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RESEARCH ARTICLE

Wood identification and tree-ring chronology building of oak pillars excavated from submerged prehistoric settlement (3000 BC), Ropotamo River estuary, Black Sea

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Abstract

Eighty one well-preserved wooden pillars were found as a result of underwater archaeological excavations of a submerged prehistoric settlement in the estuary of Ropotamo River, Black Sea. That provokes a scientific interest to identify wood materials. The longest tree-ring chronologies have been used to build floating dendrochronology series. Anatomical features of xylem showed that 34 out of the 81 studied wooden pillars belong to genus *Quercus*. The remaining 47 pillars belong to a species of the genera *Fraxinus*, *Acer*, *Ulmus* and *Platanus*. It has been found that 8 out of 34 oak pillars have a length of tree-ring series over 30 years. This was the reason to select them for dendrochronological studies. The length of the built floating master chronology for the oaks is 84 years. The lack of strong coherent signal between 34 single oak dendrochronological series can be explained with three different types of oak forest ecosystems, in the area of the Ropotamo River estuary. These forest ecosystems are as follows: oak high stand forests in Strandzha Mountain, oak coppice forests on the Black Sea coast plains and riparian 'Longoz' forests of Ropotamo River. The tree-ring series of these forest types have different tree-ring signatures. Based on the tree-ring analysis it can be assumed that the timber of the above-mentioned three types of oak ecosystems was used in the construction of the prehistoric settlement.

Keywords

Oak, wood identification, dendrochronology, underwater archaeology, submerged prehistoric settlement

Introduction

The basis of species differentiation of woody vegetation is the difference in morphology and specificity of the device of regenerative organs (flowers), buds, leaves, etc. Their study is part of a special scientific subject – systematic of plants. There are cases in which it is necessary to determine the tree species of wood found during various archaeological excavations, where it is not possible to determine the tree species on the basis of morphological systematic marks, because most often the archaeological wood is a fragment of a branch or stem of a tree. In this case, the determination of the species is carried out with the help of another subject – wood anatomy. In wood anatomy, a rigorous scientific methodology has been developed, based on analysis of the type and arrangement of histological elements in the xylem, which allows both broad-leaved (Wheeler et al., 1989) and coniferous (Richter et al., 2004) trees to be distinguished to exact species.

In Bulgaria, during various archaeological excavations, fragments of beams, pillars and other building elements used in the past in different types of constructions are found. There are cases of archaeological finds of well-preserved, incompletely burned or completely charred wood from hearths and pyres. A usual case in underwater archaeology is the discovery of wood materials from boats and ship wreckages from different historical periods. Furthermore, flooded ancient ports and other wooden constructions on the bottom of the Black Sea are objects of studies in underwater archaeology.

In the frame of underwater archaeological works (started in 2017 and finished in 2020) a number of wooden pillars have been found in a submerged prehistoric settlement in the Ropotamo River estuary, Black Sea coast.

The first main purpose of this study is to identify the wood species of the excavated materials using wood anatomy, and secondly – to construct a floating tree-ring chronology only for the oak wooden materials.

Subject of study

Underwater archaeological site – a submerged prehistoric settlement, was located in the shallow waters of the Black Sea (Fig. 1.), in the estuary of the Ropotamo River. According to Dimitrov et al. (2021), the settlement was built on the Black Sea shore around 3000 years BC. After that period the level of the Black Sea rose and as a consequence of that event the prehistoric village was flooded. On the bottom of the Black Sea, subsequently, the wooden constructions were covered by sand, originated by fragmentation of crustaceans and shellfish mineral and organic materials. Clay-rich Lixisols and Acrisols soils in Strandzha Mountain (Malinova et al., 2021) are the other major source of sea bed sediment – deponition. During the heavy rainfalls, clay and other soil particles fall into the Ropotamo River flow and from there they move into the Black Sea, where they settle to the bottom and thus bury the wooden structural elements of the submerged prehistoric settlement. Clay has an important positive role for the preservation of wood materials (Michette et al., 2017; Zeng, Hausmann, 2022), this may explain the high degree of preservation of excavated wooden pillars from the Ropotamo underwater archaeological site.

The underwater excavation was carried out in four research areas (plots) with regular rectangular shapes designated as Ropotamo T1, Ropotamo T2, Ropotamo T3 and Ropotamo T4 (Dimitrov et al., 2021).

