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Monitoring physical modifications on restored Neolithic wooden tools

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1. Introduction

Archaeological wooden pile dwellings stand as a rich and invaluable storehouse of knowledge, shedding light on landscape evolution and ancient cultural practices. The waterlogged archaeological wood within these dwellings holds precious insights into past ecological and technological expertise and the array of products and solutions crafted by humans for their daily lives (UNESCO World Heritage).

The preservation of this wood is intricately tied to the surrounding environment. These conditions can be influenced by fluctuations in groundwater levels, changes in lake levels, sediment composition, water quality, erosion, and the anthropogenic pressures arising from activities within this delicate ecosystem. Moreover, the impact of these conditions may vary within the same site, depending on factors such as the location of materials, the shape and size of buried objects, taxa, or surface treatments. Additionally, the excavation process and the subsequent steps taken to prevent the deterioration of waterlogged wood due to long-term water removal can yield significant impacts on the physical and chemical properties of these materials (Walsh-Korb et al., 2022), potentially causing irreversible alterations to the valuable information they contain.

Extensive research has delved into structural changes in waterlogged wood (Jensen and Gregory, 2006), preservation methods for waterlogged archaeological wood (Jones et al., 2009; Mortensen et al., 2007; Graves, 2004), and the long-term behaviour of consolidated wood using substances like PEG (polyethylene glycol) (Almkvist and Persson, 2008). Most of this research has concentrated on the cellular and biochemical aspects of these materials. However, less attention has been devoted to the macroscopic properties of artefacts, which hold great importance for archaeological analyses aimed at understanding how artefacts were produced and used. The structural degradation of the cells can significantly influence the size, shape, and surfaces of the artefacts. In this regard, 3D digital technology has been employed to monitor changes in waterlogged materials both before and after treatment (Bandiera et al., 2013; Schindelholz, 2005; Karsten and Graeme, 2010), demonstrating its potential as a tool for documentation and conservation purposes.

In the framework of the WoodPLake project (Archaeological Wooden Pile-Dwelling in Mediterranean European lakes: Strategies for the exploitation, monitoring and conservation, JPICH call), which focuses on assessing the impact of climate change and extreme weather events on the preservation and safeguarding of pile dwellings in Mediterranean lakes, we conducted a study on the conservation status of a collection of wooden archaeological artefacts excavated at La Draga site. The monitoring of the state of preservation of the restored wooden objects nearly 20 years after being recovered already displays some remarkable differences which could be associated with the taxa, shape and probably archaeological localization of the objects in the different sectors of the excavation (García et al., 2024). The goal of this paper is to analyse the behaviour of wooden objects more deeply after restoration by using digital models for thoroughly measuring volume and shape changes. We intend also to correlate these changes with the contextual data of the objects. To do so, a secondary objective of this paper will be to ascertain how digital models can contribute to our understanding of wood preservation and the long-term impact of the restoration and conservation of wood artefacts.

The study of objects recovered nearly two decades ago can yield measurable parameters for comparing the state of preservation of materials through time, in particular deformations. We expect this approach to test the digital model as a tool to support the research on the preservation condition of waterlogged wooden artefacts. We anticipate that new archaeological research will be conducted at the site in the coming years to monitor the condition of wood layers. Monitoring undergone changes in recent times can provide parameters for understanding the behaviour of the materials in different contexts and environments.

