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POSSIBILITIES FOR DENDROCHRONOLOGICAL DATING OF LARGE WOODY DEBRIS

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ABSTRACT

The paper deals with the possibilities of dendrochronological dating of large woody debris (LWD) and wood jams in river channels and riparian zones. Two sites have been chosen for the research, the Morávka River and the Černá Opava River. These sites have been chosen because of two different types of riparian stands. The banks of the Morávka River are soft floodplain (350 m ASL); the Černá Opava River has stands with nearly a hundred percent proportion of spruce (600 m ASL). The results of the research show that the species with diffuse-porous wood structure are very hard to date on the basis of Pressler borer cores. On the other hand, the sites with conifers are easily datable, especially if the trunks contain more than 40 tree-rings. At these sites it is possible to use the dendrochronological dating for the establishment of the temporal dynamics of the woody debris input in the river ecosystem.

KEYWORDS: Wooddy debris, dendrochronology, tree-ring, the Černá Opava River, the Morávka River.

INTRODUCTION

Woody debris is an inseparable part of natural river channels. In a river ecosystem it affects the hydraulic, hydrological and morphological properties of the channel, and it is also of a biological significance. However, besides the positive effects, the woody debris can also have a negative impact, the reduction of the flow profile capacity, the destruction of waterside buildings when the debris is moving, or the creation of obstacles for riverboat navigation. Tree trunks used to be a natural part of rivers but with the development of log driving and industry, the woody debris started to be removed from channels (Krejčí and Máčka 2009). Tree trunks (woody debris) in river channels have only been preserved in streams, which are often protected areas. Only recently, woody debris has started to be added into rivers within the process of stream restoration, both in natural and artificial ways (Štourač 2009).

The issue of woody debris which is found in stream channels has been dealt with to a great degree in the professional literature around the world since the 1980s. Currently, this issue has become a part of a new interdisciplinary scientific field referred to as biogeomorphology. Its discipline called fluvial biogeomorphology mainly endeavours to describe the effects of the woody debris in river ecosystems and explain the processes in which the wood gets into rivers (Máčka and Krejčí 2007).

Fallen dead trees and other parts of wood which come into the interaction with a river ecosystem are called woody debris (WD). Moreover, we differentiate between large woody debris (LWD) or more scarcely coarse woody debris (CWD) and small woody debris (SWD) or fine woody debris (FWD). LWD or CWD denote pieces of wood with diameter of min. 10 cm and length of min. 1 m. SWD or FWD denote minor fragments of wood (twigs, chips, etc.) of any length but the diameter smaller than 10 cm. When the woody debris starts entraining, it gets caught in places which are favourable for this purpose, and this leads to wood accumulation or wood jams. Woody debris can specifically consist of upturned trees, trunk torsos without bark and branches, or parts of trees (branches, stumps, roots) (Máčka and Krejčí 2006).

In recent years studies which use dendrochronology (a method for dating wood which is based on measuring tree-ring width (Kaennel and Sweingruber 1995)) for the purpose of reconstructing the dynamics of bank erosion and paleohydrological events (damage to the root system, drainage or flooding of soil, etc.) have been appearing (Schweingruber 1996). In riparian stands, the age of the trees can be a suitable indicator of the age of the site (Alestalo 1971). For example, dendrochronological dating was used for the reconstruction of the migration of meanders of the Mala Panew River (southern Poland), where the research made use of the local standard chronologies for Scots Pine (*Pinus sylvestris* L.), European Alder (*Alnus glutinosa* Gaertn.) and Grey Alder (*Alnus incana* Moench.) (Malik 2005). Similarly, the dendrochronological dating of Norway Spruce (*Picea abies* (L.) Karst.) was used for the reconstruction of floods in Waksmundzká dolina Valley in the Tatra Mountains (Zielonka et al. 2008).

This paper deals with the possibilities for dendrochronological dating of large woody debris (LWD) and wood jams in a river channel and the riparian zone. Thanks to dendrochronological dating it is possible to establish the temporal dynamics of the woody debris input in the river ecosystem and its disintegration. Interconnecting biogeomorhology and dendrochronology can help clarify the complications which arise during the environmental research into the significance of woody debris in river ecosystems.