Figure 1. Location of the submerged prehistoric settlement in Ropotamo River estuary

Vertical structural elements (pillars) used as wooden support material for buildings or other constructions in prehistoric settlements (Fig. 2.) were excavated from Ropotamo T4 archaeological square. The coordinates in UTM WGS 84 (Baltic high coordinate system) of the four angles of the T4 rectangular research plot are as follows: North N4686791.1246, E562263.2563; South N4686784.36.81, E 562261.1108; East N4686788.6272, E562265.5451; West N468688.8116, E562258.820 (Dimitrov et al., 2021). The dimensions of length of the wooden material vary from 18-20 cm to 58-60 cm. The diameters range between 4-6 cm up to 18-20 cm. The total number of the pillars from Ropotamo T4 archaeological square is 81.

Figure 2. Wooden pillars from the submerged prehistoric settlement (picture Dimitrov et al., 2021) in Ropotamo T4 square

Methods

For dendrochronological analysis the excavated wooden materials (wooden pillars) were treated in laboratory conditions. The pillars were cut transversely to achieve disc shape of the samples (stem discs of the tree). Diametrical bisecting of stem discs was done in order to divide the discs in two. Razor blade was used to cut the edge of each sample in radial direction in order to provide clear visual identification of the histological elements of the xylem (tree-rings). The visual wood identification of the wooden archaeological materials was performed using a Leica MS5 microscope. For the taxonomical specification (wood identification) of the samples, the xylem anatomical features were studied in accordance with Schweingruber (1990), Akkemik, Yaman (2012) and Wheeler (1989) scientific basis. Only samples of oak species (genus *Quercus*) were selected for sub sequent analysis. Before measurement, additional filtration was done to select only the stem discs with the biggest diameters and the biggest amount of tree rings in the frame of one sample. The threshold of 30 years was chosen to select the best samples for dendrochronological analyses. The main argument for this is to avoid uncertainties in the process of cross-dating of the samples with a small number of tree-rings (less than 30). The tree-ring width was measured (two radii per sample) with an accuracy of 0.01 mm using a digital station for dendrochronological analysis LINTAB 5. The cross-dating was done using TSAP Win software (Rinn, 2005) and subsequently was visually checked.

Results and discussion

The study of the structure of wood showed that 34 specimens out of the total 81 wooden pillars at site T4 from the Ropotamo estuary could be assigned to genus *Quercus*. The specific anatomical structure shows that the remaining 47 pillars belong to a species of the genera *Fraxinus*, *Acer*, *Ulmus* and *Platanus*. In each of the 34 samples identified as oaks there is clearly visible ring-porous xylem with large-diameter (visible without magnifying devices) vessels in the early wood (Fig. 3.). Vessels are the capillary elements of dead cells, whose main function is to transport water and nutrients from the roots to the assimilating organs in the crown of the tree. The presence of tyloses, which are lamellar formations in the cell lumen of the vessels, is observed in the vessels. Their function is to block the cell (vessel) thus preventing the vertical current in histological elements formed in previous years (in sapwood) and play a crucial role in limiting the spread of pathogens and wood decay organisms. There are well-formed clearly visible broad pith rays. All these peculiarities in the construction of the annual rings (xylem) of the excavated wooden material show that these fragments belong systematically to the family Fagaceae, and in particular, to the *Quercus* genus.

According to Bulgarian authors, there are 18 representatives of the *Quercus* genus in our country, which are divided into two sections: white oaks (section *Quercus*) with 16 representatives and cerris oaks (section *Cerris*) with two representatives (Yurukov, Zhelev, 2001). Although in the white oak group individual species are clearly distinguishable by morphological characters, they cannot be distinguished by anatomical characters because the histological elements in the xylem of the tree stem are too similar in structure and internal architecture. Both species of section *Cerris*, *Q. cerris* L. and *Q. coccifera* L., can be distinguished to the rank of a separate species based on the analysis of the structure of their wood, because there are clear, strongly pronounced specificities in the arrangement of cells in their annual rings. From the analysis of the anatomical structure of the wood from Ropotamo, it was determined that the oak samples belong to a species of the white oak group. No wooden elements were found that could be identified as belonging to the *Cerris* oak section.