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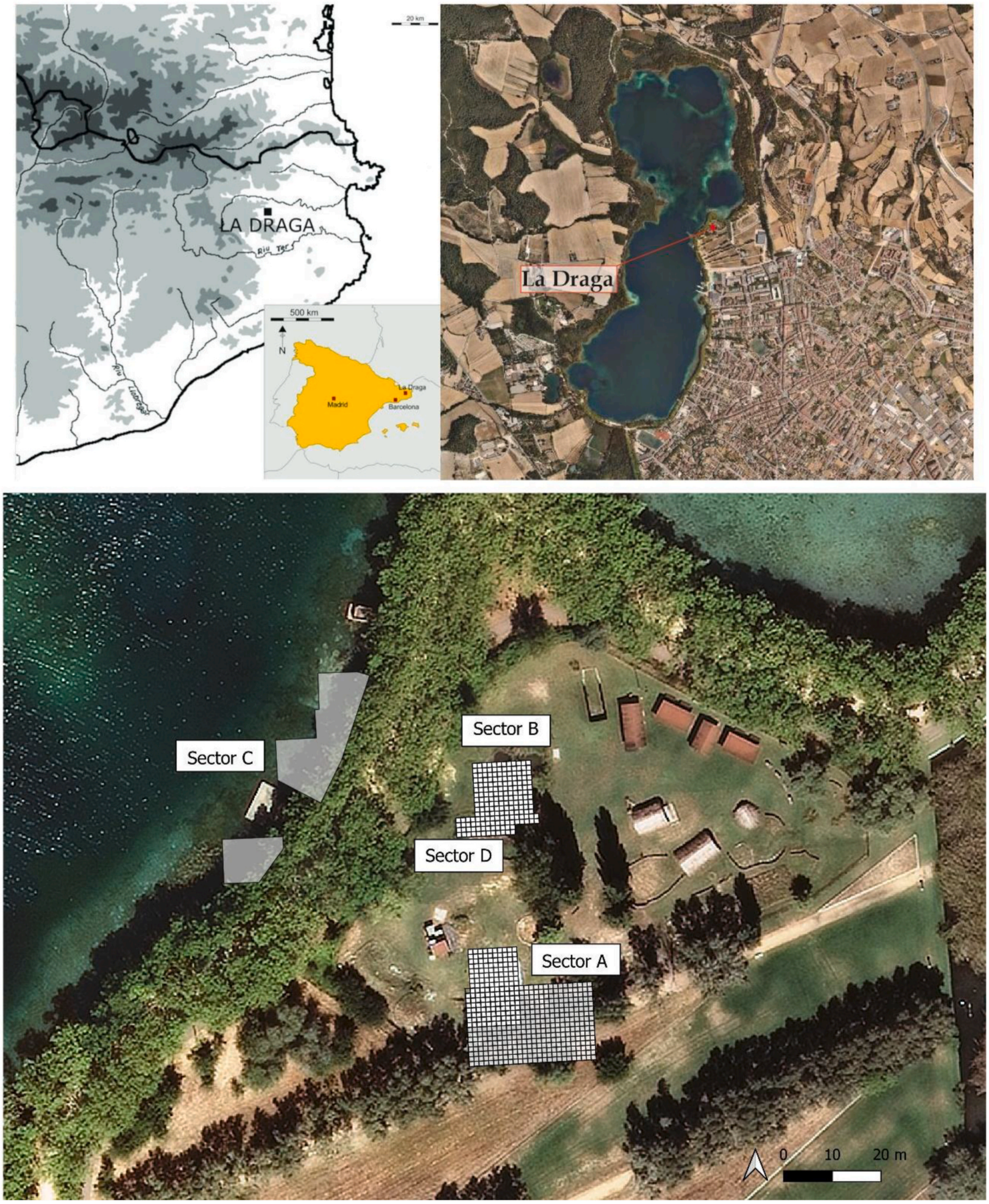

Fig. 1. Location of La Draga archaeological site.

1.1. *The site (la Draga)*

The focus of this study was on the Early Neolithic site of La Draga, which stands out as the sole lake-dwelling site on the Iberian Peninsula, making it one of the most fragile and delicate archaeological sites in the region. Situated on the western shore of Banyoles Lake in the north-eastern Iberian Peninsula (Fig. 1), the site is currently partially submerged, with its most extensive area located on the mainland. The partial submersion has led to the remarkable preservation of organic remains, a rarity in the Iberian Peninsula.

Dating back to approximately 5300–4700 BCE, the settlement at La Draga was likely established by some of the earliest farming groups to inhabit the north-eastern Iberian Peninsula (Andreaki et al., 2022; Bogdanovic et al., 2015; Bosch et al., 2011; Palomo et al., 2014; López-Bultó et al., 2025). Due to its early chronology and remarkable preservation of organic materials, it holds significant importance as one of the most relevant Early Neolithic sites in southern Europe and the Mediterranean region.

Archaeological excavations at La Draga commenced in the 1990s and continue to this day. From 1990 to 2021, approximately 1000 m^2 of the site has been excavated, accounting for about 6 % of the estimated total area of 15,000 m^2 (Fig. 1). The excavated area is divided into three distinct sectors—A, B/D, and C—defined by their relationship to the lake and the water table. Sector A is situated at the shore of the lake, at the highest point of the site, and although nowadays is in the water table it was dry in some undetermined periods resulting in the lack of preserved organic remains. The tips of the wooden piles beneath the archaeological layers are the only organic wood preserved in this sector. In sector B/D, also in the inland area, the remains of the wooden dwellings of the earliest occupation levels of the site have remained submerged below the water table since the Neolithic era, leading to excellent preservation of organic matter. Sector C is nowadays located under the water lakes,

Table 1
Tools used for the study and their characteristics.

ID	Length	Width	Thickness
DG01_JJ87_26	610 mm	30 mm	26 mm
DG01_KD89_11	635 mm	35 mm	14 mm
DG02_KC91_09	545 mm	40 mm	25 mm
DG03_FA73_02	555 mm	23 mm	23 mm
DG03_JE88_04	705 mm	30 mm	20 mm
DG03_JE89_32	780 mm	30 mm	30 mm
DG03_JH88_10	605 mm	20 mm	15 mm
DG03_JF90_06	600 mm	21 mm	14 mm

also enabling exceptional preservation of organic materials.

Through the excavations, two distinct archaeological horizons have been identified, corresponding to different phases of occupation with some variations depending on the sector. Recently, the excavation of sector B/D revealed a clear distinction between these horizons, separated by a paved surface of travertine slabs overlapping an older layer of timber logs. The layers above this pavement pertain to the last Neolithic occupations (5216–4981 cal BC) and were above the water table at some moment since the Neolithic times, leading to the lack of preserved organic material. In contrast, the layers below the pavement belong to the earliest occupation (5372–5067 cal BC) and boast exceptional preservation of organic matter, facilitating the recovery of an exceptional collection of wood remains, including numerous piles, beams used in construction, and wooden tools used in daily life practices.