MATERIAL AND METHODS

The research was conducted at two sites. The first one is located between villages Skalice and Raškovice on the Morávka River (the beginning of the area: 49°37'42.844"N, 18°27'18.453"E (377 m ASL), the end of the area: 49°39'50.627"N, 18°25'19.567"E (335 m ASL). The second site is located on the Černá Opava River above the city of Vrbno pod Pradědem (the beginning of the area: 50°9'36.419"N, 17°21'55.563"E (603 m ASL), the end of the area: 50°10'19.304"N, 17°21'33.58"E (579 m ASL).

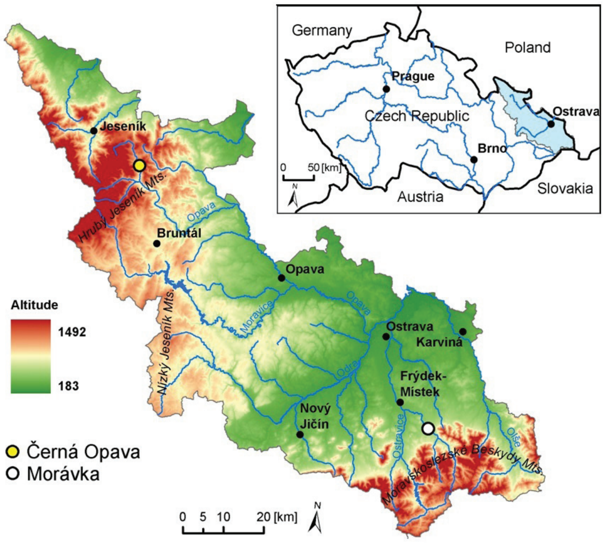

Fig. 1: Location of the study area

Sampling and sample processing were conducted in accordance with standard dendrochronological methodology (Cook and Kairiukstis 1990). 29 samples from woody debris and 21 reference samples from the riparian stands were taken at the first site; 35 samples from woody debris and 23 reference samples from the riparian stands were taken at the second site. The samples were collected with the Pressler borer. The obtained cores were fixed into wooden slats with grooves. Once fixed, the samples were ground off or worked by blade. Subsequently, the samples were subjected to the anatomical and dendrochronological analysis.

The ring width of the samples was measured on a specialized measuring table which is equipped with an adjustable screw device and an impulsemeter recording the interval of the table top shifting and in this way also the tree ring width. The annual increments were measured in the PAST application with 0.01 mm accuracy (Rybníček et al. 2007).

The samples were divided into groups according to their genus. The tree-ring curves of the reference samples were used to create reference average tree-ring curves for individual groups of species. As the next step, the reference average tree-ring curves were used to date the tree-ring curves of the woody debris. The degree of resemblance was judged by the Gleichläufigkeit and the t-test. These calculations serve as a facilitation of an optical comparison of both curves, which is crucial for the final dating (Cook and Kairiukstis 1990).

For the anatomical analysis temporary microscopic preparations were created. Basic microscopic sections (cross section, radial section, and tangential section), which are necessary for the identification of wood, were made using a blade. They were mounted with distilled water. The microscopic preparations were observed with an optical microscope. The samples were classified on the basis of the differences in the wood microscopic structure according to their genus (Vavrčík and Gryc 2004).

RESULTS

The Morávka River

The tree species composition of the woody debris in the river was established using the anatomical analysis (Fig. 2). The results show that 80 % of the samples were collected from species with diffuse-porous wood structure (alder, willow, poplar, maple, and lime).

