BRIEF REPORT

The First Evidence of Subfossil Oak Wood from Riverine Sediments in Lithuania: A Dendrochronological Investigation

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Abstract

The article discusses the results of the dendrochronological investigation on a subfossil oak extracted from the Nemunas riverine sediments in Punios šilas, South Lithuania. The radiocarbon dating has demonstrated that the oak grew in the Late Atlantic period, approximately from 3815 to 3649 BC. The investigated sample was slow growing and is characterized by medium mean sensitivity. Sharp growth depressions and long-term cycles (45 years, on average) in the oak tree-ring width series indicate wet growing conditions.

Key words: subfossil oak, Punios šilas, radiocarbon dating, tree-ring width, dendrochronology.

Introduction

Tree-ring widths carry information on environmental conditions during the whole period of tree growing with annual resolution (Nabais et al. 2014). Long-term millennial chronologies in Europe have been constructed using subfossil oak (*Quercus* sp.) and pine (*Pinus sylvestris* L.) wood from bogs, lakes and river deposits (Grudd et al. 2002, Leuschner and Delorme 1988).

Based on wood anatomy, it is not possible to distinguish the oak wood to species *Quercus robur* L. and *Quercus petraea* (Matt.) Liebl. (Schweingruber 1990). Therefore, subfossil oak wood is usually referred as European oak (*Quercus* sp.). Constructed chronologies are used for dating of the samples of unknown age (Crone and Mills 2012) and reconstruction of environmental (Helama et al. 2004), hydrological (Leuschner et al. 2002) and climatic conditions (Koprowski et al. 2012) during the Holocene.

Oak wood has several advantages for dendrochronology over pine wood, including long life, easily distinguished sapwood rings and high similarity in tree-ring width patterns between sites (Baillie 1982, Cufar et al. 2014, Haneca et al. 2009). In addition, oak does not produce missing rings (Baillie 1982, Sohar et al. 2012). Long-term oak chronologies have been developed for many European countries, including the Czech Republic (Kolar et al. 2009), Germany (Delorme 1977), Ireland (Pilcher et al. 1984), Poland (Starkel and Krąpiec 1995) and other countries. New achievements were made recently in the investigation of the subfossil oaks extracted from the river Viliya sediments in Smarhoń, Belarus (Vitas et al. 2014).

The documented finding places of subfossil oaks in bogs are limited in Lithuania, and the number of samples is small (Pukienė 2003, Vitas and Zunde 2007). In the meantime, there are no documented finding sites of subfossil oak wood from riverine gravels in Lithuania. Therefore, the subfossil oak wood from riverine sediments in Lithuania is not explored by dendrochronology before.

The aim of this study was to assess the potential of the tree rings from subfossil oaks found in Nemunas (Punios šilas, South Lithuania) riverine deposits to document forest history in Lithuania during the Holocene.

Material and Methods

An oak stem was found accidentally in the river Nemunas in Punios šilas (Alytus district, South Lithuania) in August of 2015. The summer in 2015 was extremely dry in Lithuania. As a result, the water level of the river has significantly abated. For example, in August of 2015, the water discharge was 98 m³/s, while the average long-term water discharge of the river Nemunas is 183 m³/s (Pupelienė et al. 2015).

The finding location is situated (54° 31’ 12.8”N, 24° 05’ 57.3”E) on the left bank of the river Nemunas (Figure 1). The site is located in Punios šilas, 46 m above the sea level. The river bank is overgrown by solid grass with scattered oaks (*Quercus robur* L.) and domestic species (*Malus domestica* Borkh. and *Syringa vulgaris* L.) indicating that the site was inhabited before the Second World War. The left bank is ca. 9 m high with no visible signs of erosion at present, although the stream bed is curved at the site. The river deposits are formed of silt (10–20 cm), which deeper transforms into gravel with cobbles.

