modelling

The reconstructed boat (Nin MNS 2530), which was taken as the basis for making the 3D model, consists of original or archeological wooden elements but also additional wooden reconstructions of the missing parts. The original, archaeological component of the boat consists of the bottom section of the external planking with two longitudinal parallel beams and two thirds of the starboard. Inside the hull there are 24 incomplete frames and a mast step between frames 8 and 9. The boat's portside, missing parts of the starboard, bow and stern, along with nine frames (two on the bow and seven on the stern) were reconstructed during the 1970s and 1980s (Jurić, Oguić, Vilhar 1991).

During scanning process, special attention was accorded to the scanning of the original frames on which basis the reconstruction of the ship lines was planned and done. While creating a 3D model, the program highlighted certain irregularities. The program noted that individual frames do not follow the line of the model in their shape and it was not possible to fully fit them into the final projection (frames 6 and 9; Fig. 2). Due to their fragmentation, some frames provided insufficient information for their complete reconstruction (frames 11 and 16), while some were deformed and did not match the rest of the vessel contours (frames 5 and 21). Furthermore, some frames aligned more with the position of another frame, while some frames were used in the reconstruction of other frames (frame 15 used to reconstruct frame 21). The assumption is that parts of the wooden elements likely do not correspond to the newly made 3D model because the wood had dried and the frames had moved several centimetres back and forth compared to their original position and bending angle, as well as the lack of degraded parts in certain wooden elements (Budimir 2021).

Therefore, when making the reconstruction, only well-preserved original frames were taken as the basis for deriving the adequate line of the hull's shape. Certain corrections were made to adjust the position of the frames and optimize their shape in order to achieve a satisfactory visual and technical presentation of the hull's shape in 3D reconstruction (Budimir 2021).

¹ The boat that was scanned for the purpose of revision of the structural drawings in this article is inventoried in the Archaeological Museum in Zadar, Museum of Nin Antiquities, under number NIN INV BR MNS 2530. In the previous bibliography, this boat is also known as Nin 2. However, the written records and photo documentation of the work conducted by the International Centre for Underwater Archaeology in Zadar the same boat is referred to as Nin 1. Due to this unintentional name change, neither Nin 1 Nin 2 is used in the text in order to avoid further confusion.