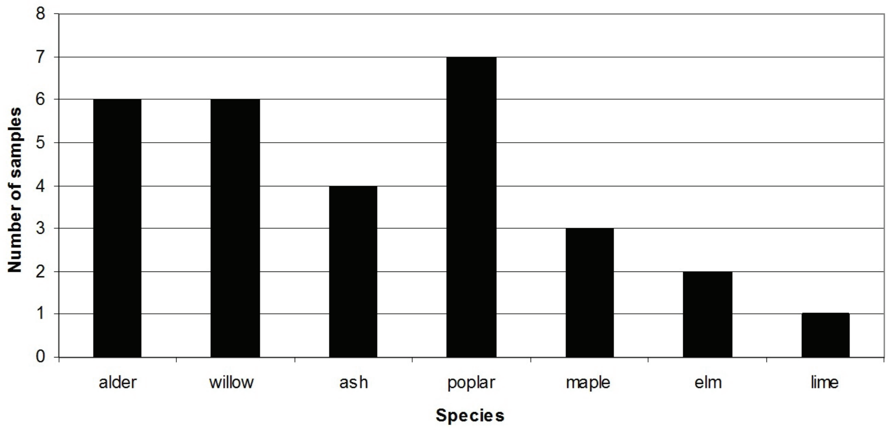

Fig. 2. The tree species composition of the woody debris in the Morávka River

The tree-ring curves of the reference samples from willows, limes, alders and poplars could not be used to create reference average tree-ring curves by means of which we could date the tree-ring curves of the woody debris. We could only make the reference curves for maple, ash and elm. Moreover, the reference curve for oak was made. These reference average tree-ring curves were then used to date the tree-ring curves of the woody debris. A high number of woody debris samples had to be sorted out as the number of measurable tree-rings was insufficient for reliable dendrochronological dating.

As a result of the analysis four samples of woody debris were dated. These were only dated on the basis of the oak and ash reference curves (Tab. 1, Figs. 3-6).

When the dated curve overlaps with the average tree-ring curve by twenty-five tree-rings (our smallest overlap), the critical value of Student's t-distribution with 0.1 % significance level is 3.725 (Šmelko and Wolf 1977). The values of our t-tests are much higher than 3.725 (Tab. 1), which proves that the dating was conducted correctly. The correctness of our dating is also confirmed by the agreement of reference tree-ring curves with the tree-ring curves of the dated samples in most of the extreme values (Figs. 3-6).

If a sample contains the terminal ring (waldkante – wk), it is possible to determine the exact year when the tree stopped growing. In some samples it is possible to find out whether the terminal ring contains early wood (swk – the tree stopped growing in the summer of that year) or late wood (wwk – the tree stopped growing in the autumn or the winter of that year of in the spring of the following year). For the samples which do not retain underbark rings (ak) only the year after which the trees stopped growing can be determined.

Tab. 1: The results of the correlation of average tree-ring curves of the reference samples with tree-ring curves of the woody debris

Reference curve	T.test (according to Baillie & Pilcher)	T.test (according to Hollstein)	Gleichläufigkeit (%)	Curve overlapping (years)	Dating
sample 3 (alder)					
Oak - reference	3.95	3.83	74	25	1999
sample 7 (ash)					
Ash - reference	4.24	6.4	75	53	1971
sample 18 (elm)					
Oak - reference	4.25	4.69	71	29	1997
sample 21 (alder)					
Oak - reference	5.84	5.02	72	37	1999

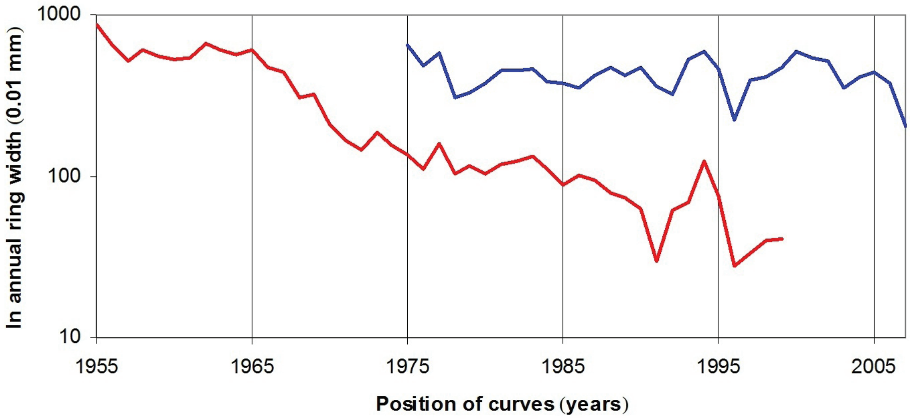

Fig. 3: Synchronization of sample 3 tree-ring curve (red) with the oak reference curve (blue)