Between 1991 and 2005 more than a thousand wooden piles and about 200 plant-based objects were recovered, forming one of the most diverse archaeological wooden tools ensembles in the Mediterranean region. According to functional hypotheses taken from ethnographic and archaeological analogies, and from observing the characteristics of these elements, we can relate them to the following uses (Bosch et al., 2006; Palomo et al., 2014; Piqué et al., 2015; López-Bultó, 2015; López-Bultó et al., 2020; Berihuete-Azorín et al., 2022): construction (poles, posts and planks), agriculture (sickle handles and pointed sticks), hunting (bows, arrow shafts and projectile points), food processing (mixer, ladles and containers), woodworking (adze handles and wedges), textile use (combs and spindle-like objects) and other objects of indeterminate use (paddle, hook-shaped objects, etc.). As part of its process of conservation, the objects were freeze-dried and, while some photographic documentation and certain analyses (such as those related to taxa and morphometry) were carried out, no further assessments regarding the wood's degradation were conducted at that time. Since then, these objects have been kept in controlled temperature and humidity on the local museum reserves. Previous studies (García-Alonso et al., 2024) have already shown degradation tendencies of the objects about their taxon and their shape; for instance, boxwood (*Buxus sempervirens*) objects tend to crack in the transverse direction of the fibre whereas oak porous wood was affected by post-depositional processes such as the growth of the monocotyledon roots which perforated the objects. Moreover, materials deposited in the underwater layers of Sector C were more damaged than those from Sector B/D. Finally, the size and shape of the objects also resulted in an unequal state of preservation.

2. Materials

2.1. The wooden tools

This paper focuses on examining 8 wooden tools that were recovered during the years 2001, 2002 and 2003. The tools chosen for analysis in this study (Table 1) were all of the same type (pointed sticks), morphology (straight) and raw material (*Buxus sempervirens*). All the tools under investigation were unearthed from sectors B and C of the site, which can be attributed to the site's initial phase of occupation. Upon excavation, these tools were restored and subjected to freeze-drying processes previous impregnation in PEG.

The objects were first digitalized between the years 2012 and 2013 after their restoration (López-Bultó, 2015), and a new model has been created in the frame of the current project (during 2022) to compare their physical properties.

2.2. Restauration process

Concerning the state of the wooden archaeological artefacts from La Draga at the time of their excavation, some appeared to be in excellent condition when examined at a macroscopic level. Nonetheless, some horizontal architectonical timber had clear signs of degradation, probably as a result of being long time exposed to the environmental agents during the Neolithic. The portion of the wooden posts driven into the lakebed chalk is better preserved, conserving still the bark, however, the in-depth physical-chemical analysis has unveiled a significant degree of degradation in specific samples of this construction wood. Moreover, as previously noted, variations in the preservation state are evident, depending on the type of wood that was used, its morphology and/or archaeological sector.

The intervention to prevent the degradation process at the excavation site started immediately in the field through prompt action (Brunning and Watson, 2010). To prevent further deterioration, the objects were immersed in water immediately after excavation until they were transported to the laboratory for restoration. The chosen method for stabilization involved impregnation with Polyethylene glycol (PEG-400 and PEG-4000), followed by freeze-drying, as air-drying would have resulted in significant and irreversible deformation. Since 1999 the freeze-drying process has been carried out at the facilities of the Centre for Underwater Archaeology of Catalonia (CASC) (Bosch et al., 2006).

The objects analysed in this study underwent a uniform conservation-restoration treatment. Upon excavation, the objects were immersed in water containing a minimal amount of fungicide (1 % boric acid and borax in a 7:3 ratio). The conservation treatment of the pieces recovered in 2001 and 2002 began in January 2004, with an impregnation process lasting 98 days. The ones excavated in 2003 were processed in December 2005, and polyethene glycol impregnation was extended for 155 days. After being taken out of the solution, any excess polyethene glycol was removed from the object's surface, and they were then placed in heat-sealed bags and frozen at approximately −20 °C. Subsequently, freeze-drying was performed to complete the conservation process. Following the freeze-drying process, the objects underwent restoration, with fragments being connected using nitrocellulosic adhesive. On the objects labelled DG03_JE88_04, DG03_JE89_32, DG03_JH88_10, and DG03_JF90_06, putty was employed to fill the cracks in the wood. Finally, a protective layer of acrylic resin was applied to the entire collection. Detailed descriptions of these protocols can be found in publications by Chinchilla (2003), Bosch, Chinchilla, and Tarrús (2000), and Chinchilla et al. (2017).

Since 2010, these objects have been stored in a museum reserve with a controlled temperature where the ambient humidity is consistently maintained between 50 and 55 %, though the temperature experiences slight seasonal variations ranging from 18 to 20 °C.

As for the DG02_KC91_09 piece, it experienced accidental fragmentation in 2022, but the fragments were successfully reconnected using nitrocellulosic adhesive. On the other hand, the piece DG03_FA73_02 was found to be in two separate pieces during this study.