Figure 1. The finding sites of subfossil oaks in Lithuania and Belarus: 1. Punios šilas, S. Lithuania, 2. Kegai mire, NW Lithuania, 3. Smarhoń (Belarus), 4. Telšiai, NW Lithuania, 5. Biržai, N Lithuania

An oak trunk of dark black colour, which was located above the ground surface, has a diameter of 42 cm. The oak was found lying with acute angle to the bank. The thickest part of the trunk together with stump is pointed upstream and covered with several meters of gravel (Figure 2). Therefore, the full length of the trunk was not accessible. The length of manually excavated oak trunk is ca. 5 metres. During excavation work (August of 2015), the trunk was exposed ca. 50 cm above the water level. It means that the trunk is under the water during the summer with usual river discharge.

An accumulation of light brown colour oak wood was observed deeper than the above-mentioned oak

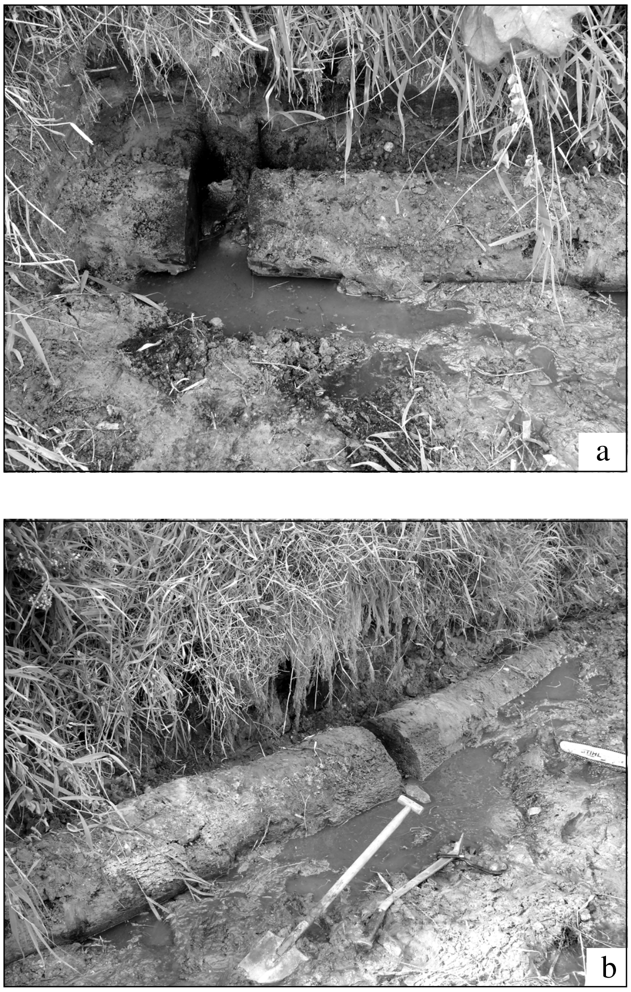

Figure 2. The sampling place on the 27th of August 2015. Photos by A. Vitas

trunk. The diameter of the nearest rotten stem was 21 cm. The wood situated deeper were not accessible for excavation even during the dry summer of 2015. Therefore, only one oak trunk was sampled using a chainsaw.

Inventory No. 3462 was attached to the sample, and the wood, 130–150 rings respectively, was provided for radiocarbon dating. The ^{14}C dating was accomplished at the Radiocarbon dating laboratory in Kyiv (Laboratory code IHME-2990). The ^{14}C dates were calibrated to calendar years by using the OxCal 4.2 program (C.B. Ramsey, Oxford Radiocarbon Accelerator Unit) (Bronk Ramsey 2001) with the IntCal13 calibration curve (Reimer et al. 2013).

The tree-ring widths of the subfossil oak were measured using a Lintab tree-ring measuring table and TSAP computer program (F. Rinn Engineering Office and Distribution, Heidelberg) in seven radii. Then, the tree-ring width series were synchronized by visual comparison (Eckstein 1987) of the ring-width graphs and statistically by calculating the coefficients of similarity "Gleichläufigkeit", correlation coefficients and t-values (Eckstein and Bauch 1969, Baillie and Pilcher 1973).