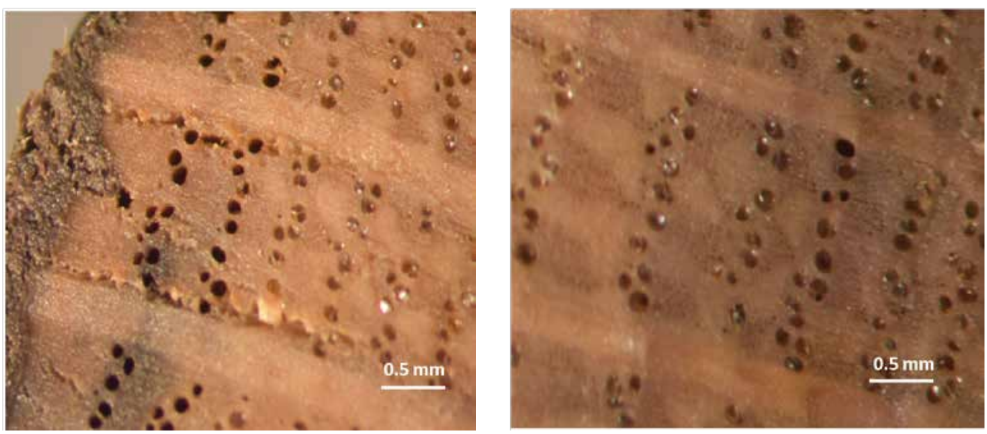

Figure 3. Cross section of oak wood excavated in archaeological works in the prehistoric settlement in Ropotamo River estuary

Following the work method indicated above, 8 oak samples of the pillars were used to construct a floating tree-ring chronology. It should be mentioned that the diameters of the oak samples vary from 4 cm to 18 cm, and the number of annual rings – from 6 to 63. The lack of coherence between the variations in the width of the annual rings between individual samples also makes a strong impression. Another fact that is worth noting is that some of the wider diameter samples (diameters above 15 cm) have wide annual rings, their number does not exceed 30, and therefore they were not used in the construction of the main chronology. Only 8 of all 34 oak pillars have a length of dendrochronological series over 30 years, and this is an argument that provides reason to subject them to dendrochronological studies. After their processing, which includes measuring the widths of the annual rings and cross-dating them, the main chronology was built. Fig. 4 shows both individual chronologies of oak pillars (T4 compound) and the master chronology based on them (T4 master) for T4 Ropotamo. The length of the floating chronology is 84 years, and the overlapping segments of 8 chronology, composing the master chronology, contain 21 years (Fig. 4). The longest tree-ring chronology was built for the oak "pile ?" – 63 years, and the shortest is for the oak “pile 67” – 37 years. The low number of annual rings in dendrochronology is considered unfavourable from the point of view of cross-dating, even more so when it comes to floating chronologies, which cannot be dated by a reference master chronology. Cross-dating certainty greater than 90% accuracy requires a segment of overlap between individual chronologies greater than 60 years in length (Schweingruber, 1990). At site T4 Ropotamo this is not possible due to the short dendrochronological series. However, in this case we can claim that the eight chronologies are dated to each other with satisfactory certainty. However, it should be emphasized that in order to increase the percentage of certainty in the coherence of the dendrochronological series of the oak wooden material, it is necessary to increase the number of the studied materials. This can be achieved in future expansions of archaeological excavations in the Ropotamo River estuary submerged prehistoric settlement.