3. Methods

Methodologies and techniques to assess preservation in waterlogged archaeological wood have greatly improved in recent years. There is still no single technique that can be considered the best option in that regard (High and Penkman, 2020), but laser scanning has been proven as a solid option so far (Lobb et al., 2010; Bandiera et al., 2013; Middleton, 2016;

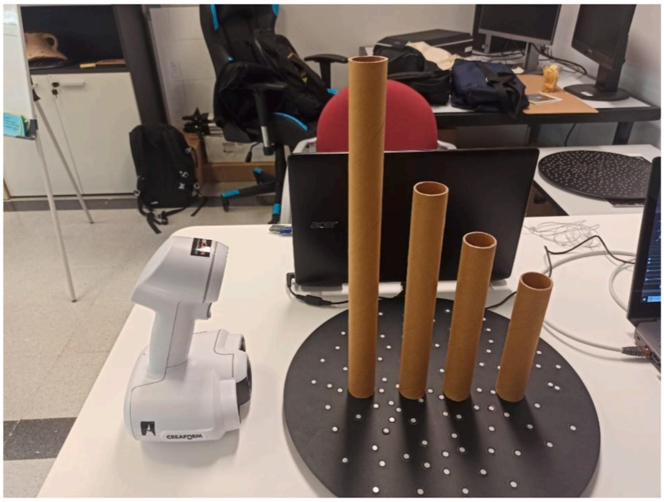

Fig. 2. Picture of some of the reference pieces used to characterize the volume uncertainty.

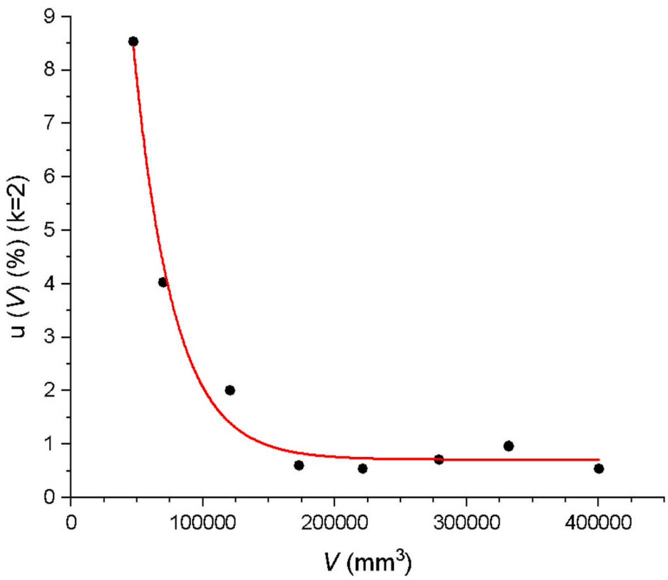

Fig. 3. Introduced uncertainty u(V) (k = 2) due to the measurement methodology for different scanning volumes.

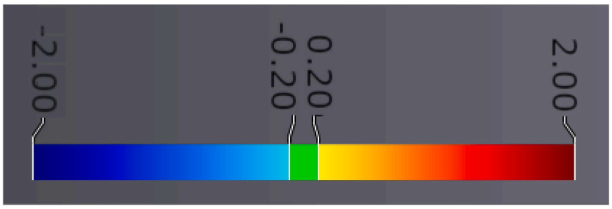

Fig. 4. Colour bar representing the difference between compared meshes and the error margin in mm.

Stelzner et al., 2022). Previous research conducted with la Draga's wooden tools through 3D scanning and digital models (Moitinho, 2013; López-Bultó, 2015) came as a great opportunity to monitor the volumetric and morphological changes. La Draga's freeze-dried wooden tools were 3D scanned in two different moments: 2015 and 2022. Because from 2015 to 2022 3D acquisition techniques changed and improved considerably, different 3D scanning devices were used.

3.1. Hardware, software and 3D scanning process

The scanning process in 2015 was developed with a structured light scanner: Breukmann's SmartSCAN3D Duo System. It was equipped with 90 mm field of view optical sensors. The digital models were processed and analysed with "Rapidform XO Scan 2010" software. The acquisition of the 3D models followed previously described protocols (López-Bultó, 2015; Moitinho, 2013), covering aspects such as materials and preparation of the working place, digital data acquisition, digital data processing, and the generation of the digital model. The "Archaeology of Social Dynamics Group" provided both hardware and software at CSIC-IMF (Spain).

In 2022, the device used for the 2015 scans was not available anymore, so the new models were captured using new hardware and software which could be comparable with the 2015 3D models. The 2022 3D scanning was performed using Creaform's "GO! Scan" (high-precision laser scanner) equipped with a lens of 0.1 mm of structural resolution. The software used to capture, edit and analyse the 3D models were "VXmodel" and "VXinspect" from Creaform. The scanning protocol that this new device required was much less complex than the previous one in 2015. It consisted of a controlled environment with little light and movement alterations. The "Digital Lab- UAB Open Labs" (Spain) provided both hardware and software.

3.2. Uncertainty and margin of error of the measurement

To compare a series of measurements among themselves, it is necessary to express their results indicating their uncertainty, i.e., the interval or range of values in which there is a non-negligible probability of finding the true value. The uncertainty mainly depends on the instrumentation used and the measurement methodology. Once all sources of uncertainty have been evaluated, a coverage factor k = 2 is usually applied, called expanded uncertainty, which indicates that the range defined by the measured value and its uncertainty encompasses a 95 % probability of finding the true value (JCGM, 2008). This assertion assumes that the overall computation of uncertainty sources follows a Normal Distribution.