Standardisation of the series was carried out using Chronol 6.00P program (R.L. Holmes, Tucson). The polynomial function – spline, preserving 50% of variance at wavelength 128 years was fitted. The index values were calculated as ratios between the actual values and the respective values of the fitted function and then combined using bi-weight robust estimation of the mean (Mosteller and Tukey 1977) into a tree-ring chronology.

Common statistics used in dendrochronology were calculated, such as mean tree-ring widths and mean sensitivity. The mean sensitivity measures the year-to-year variation of ring widths. Cycles expressed in the tree-ring width series were determined by using a single series Fourier (spectral) analysis (Statistica 6.0, StatSoft Inc.).

Results

The investigated oak tree was slow growing. The radial growth measured in seven radii ranges from 0.80 to 1.23 mm. The radial growth is characterized by medium mean sensitivity, which ranges from 0.14 to 0.23. The similarity (coefficient of correlation) between the radii ranges from 0.69 to 0.92. The mean curve of the oak sample No. 3462 spans for 167 years (Table 1). The average radial growth was 0.98 mm and mean sensitivity 0.17. The long-term growth depressions, when the radial growth decreased for several decades, are typical for the radial growth of the investigated oak (Figure 3). The unfavourable growth conditions occurred from 3745 to 3775 BC, when the average radial growth decreased to 0.62 mm per year. It was followed by the growth release in 3677–3695 BC (1.42 mm per year).

The radiocarbon dating has given the date 3900±40 BP, which is calibrated to 3705–3648 BC (68.2% probability) and 3768–3638 BC (95.4% probability). The calculated median date is 2385 BC (68.2% probability). According to the results of the radiocarbon dating (Figure 4), we conclude that the investigated oak grew in the Late Atlantic period, approximately from 3815 to 3649 BC (Figure 3).

The longer cyclical components predominate in the chronology of oak. Ten cycles with the largest periodogram values are: 7, 11, 17, 18, 24, 28, 42, 55, 83 and 166 years. The average length of the cycles is 45 years (Figure 5).

Table 1. Statistical characteristics of the investigated subfossil oak chronology and results of the radiocarbon dating

Number of measured radii	7
Similarity between the radii, correlation	0.69-0.92
Average tree-ring width, mm	0.98
Mean sensitivity	0.17
Span, years	167
Radiocarbon date, BP	3900±40
Calibrated radiocarbon date (68.2%), BC	3705–3648
Calibrated radiocarbon date (95.4%), BC	3768–3638

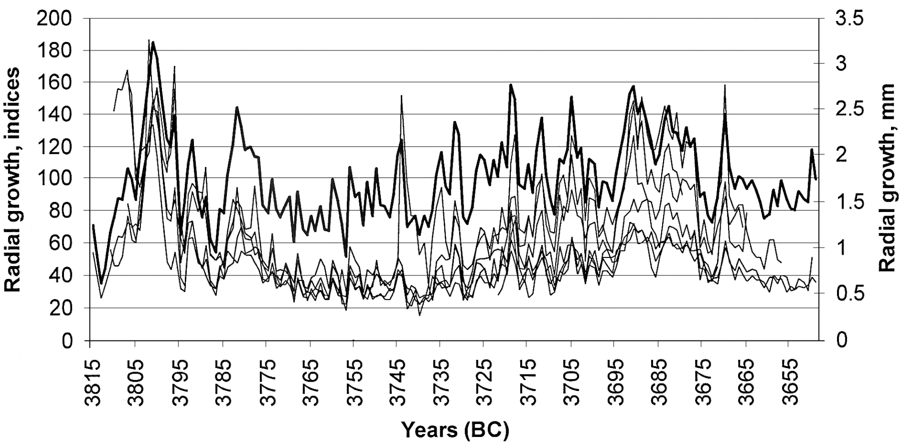

Figure 3. The radial growth pattern of the subfossil oak No. 3462; series from the seven radii (mm) and the mean curve (bold line, indices)

Discussion and Conclusions

The mechanism of the deposition of oaks in riverine gravels is related to the lateral channel migration (Florek 1984), erosion (Kalicki 1991, Spurk et al. 2002), intensified activity of rivers (Kalicki 2006, Krąpiec 1992, Spurk et al. 2002) and water discharge during wet periods (Krąpiec 1994, Spurk et al. 2002).