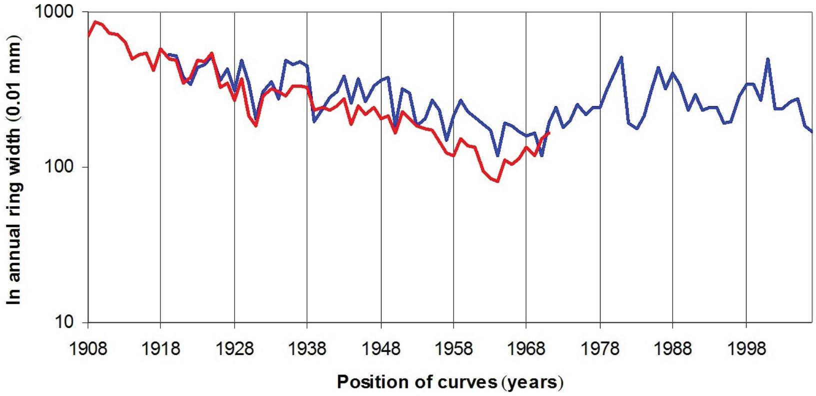

Fig. 4: Synchronization of sample 7 tree-ring curve (red) with the ash reference curve (blue)

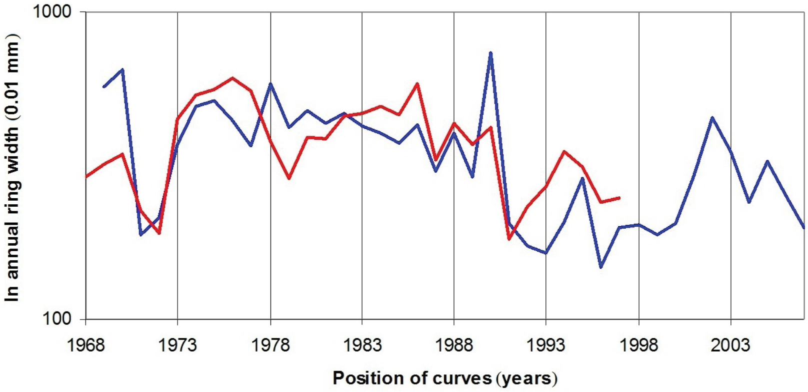

Fig. 5: Synchronization of sample 21 tree-ring curve (red) with the oak reference curve (blue)

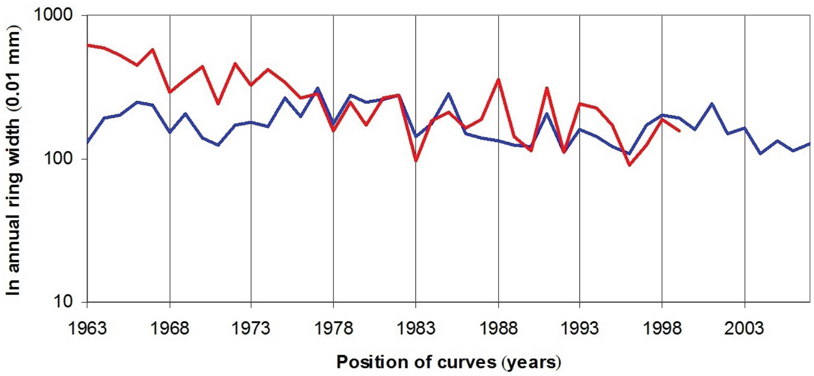

Fig. 6: Synchronization of sample 21 tree-ring curve (red) with the oak reference curve (blue)

Two of the dated samples contained terminal rings, therefore the exact year when the trees stopped growing could be determined. The other two dated samples did not retain terminal rings and for this reason only the year after which the trees stopped growing could be determined (Tab. 2).