The surface model of each piece has been obtained from the 3D scanning as described before. The comparison of the surface is conducted by overlapping the corresponding models from the years 2015 and 2022 and establishing a minimum threshold point-to-point perpendicular to the surface to consider such a difference significant. The threshold has been determined based on the uncertainty in the measured distance given by the calibration certificate of the 3D scanner. The calibration is based on the comparison of the distance between two equal spheres (Mendricky, 2016), and the uncertainty obtained in the distance between these spheres is 0.18 mm (k = 2), a value that will be taken as the threshold. Beyond this threshold, greater differences in the distance between two points on the surface of both models will be considered a significant change.

The volume in each studied piece has been obtained from the value provided by the 3D model. Its main sources of uncertainty are that introduced by the measuring equipment, the differences introduced by the operator during scanning, and possible variations in the post-processing of the software. To estimate the uncertainty in the volume $u(V)$, various reference objects with volumes in the range of 50.000–400.000 m m^3 have been used. These objects are regular geometric shapes such as parallelepipeds and cylinders, whose nominal value has been obtained from their dimensions measured with a resolution of 0.02 mm calliper and the mathematical formula governing their volume.

Different operators have scanned and post-processed the reference objects n times, with n = 3. Repeating the measurements provides the uncertainty of the equipment while using multiple individuals to perform the process fully characterizes the uncertainty introduced by them. Finally, an additional source of uncertainty considered is the

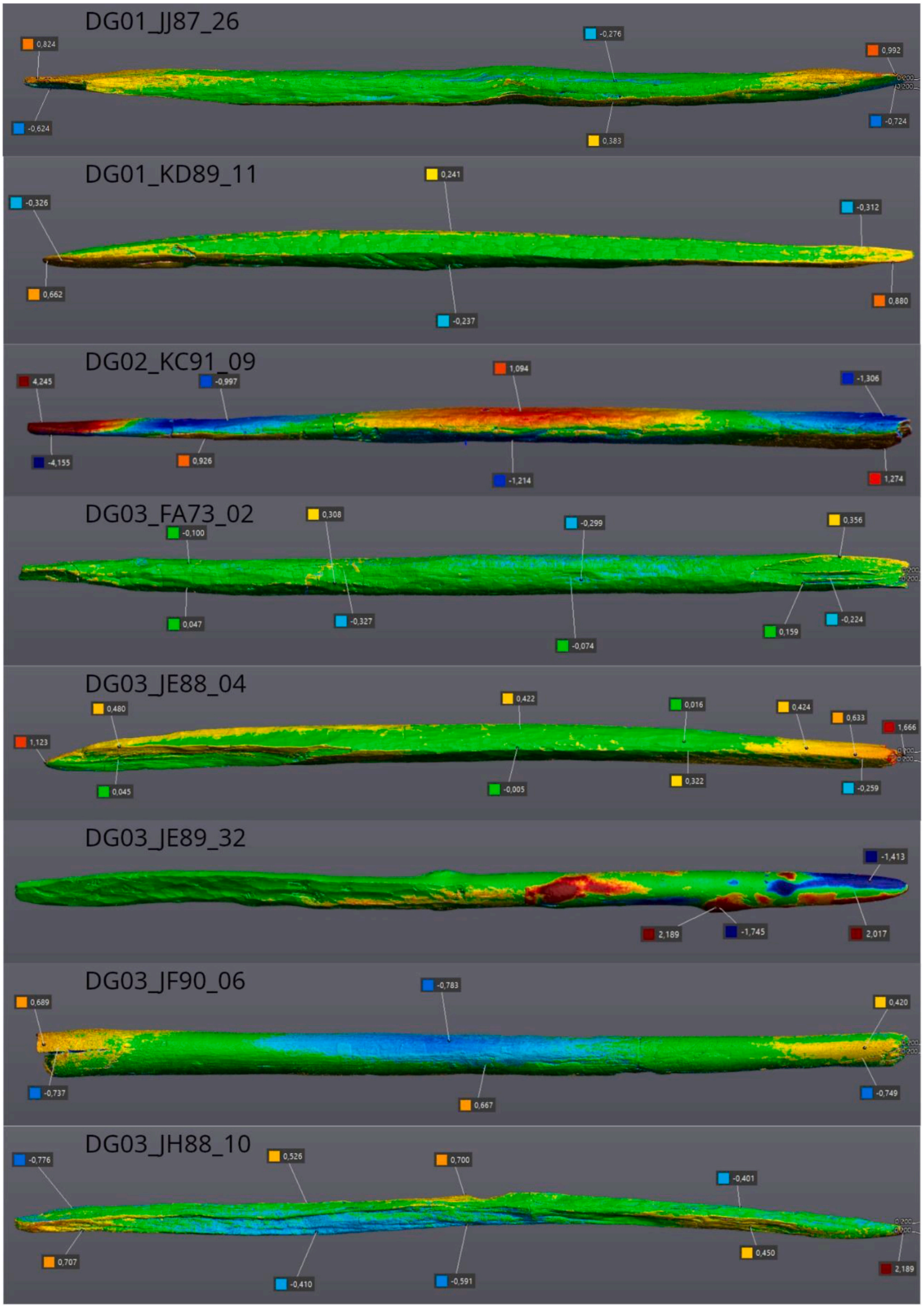

Fig. 5. Morphological differences between de 2015 and the 2022 digital meshes of all the analysed archaeological wooden tools (for scale reference see Fig. 4).

systematic error ε, which is the difference between the volume measured by the equipment and the nominal value of the reference objects (Fig. 2). This systematic error is due to the inherent margin of error in the software and hardware.