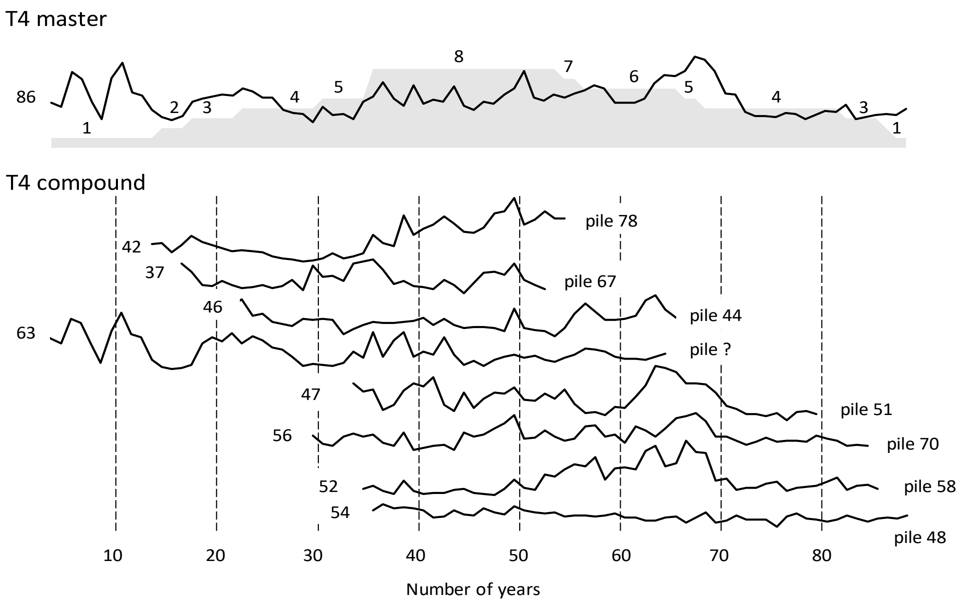

Figure 4. Oak tree-ring chronologies (master and compound) of tbe T4 Ropotamo submerged archaeological site. Explanation notes: the sample depth of the oak master chronology is shown as a background (grey colour) of the master chronology (the number of compound chronologies is shown as numbers above); the absolute number of the measured tree-rings of the compound and master chronologies is shown at the front of the tree-ring series.

It is important to note that the indicated species of the white oak group are involved in different types of ecosystems. In the region of the mouth of the Ropotamo River in the Black Sea, there are three types of forest ecosystems dominated by oaks. Strandzha Mountain boasts mixed high stands forest communities that are highly productive in terms of biomass production; they are made up of various oak species from the *Quercus* section, mixed with elm (*Ulmus minor* Mill.), ash (*Fraxinus oxycarpa* M.

Bieb. ex. Willd.), species of the *Acer* genus, etc. Oriental beech (*Fagus orientalis* Lipsky) forests are also characteristic of Strandzha. The second type of forest ecosystems are monodominant coppice oak forests located on dry plains in the immediate vicinity of the sea. These oak forests have a slow rate of biomass production owed to slow tree growth, both in height and in diameter. The third type of forest ecosystem with participation of oak (*Quercus robur* L.), elm (*Ulmus minor* Mill.) and ash (*Fraxinus oxycarpa* M. Bieb. ex. Willd.) are the flooded forests, the so-called 'Longoz', through which the Ropotamo River itself flows, before its confluence with the Black Sea. It is characteristic of this type of ecosystem that during several months of the year the incoming waters of the river flood the stems of the trees and vegetation. Even in the dry part of the year, at the lowest river levels, the 'Longoz' forests are well-moisturized due to the high groundwater level along the riverbed. Each of the three types of forest ecosystems mentioned was formed under the influence of different ecological conditions – limiting for the coppice oak forests are the summer amounts of precipitation, for the 'Longoz' forests it's the Ropotamo River water levels, and for the oak forests of Strandzha – the temperatures. These specific factors influencing the environment are reflected in a specific way on the dynamics of the formation of annual tree-rings. For example, the trees from the 'Longoz' forests have similar growth dynamics among themselves, because they were formed under the influence of the same limiting factor. The same applies to the trees from the coppice forests and to those from the interior of Strandzha. However, the trees from each of the indicated ecosystems do not contain a definite and strong common signal with the trees from the other two, because the annual rings were formed under different ecological conditions under the determining influence of different limiting factors. All these features greatly complicate the cross-dating of dendrochronological samples. The narrow annual rings of some of the studied oak samples from T4 can be explained by the lack of sufficient resources to form rapid growth in diameter, leading to the thought that these trees grew in poor and dry habitats, and are very likely of coppice but not high stand origin. The diversity in the variations of the annual rings and the lack of categorical similarity between the individual samples speaks in favour of the fact that the pillars are of a rather different type of ecosystem than can be explained by a difference in the time in which individual trees grew. Additional noise in the variation of annual rings may also come from the fact that small diameters of the samples may also be explained by the use of branches and not tree stems for the construction of the prehistoric settlements. It cannot be ruled out that trees from the interior of Strandzha, washed away from the shore and caught in the current of Ropotamo River, were naturally transported to the sea during high waters. This timber may also have been used as a building element in the prehistoric settlements.

Conclusions

Wood identification of 81 pillars excavated from a submerged prehistoric settlement (3000 BC) in the Ropotamo River estuary, Black Sea unveiled that they belong to 5 genera – *Quercus*, *Fraxinus*, *Acer*, *Ulmus* and *Platanus*. Eighty-four year floating master chronology was built for the oaks. The coherence of the signal among the single *Quercus* series is low due to the origin of the wooden material used in the prehistoric constructions. Oak high stand forests in Strandzha Mountain, the oak coppice forests on the Black Sea coast plains, and riparian 'Longoz' forests of the Ropotamo River are the main sources of wood built in the ancient settlements from the Ropotamo River estuary. Different types of these three ecosystems cause different rhythms in the formation of annual tree-rings.

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