Tab. 2: Dating of samples

Laboratory code	Number of sample	Species	Length	End	Dating
L5929	1	alder	46+1wk	-	not dated
L5930	2	alder	57+4wk	-	not dated
L5931	3	alder	45+1wk	1999	2000/2001
L5932	4	willow	7+1ak	-	not dated
L5933	5	willow	20+1wk	-	not dated
L5934	6	willow	6+1wk	-	not dated
L5935	7	ash	64+22ak	1971	after 1993
L5936	8	poplar	12+7ak	-	not dated
L5937	9	willow	14+1wk	-	not dated
L5938	10	poplar	10+1wk	-	not dated
L5939	11	poplar	18+1wk	-	not dated
L5940	12	poplar	20+1wk	-	not dated
L5941	13	poplar	14+1ak	-	not dated
L5942	14	willow	16+1wk	-	not dated
L5943	15	maple	37+1wk	-	not dated
L5944	16	maple	67+1ak	-	not dated
L5945	17	ash	82+2wk	-	not dated
L5946	18	elm	30+1wk	1997	1998/1999
L5947	19	poplar	26+1wk	-	not dated
L5948	20	willow	27+3ak	-	not dated
L5949	21	alder	35+1ak	1999	after 2000
L5985	22	maple	22+1wk	-	not dated
L5986	23	lime	37+1wk	-	not dated
L5987	24	elm	19+14ak	-	not dated
L5988	25	alder	29+1wk	-	not dated
L5989	26	ash	42+12ak	-	not dated
	27	poplar		-	not measured
L5990	28	alder	31+1ak	-	not dated
L5991	29	ash	24+1ak	-	not dated

Černá Opava

The anatomical analysis showed that with the exception of one sample (poplar) all the samples were spruce. In total, 17 samples could be dated, the exact half of the collected spruce samples.

The tree-ring curves of spruce reference samples were used to create the average reference tree-ring curve. The average tree-ring curve created using the tree-ring curve of spruce woody debris was dated by means of the average tree-ring curve of the spruce reference samples (Tab. 3, Fig. 7). Finally, the individual samples were dated (Fig. 8).

When the dated curve overlaps with the average tree-ring curve by thirty tree-rings, the critical value of Student's t-distribution with 0.1 % significance level is 3.646 (Šmelko and Wolf 1977). The values of our t-tests are higher than 3.646 (Tab. 3), which proves that the dating was conducted correctly. The correctness of our dating is also confirmed by the agreement of the reference tree-ring curve with the tree-ring curve of the woody debris in most of the extreme values (Fig. 7).

Tab. 3: The results of the correlation of the average tree-ring curve of reference samples with the tree-ring curve of the woody debris

Reference curve	T.test (according to Baillie & Pilcher)	T.test (according to Hollstein)	Gleichläufigkeit (%)	Curve overlapping (year)	Dating
samples_Opava3					
Opava - reference	11.38	9.91	77	95	2007

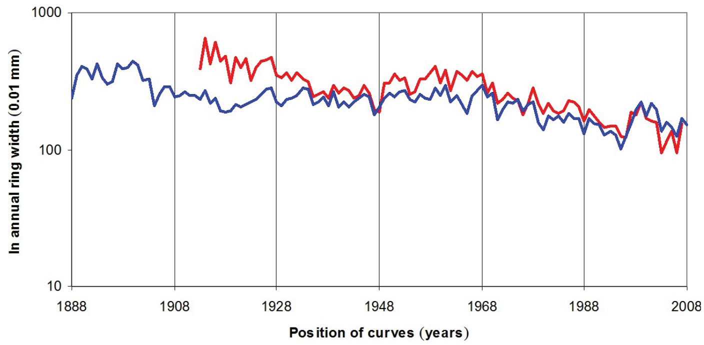

Fig. 7: Synchronization of the avera55228ge tree-ring curve for woody debris (red) with the average reference tree-ring curve (blue)

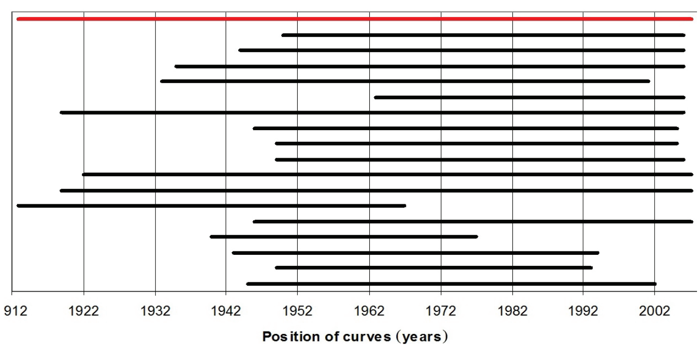

Fig. 8: Position of the dated curves

Tab. 4 presents the results of the dating of samples from the second site.