In this way, uncertainty is obtained for each reference volume V, considering all the mentioned sources, such as:

$$u(V)(k=2)=2\cdot\sqrt{\delta^2+\varepsilon^2}$$

Where δ includes type A statistical uncertainty from the n repetitions obtained as SD/√n, with SD being the standard deviation of the mean, and ε is the systematic error.

In Fig. 3, the uncertainty obtained for each of the measured reference volumes is shown. An exponential fit of the form $u(V) = \mathrm{a} + \mathrm{b}\cdot \mathrm{e}\hat{}(\text{-}V/\mathrm{c})$ has been performed to model the volume uncertainty as a function of the average volume per scanner. The resulting values are a = 0.7, b = 37, and c = 30195 mm^{-3} with an adjusted $\mathrm{R}^2 = 0.98$.

It can be observed (Fig. 3) that for volumes starting from 150000

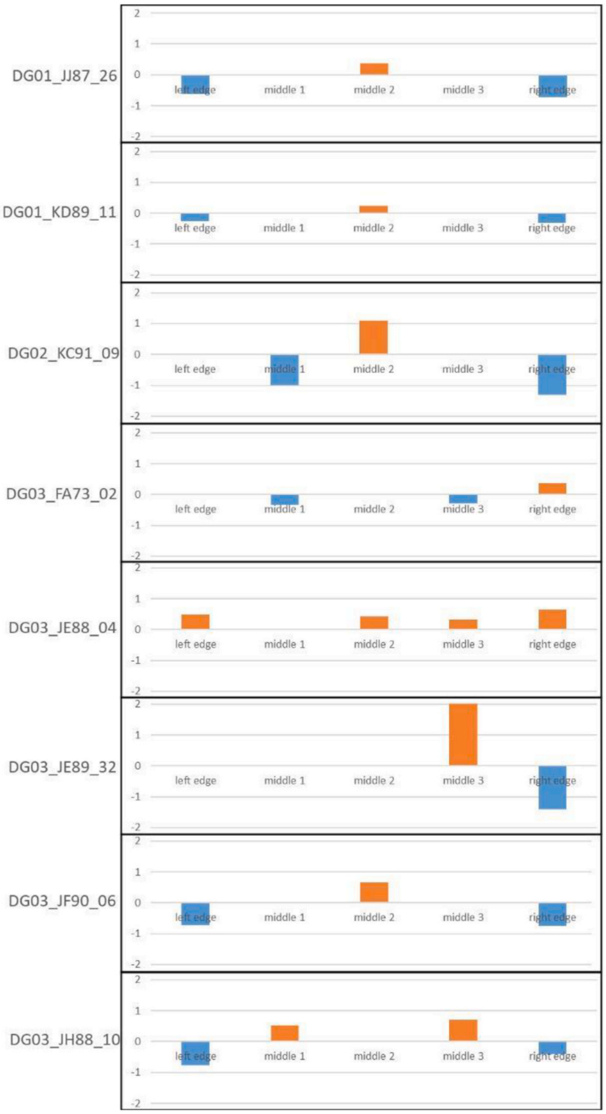

Fig. 6. Column chart representing the differences between the 2015 and 2022 digital models through the models and both edges.

Table 2
vol measured in the years 2015 and 2022 for each of the samples, their absolute difference ΔV, and the percentage difference D concerning the one corresponding to the year 2015.

ID	V [2015] (mm^3)	V [2022] (mm^3)	ΔV (mm^3)	D (%)
DG01_JJ87_26	268319	265215	−3104	−1,16
DG01_KD89_11	244683	238839	−5844	−2,39
DG02_KC91_09	243217	243102	−115	−0,05
DG03_FA73_02	184416	184812	396	0,21
DG03_JE88_04	295621	287879	−7742	−2,62
DG03_JE89_32	423847	414407	−9440	−2,23
DG03_JH88_10	99740	100784	1044	1,05
DG03_JF90_06	257049	257524	475	0,18

mm^3, the uncertainty remains approximately constant below 1 %. For smaller volumes, the uncertainty increases exponentially in the range of approximately 1 %–8 %, and it keeps increasing for even smaller volumes.

3.3. *Parameters used for the comparison*

The comparison of the 3D digital models of the wooden archaeological tools of la Draga was based on two main parameters: morphology and volume.

The morphological comparison of the 2015 and 2022 3D digital models was developed using Creaform's "VX Elements" software. The two models of the same archaeological wooden tool were automatically aligned, and this alignment was visually checked. After obtaining a reference mesh from the two entities being compared, the "Compare" tool of the software will then apply a colour scale. On the digital surface where blueish colours represent a negative difference (which means that the 2022 model stands below the 2015 model) whereas reddish colours represent a positive difference (the 2022 model stands above the 2015 model). The software also allows the application of an error margin. The colour bar limits were set at a difference of 2/-2 mm in all the models, where -2mm was represented by dark blue and 2 mm difference by dark red. Also, in all the cases the error margin was established from 0.2 to −0.2 mm (Fig. 4).