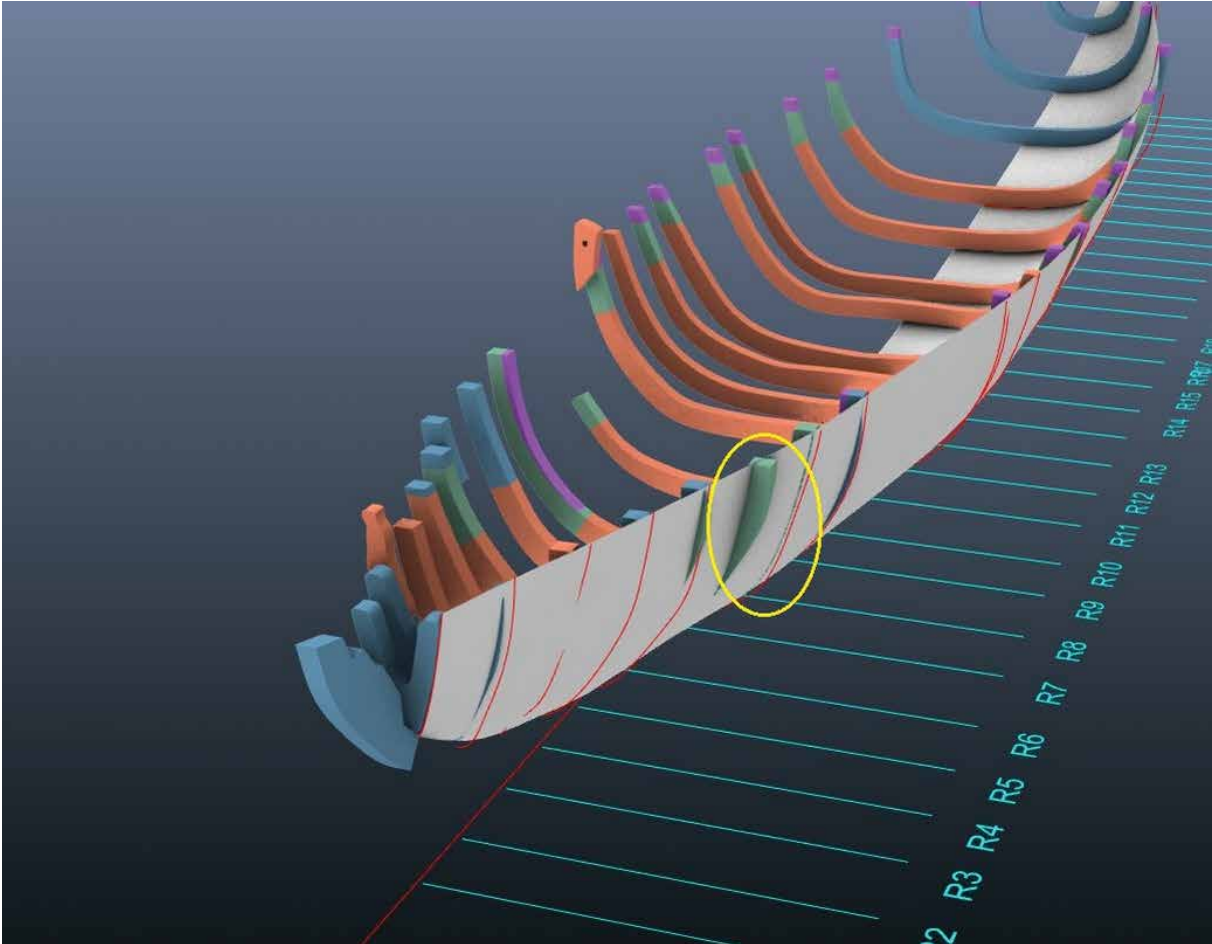


Fig. 2 Frame 6 does not adhere to the model line (model: N. Budimir, ViaKornel Ltd)

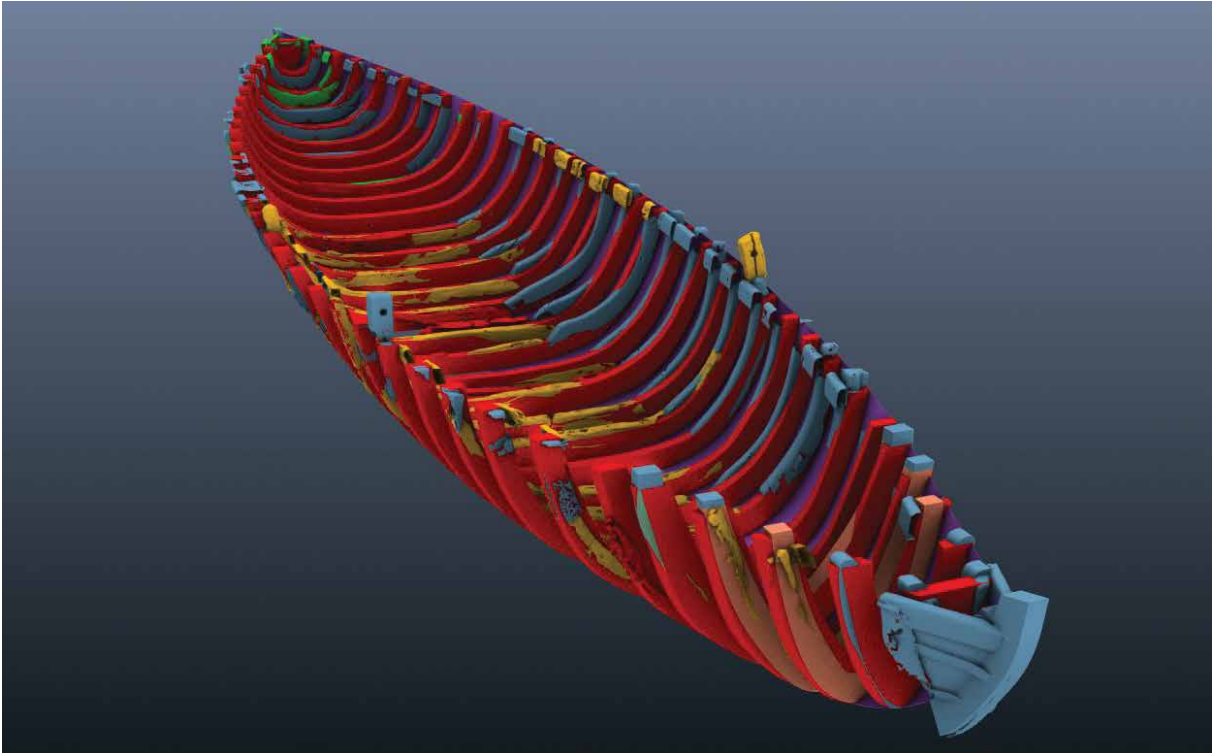


Fig. 3 Ideal reconstruction of the boat by 3D modelling (model: N. Budimir, ViaKornel Ltd)