According to Kalicki (2006), the level of lake water in Belarus has abated from 4000 to 3000 BC and the activity of rivers increased. The increase in meandering activity in the Zahodnyaya Dzvina – Daugava

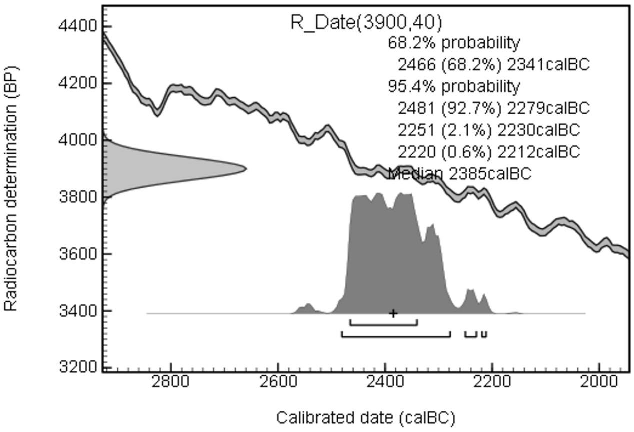

Figure 4. The results of radiocarbon calibration of the date 3900±40 BP. "+" indicates the median date (2385 BC) in the 68.2% probability range

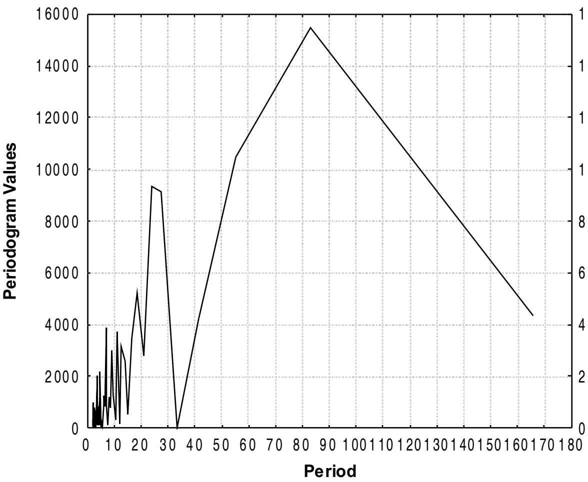

Figure 5. Spectral analysis (periodogram) of the oak tree-ring mean curve radiocarbon dated to 3815–3649 BC

is dated to 3730 and 3680 BC and in the Nemunas basin – 3780±70 BC and 3600±180 BC. However, the meanders of the Vistula were less pronounced and less frequent in the Late Atlantic (Kalicki 1991).

The oak trunks in the river Nemunas were found lying with acute angle to the bank and stumps pointed upstream. According to the position of the trunks, it could be supposed that we have accidentally found an old meander. This indicates that oak trunks were probably transported from the upper reaches. The curved channel of the river at the finding site supports this theory.

The investigated oak from the river Nemunas grew in the Late Atlantic period, approximately from 3815 to 3649 BC. In Lithuania, the Late Atlantic period (4500–3000 BC) was preceded by the Early Atlantic period (5800–4500 BC) and followed by the Subboreal period (3000–500 BC). It was the warmest period during the Holocene in Lithuania: reconstructed average yearly temperature +12 ºC, January -8 ºC and July +17 ºC and the average annual precipitation 802 mm (Kabailienė 2006). In the warm climate of the Late Atlantic period, the proportion of oak among broadleaved species increased. On the basis of pollen analysis, it is demonstrated that the spread of deciduous tree species (*Quercus*, *Tilia*, *Ulmus*, *Fraxinus* and *Corylus*) reached its peak in Lithuanian forests, while the spread of *Picea* decreased in the Late Atlantic (Kabailienė 2006). This is in accordance to Heikkilä and Seppä (2010), who reconstructed the highest increase in the summer air temperature in Latvia from 5800 to 4400 BC.