Almost all 3D editing software offers the volume measure tool. This is an almost automatic and fast measuring tool, which only requires the digital meshes to be hermetic. To do so, some of the meshes obtained after scanning the wooden archaeological tools required some healing and editing which has been developed with the "VX Inspect" software. Once the 3D meshes were hermetic the volume measuring was fast and accurate.

4. Results

4.1. *Visual morphological comparison*

Fig. 5 shows the morphological comparison of the 2015 and 2022 digital models of the analysed archaeological wooden tools from La Draga. In the colour palette, the blueish colours represent a negative difference from the reference mesh (2015) with the compared one (2022) while the reddish colours represent a positive difference. The green colour means virtually no difference between the two digital meshes. The same results are represented by a column chart in Fig. 6.

Different considerations can be made regarding the morphological comparison of every one of the wooden digging sticks, but, in general, there is a trend that can be observed. Almost all the comparisons show an increase in the curvature of the wooden digging stick where the two edges shifted in one direction whilst the centre moved in the opposite direction. Even with differences in the degree of modification, this is the case of tools DG01_JJ87_26, DG01_KD89_11, DG02_KC91_09, DG03_JE88_04, DG03_JE89_32, DG03_JF90_06 and DG_03_JH88_10 (Figs. 5 and 6).

When it comes to absolute numbers model DG02_KC91_09 should be excluded from the analysis given that, as it has been stated in the "restoration process" section, it suffered a fracture in a moment from 2015 to 2022 and therefore the extreme left edge was excluded from this analysis. Even though the fracture only affected the extreme left edge of DG02_KC91_09, it is clear (Fig. 6) that even the rest of the model displays outstanding figures compared with the rest of the models. The rest of the models show an average deviation of 0.62 mm on every edge ranging from 0.26 to 2. 1 mm. At the same time, the middle part has also been moved an average of 0.46 mm through the other direction, ranging from 0.24 to 0.78 mm (Fig. 5).

The wooden tools that stays out of this bending dinamic is DG03_FA73_02, which follows the trend but it is very slight blending compared with the rest of the models. Its average measured modification is 0.21 mm (ranging from 0.05 to 0.36 mm), which is lower than the average measured in the other models. Therefore, we've considered that this tool presents virtually no modification in their morphology.

Digging stick DG03_JE89_32 is a special case. It presents a strong bending exclusively on its right half, while no modification at all on its

Table 3
Summary of the results discussed in this paper.

ID	Morphological modification	Volume modification	Archaeological Sector
DG01_JJ87_26	Clear bending	Clear modification	B/D
DG01_KD89_11	Clear bending	Clear modification	B/D
DG02_KC91_09	Clear bending	No clear modification	B/D
DG03_FA73_02	No clear bending	No clear modification	C
DG03_JE88_04	Clear bending	Clear modification	B/D
DG03_JE89_32	No clear bending	Clear modification	B/D
DG03_JH88_10	Clear bending	No clear modification	B/D
DG03_JF90_06	Clear bending	No clear modification	B/D

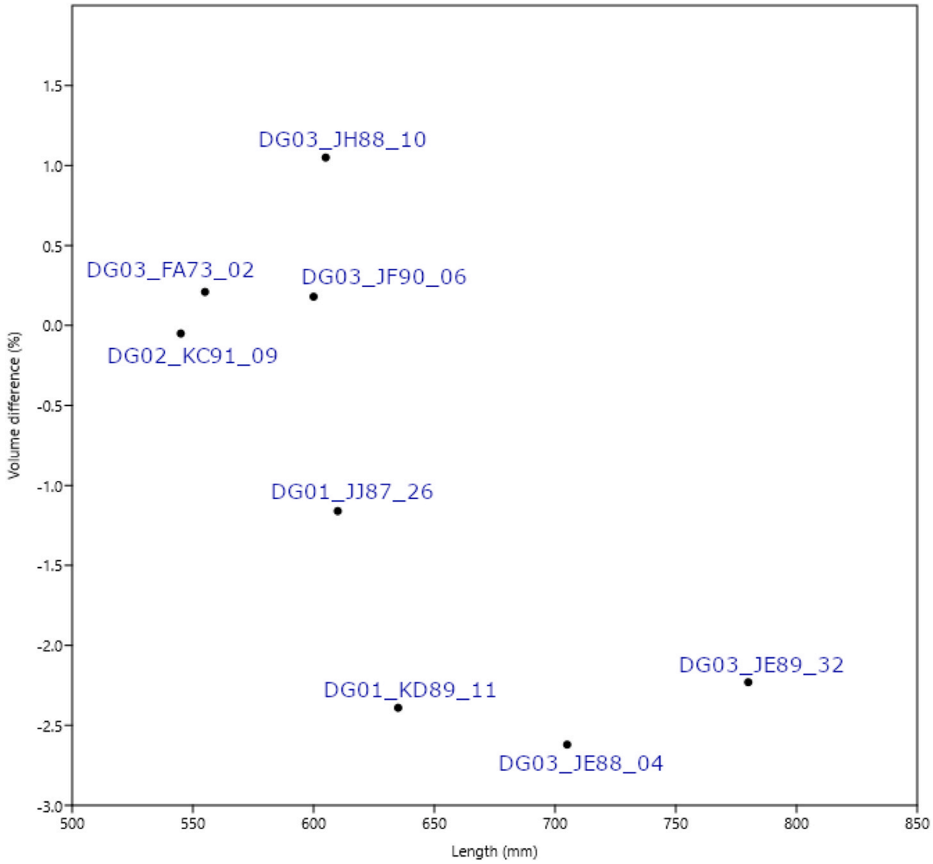

Fig. 7. Graphic distribution of the volume difference of the wooden tools based on the length (mm).

left half, which is a difference with the other bended models. Moreover, the numbers of this modification are outstanding, even higher than the broken model DG02_KC91_09.