Furthermore, because the stern end of the reconstructed boat (Nin MNS 2530) does not have preserved original parts, a compromise was reached between the original parts of the vessel's construction and reconstruction of the existing carpentry. Accordingly, individual frames of carpentry which best corresponded to the originally preserved lines of the frames were used in 3D modelling for the purpose of ideal reconstruction. As for other elements, such as the inner side plank, cleats and mooring elements, bow and stern loom and side beams, the original elements were used to make the model where they were available, and the model was supplemented based on carpentry reconstructions in those parts where original was missing. An ideal reconstruction of the vessel was obtained (Fig. 3) as result of 3D modelling, and the elements used were indicated in different colours i.e., yellow was used for the original preserved wooden parts, blue was used for the existing carpentry reconstruction, and red indicated the parts that make up the ideal line of 3D models (Budimir 2021).

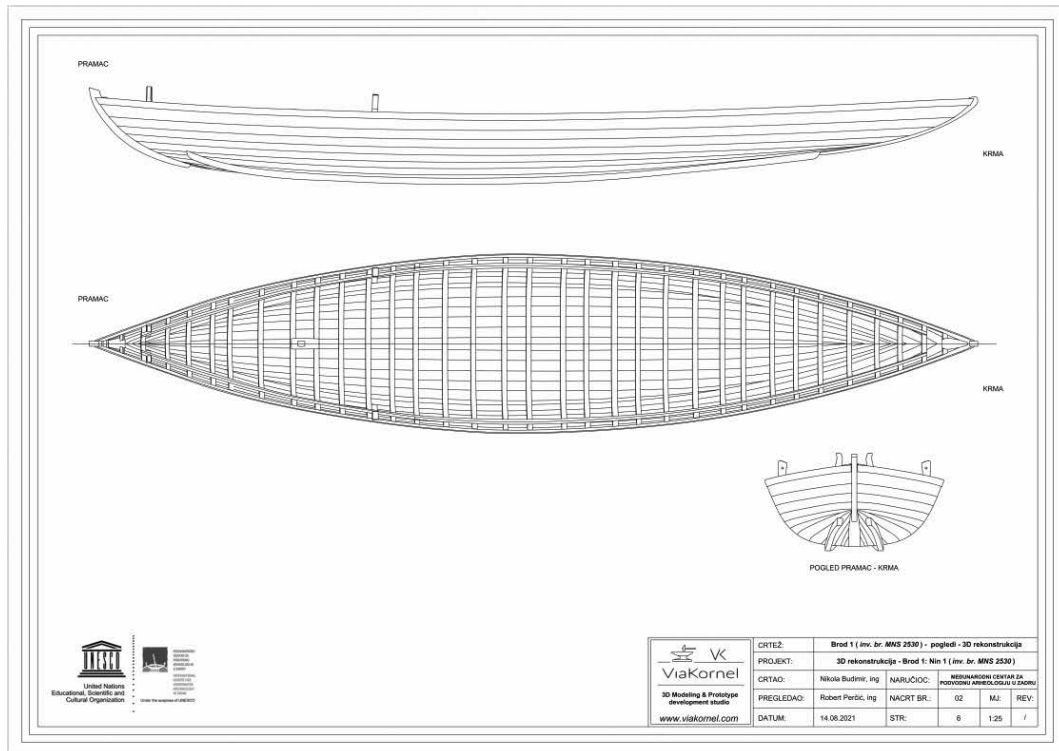


Fig. 4 Final drawings of the boat structure based on 3D modelling (drawing: N. Budimir, ViaKornel Ltd)

3.2. 2D documentation

Based on the information obtained by 3D scanning, 2D drawing documentation of the reconstructed boat (Nin MNS 2530) was compiled. A complete 3D reconstruction of the boat had to be done first to ensure that the 2D drawing documentation was accurate. This meant that within the 3D reconstruction, the missing elements of the vessel, as well as cracks, fissures or holes caused by marine organisms, cargo sludge, the marine environment or the conservation process had to be reconstructed. The creation of detailed 2D drawing documentation was possible after these irregularities were rectified. The 2D drawings clearly indicate which original elements were used to make the 3D model (Fig. 4). Since the 2D drawings are based on the 3D documentation of the current condition of the boat displayed in the Museum, the drawings represent only basic or introductory material for the possible future, more detailed analyses of vessel construction, and facilitate the comparison and revision of existing drafts of the boat lines (Budimir 2021).