In the meantime, two finding sites of subfossil bog oaks have been documented in Lithuania (Figure 1 and 6), and each site is limited to 1–5 samples, on average (Pukienė 2003, Vitas and Zunde 2007). Oak wood in both sites was dated by radiocarbon. The oaks from Biržai grew much earlier than from Punios šilas: 5100–4987 BC and 4600–4393 BC (Figure 6). The oak sample from Telšiai grew in 3545–3313 BC, i.e. in the similar period than the oaks from Smarhoń (3542–3263 BC). The largest periodogram values in the oak chronology from Telšiai are: 5, 6, 7, 14, 19, 39, 46, 58, 116 and 232 years. This indicates that in spite of the different hydrological regime of oaks from Punios šilas and Telšiai, longer cyclical components predominate in both chronologies.

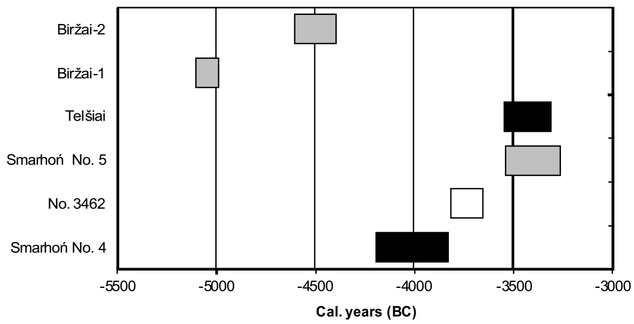

Figure 6. Living spans of the subfossil oak No. 3462 (Punios šilas) and the subfossil oaks from Biržai (5100-4987 BC and 4600-4393 BC), Telšiai (3545-3313 BC) and Smarhoń (4191–3830 BC and 3542–3263 BC)

Five constructed chronologies of subfossil oaks from Smarhoń (the river Viliya, Belarus) are attributed to the Late Atlantic period: the two nearest chronologies were dated to 4191–3830 BC and 3542–3263 BC (Figure 6). The average radial growth of the chronologies No. 4 and 5 from Smarhoń is 1.18 and 1.82 mm and the mean sensitivity – 0.23 and 0.26, respectively

(Vitas et al. 2014). The subfossil oak from the river Nemunas (Punios šilas) was growing much slower (0.98 mm) and its mean sensitivity was lower (0.17) and the mean sensitivity of oaks from Smarhoń. Mean sensitivity indicates a responsiveness of the radial growth to environmental variables. The cycles of the similar length (on average, 47 years) were detected in the oak tree-ring width chronology No. 4 (4191–3830 BC) from Smarhoń (Belarus). It indicates that the increases and decreases of the radial growth of oaks in Lithuania and Belarus from the Late Atlantic period repeated with the same frequency, i.e. the trees grew under the influence of similar environmental conditions. However, the crossdating attempt between the constructed mean curve and the chronology No. 4 was not successful in spite of the 160 km distance between Punios šilas and Smarhoń. Although, successful dating of the chronology No. 16 (AD 778–1326) from Smarhoń (Belarus) against East Pomeranian (Gdańsk) oak chronology was possible at the distance of 350 km (Vitas et al. 2014).

On the other hand, longer cycles and pronounced depressions in the radial growth pattern are usually related to wet growing conditions as shown by Stasytytė et al. (2005), Vitas (2009) and Vitas (2010). This is in agreement with Spurk et al. (2002), who documented wetter conditions and a higher river runoff during the reduced depositions of oaks in Europe from 4160 to 3870 BC. The reasons, why the amount of subfossil oak wood found in Latvia and Belarus is higher than in Lithuania, are unclear (Vitas et al. 2014, Vitas and Zunde 2007).

The oak trunk found in the Nemunas (Punios šilas) is covered by thick gravel deposits indicating an intense erosion processes on the left bank of the river Nemunas during the last 5000–6000 years. Further search of buried oaks on the finding site is not possible, because the area belongs to the Nemunas Loops Regional Park and the Regional Park does not allow to perform extensive excavations. Therefore, the further work in the following years will be aimed at the search of other potential finding sites of subfossil oaks in the riverine gravel deposits in Lithuania.

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