4.2. Volume comparing

Next, Table 2 shows the results of the calculated volumes for the wooden pieces at the two time points (2015 and 2022), as well as their absolute and percentage differences. All the measured models except DG03_JH88_10 measure more than 150000 mm^3 (Table 2) and therefore the uncertainty threshold of the measured volume is lower than 1 % (Fig. 4). Meanwhile, DG03_JH88_10 the considered threshold should be a little bit higher.

Taking into account the volume of each piece and the uncertainty threshold from Fig. 4, it can be stated that objects DG01_JJ87_26, DG01_KD89_11, DG03_JE88_04, and DG03_JE89_32 have had their volume significantly modified with 95 % confidence. Specifically, their volume has decreased in the range of 1.2 %–2.6 %, depending on the sample. Meanwhile, models DG02_KC91_09, DG03_FA73_02 and DG03_JF90_06 present almost no volume difference at all, and model DG03_JH88_10 have a considerable difference (1.05 %), but given its smaller volume, it sticks in the error threshold.

5. Discussion

In summary, it can be stated a clear volume modification in 50 % of the wooden tools and a clear bending in 75 % of the cases. Overall, it has been identified an unequivocal physical modification of any kind in 7 of the 8 wooden tools studied (87.5 %), being the digging stick DG03_FA73_02 the only one with no evident modifications from 2015 to 2022 (Table 3).

As we stated before all the wooden tools analysed corresponded to the same functional adscription, had similar morphometric characteristics, corresponded to the same taxon, and were found in similar archaeological and taphonomic conditions. The main difference between DG03_FA73_02 and the rest of the tools is that it is the only one excavated in sector C, the underwater archaeological sector. It could also be considered that it is the second smallest wooden tool among the ones selected for this study.

The reasons for these clear morphometric modifications can be diverse and it is difficult to highlight one above the others. However, the morphological modification bending the two edges in one direction and the centre in the opposite most probably is due to a contraction of the longitudinal fibres.

Focusing now on the volumetric modification, there seems to be a clear relation between the length of the tool and the volume difference: the longer the tool is, the higher the percentage of decrease (Fig. 7). Curiously, this contraction is not clearly related to the 2015 volume of the objects; shorter objects, even being more volumetric, don't decrease in the same percentage to longer but thinner wooden tools. Therefore, it is stated that while the longitudinal contraction of the fibres tends to bend the material, the radial and tangential contractions result in a volume decrease.

Digital monitoring through 3D scanning on restored archaeological wood has become more and more common in recent years. The most relevant examples are the monitoring of big wooden structures such as ships (i.e. Collett et al., 2021) or historic wooden constructions (i.e. Bandiera et al., 2013). Some comparable examples to la Draga's wooden tools, assessed a mass loss of 4 % after the PEG restoration and a volume loss of 6 % from the original wooden object after 10 years (Stelzner et al., 2022), which implies a mass loss of 2.1 % from the restored object after this period, similar results to the ones obtained in this study.

6. Conclusions

Aiming to assess the conservation status of the collection of wooden archaeological artefacts excavated at the waterlogged site of La Draga and to monitor their morphometric modification over time after their restoration, 3D digital models of eight wooden tools were obtained in 2015 and again in 2022 and compared. All the tools digitally compared have the same taxonomic identification, have similar morphometric conditions, were excavated in similar years, their archaeological and taphonomic conditions were almost the same, the restoration and conservation processes applied to them followed the same protocols and have been stored in the same facilities on within the same environment.

After the comparison of the models obtained in every tool, it can be stated a clear volume modification in 50 % of the wooden tools and a clear bending in 87,5 % of the cases. Overall, it has been identified an unequivocal physical modification of any kind in 7 of the 8 wooden tools studied (87.5 %). The only wooden tool which doesn't display morphometric modifications is the second smaller, and the only one excavated in sector C. The causes of these alterations are still not clear, but it is certain that during the seven years from 2015 to 2022, longitudinal, radial and tangential shrinkage of the wooden fibres occurred. The results observed in this study are comparable to other laser scanning monitoring on restored archaeological wooden tools in terms of volume modification.

Archaeological wooden materials are extremely valuable archaeological data but very fragile at the same time. Their excavation, documentation, restoration and preservation are critical steps to restrain the degradation process, which is still unpreventable. The present situation in the Mediterranean area with global warming and severe droughts doesn't make but aggravate this situation. It is therefore critical to protect waterlogged sites as an extremely valuable and endangered heritage, as well as to systematize the documentation and registering process, and improve the restoring methods and museum reserves preservation conditions.

CRediT authorship contribution statement

Oriol López-Bultó: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Irene García-Alonso:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Daniel Rábago:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis. **Raquel Piqué:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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