Consequently, it became possible to compare the two drafts because the reconstructed boat (NIN MNS 2530) was documented before the aforementioned comprehensive conservation and restoration procedure was launched. Namely, in 2016 the studio Arheo Ko-op documented the then current condition of the reconstructed boat (NIN MNS 2530) by making 2D drawings. The boat was documented together with the metal cradle in which it is displayed (Fig. 5). A comparison of the 2D documentation from 2016 and the new drafts obtained by 3D documentation shows a noticeable difference in the shape of the boat. Since the metal cradle was probably built according to measurements made after excavation of boat from the seabed, when dimensional changes in wood due to various causes were most likely neglected, the shape of the boat is defined according to the shape of the metal cradle in which the boat is displayed.

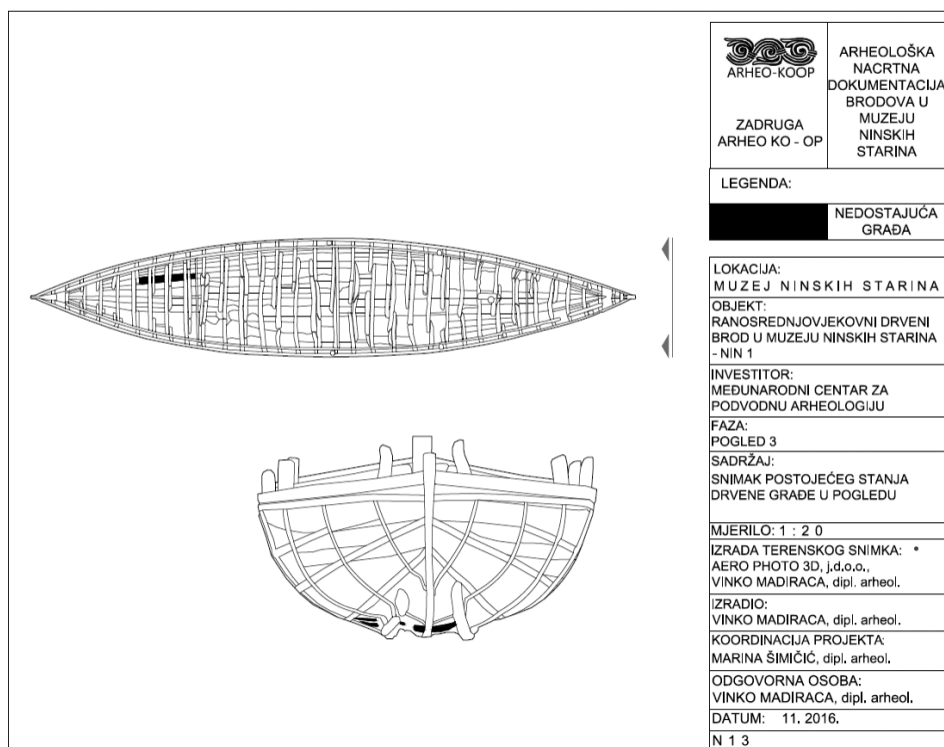


Fig. 5 Drawing of the reconstructed boat (Nin MNS 2530) with its metal cradle, made in 2016 (drawing: V. Madiraca, Arheo Ko-op)



Fig. 6 Photorealistic image or rendering of the *Condura Croatica*, based on the model of boat Nin MNS 2530 (model: N. Budimir, ViaKornel Ltd)

Therefore, a comparison of the two bow-to-stern views shows that the shape of the hull is less rounded than thought. The 2D documentation obtained by means of the 3D documentation clearly shows that the bottom of the boat is flatter, its bilge is wider and its sides are straighter.

The aforementioned demonstrates that the size and shape of the metal cradle does not correspond to the shape of the boat's hull and continues to define and refer to an inaccurate and untrue line for the boat. There is an obvious need to present both vessels differently. This would provide better insight into the hull shapes as well as their construction, and the data obtained by 3D scanning can greatly simplify and accelerate the choice of how to display the boats – if a decision on their different presentation is ever made.

The final phase of this project was the creation of a photorealistic image or rendering of the *Condura Croatica*, during which the model was 'painted' and visualized entirely according to historical materials used in construction. In this case, it was about several varieties of oak (Radić Rossi, Liphshitz 2010: 263–264). The photorealistic image or rendering of the *Condura Croatica* was presented by the studio ViaKornel as a final result of 2D documentation and 3D modelling (Fig. 6).

4. Conclusion

3D scanning is a new technology which has also found its application in the documentation, recording and measurement of objects with great historical significance. The technology is efficient and accurate and has been selected as the contemporary method for documenting *Condura Croatica* boats. The benefits of documenting the current condition of boats by 3D scanning are multiple. With 3D scanning, the boats were archived in digital format and each piece was measured and documented without the need to touch or move them. By using 3D printing and laser cutting technology, it is possible to create and replace damaged or destroyed elements that are virtually identical to the originals.

Once documented in this way, 3D reconstructions, restorations or replicas of the boats based to the existing originals can always be made subsequently. Furthermore, the digital documentation of both boats has created an opportunity to display each boat more appropriately, which will better highlight their specific construction.

With 3D technology, the present ship lines were successfully reviewed and more accurate lines were obtained. The previously mentioned gap between the planking and frames was created not only due to the ill-fitting cradle in which the boat is exhibited, but also as a consequence of the wood drying and the frames moving a few centimetres back and forth from their original position. The bending angle of the frames due to drying and the absence of degraded parts in certain wooden elements also contributed to the aforementioned gap, as well as the different hull's shape. The revision resulted in an improved shape for the boat's structure and a corrected visual identity. The documentation materials may contribute to more detailed analyses of boat construction in the future.

Moreover, the accelerated development of augmented virtual reality applications can bring newly created and reconstructed technical 3D/2D materials closer to the public or museum visitors, shipbuilders and anyone interested in historical and traditional naval architecture. Augmented virtual reality applications can create a boat in the form of attractive virtual models and animations or as a virtual replica of the *Condura Croatica*, which can be presented in detail on the screen and thus combine technical documentation with modern digital technologies.

References

- Brusić, Z. 1969. Podmorska arheološka istraživanja starohrvatskih brodova na ulazu u ninsku luku. *Radovi Instituta JAZU u Zadru* 16-17: 443–448.
- Brusić, Z. 1978. Rezultati najnovijih istraživanja i vađenje starohrvatskih brodova na ulazu u ninsku luku. *Adriatica Maritima* II: 5–14.
- Budimir, N. 2021. *Condura Croatica – 3D dokumentiranje*. Iskaz radova, ViaKornel, Rijeka. (unpublished report)
- Hauer, D., Ellingsen, S., Vedholm, K., Kosche, F., Brekke, A. 2023. New methodologies on the analysis of archaeological wooden structures. Establishing protective measures of Viking age ships and sledges prior to construction work and relocation processes. In I. Hovmand, M. Felter, I. Stelzner (eds), *Proceedings of the 15th ICOM-CC Group on Wet Organic Archaeological Materials Conference, Mainz 2023*. ICOM-CC: 48–56.
- Jelić, A. 2023. *Condura Croatica – The 11th century ship, re-conservation and new discoveries*. In I. Hovmand, M. Felter, I. Stelzner (eds), *Proceedings of the 15th ICOM-CC Group on Wet Organic Archaeological Materials Conference, Mainz 2023*. ICOM-CC: 228–235.
- Jurić, R., Oguić, S., Vilhar, B. 1991. Konzervacija i početak rekonstrukcije ranosrednjovjekovnih brodova iz Nina. *Adrias* 4-5: 43–62.
- Jurić, R., Sutlović, S., Vilhar, B. 1997. The Early Croatian Boats from Nin. *Diadora* 18-19: 379–394.
- Kozličić, M. 1991. *Brod istočnog Jadrana u starom i novom vijeku, katalog izložbe*. Kaštel Novi, Zavičajni muzej Kaštela: 15–17.
- Kozličić, M., Brusić, Z. 1991. Liburnski i starohrvatski brodovi iz Nina (rekonstrukcija). *Adrias* 4-5: 33–42.
- Radić Rossi, I., Liphshitz, N. 2010. Analiza drvene građe srednjovjekovnih brodica iz Nina. *Archaeologia Adriatica* IV: 257–270.
- Šimičić, M., Vrgoč, Z. 2016. *Konzervatorsko restauratorski elaborat – brodovi tipa Condura Croatica, Muzej ninskih starina, Nin*. Elaborat, Međunarodni centar za podvodnu arheologiju u Zadru, Zadar. (unpublished report)