Tab. 4: Dating of samples

Laboratory code	Number of sample	Species	Length	End	Dating
L6393	1	spruce	47+1ak	-	not dated
L6384	2	spruce	58+1wk	2002	2003/2004
L6385	3	spruce	45+1ak	1993	after 1994
L6386	4	spruce	47+1wk	-	not dated
L6387	5	spruce	57+1wk	-	not dated
L6388	7	spruce	52+9wk	1994	2003/2004
L6389	8	spruce	38+1ak	1977	after 1978
L6390	9	spruce	46+1wwk	-	not dated
L6391	10	spruce	62+1wwk	2007	2008/2009
L6392	11	spruce	55+16ak	1967	after 1983
L6393	12	spruce	49+17wk	-	not dated
L6394	13	spruce	39+1wk	-	not dated
L6395	14	spruce	89+1swk	2007	summer 2008
L6396	15	spruce	59+1wwk	-	not dated
L6397	16	spruce	43+1wk	-	not dated
L6398	17	spruce	41+1wwk	-	not dated
L6399	18	spruce	39+1wwk	-	not dated
L6400	19	spruce	86+1wwk	2007	2008/2009
L6401	20	spruce	50+1swk	-	not dated
L6402	21	spruce	51+1wwk	2006	2007/2008
L6403	22	spruce	55+1wwk	-	not dated
L6404	23	spruce	57+1wwk	2005	2006/2007
L6405	24	spruce	60+1wk	2005	2006/2007
L6406	25	spruce	88+1wwk	2006	2007/2008
L6407	26	spruce	44+1wwk	2006	2007/2008
L6408	27	spruce	52+1wwk	-	not dated
L6409	28	spruce	69+6wwk	2001	2007/2008
L6410	29	spruce	36+1wk	-	not dated
L6411	30	spruce	75+1wwk	-	not dated
L6412	31	spruce	72+1wwk	2006	2007/2008
L6413	32	spruce	63+1wwk	2006	2007/2008
L6414	33	spruce	37+1wwk	2006	2007/2008
L6415	34	spruce	13+1wwk	-	not dated
L6416	35	poplar	37+1wk	-	not dated

DISCUSSION

To examine the possibilities of dendrochronological dating of woody debris in river ecosystems, two sites were chosen, the Morávka River and the Černá Opava River. These sites have been chosen mainly because of two different types of riparian stands. The banks of the Morávka River are soft floodplain (350 m ASL); the Černá Opava River has stands with nearly a hundred percent proportion of spruce (600 m ASL). Due to the fact that there is a long-term research being carried out at these sites, it was not possible to take cross sections and the samples had to be taken with the Pressler borer.

The tree-ring curves of the reference samples for individual species groups were used to create reference average tree-ring curves. Subsequently, the tree-ring curves of the trunks found in the riverbed were dated by means of the average tree-ring curves. 79 % of the samples taken at the first site were species with diffuse-porous wood structure and 21 % were species with ring-porous wood structure. From the dendrochronological perspective, wood with diffuse-porous structures is the most difficult to date (Vyhlídková et al. 2005). The borders of tree-rings are often unclear in this group of wood species, there is a frequent occurrence of false tree-rings, or a tree-ring is not formed at all in a part of the trunk radius (Schweingruber 1993). A high number of samples had to be excluded from the dating procedure as they did not contain the number of tree-rings sufficient for dendrochronological dating. The tree-ring curves of the woody debris could not be used to create an average tree-ring curve. Therefore, the samples had to be dated individually according to the average tree-ring curves of reference samples. Only the reference curves for maple, ash and elm could be created; moreover, the reference curve for oak was created. As a result, only 4 samples were dated (2 alder samples, 1 ash and 1 elm). The ash sample was dated using the average tree-ring curve of reference ash samples. The elm sample and the two alder samples were dated using the average tree-ring curve of reference oak samples. It is interesting that the elm sample could not be dated by the elm reference curve but only by the oak reference curve. Since there is no elm standard chronology, oak standard chronologies are successfully used for dendrochronological dating of archaeological wooden samples or historical artefacts. The main reason is that both elm and oak are in the group of species with ring-porous wood structure and they also have similar ecological demands (Úradníček et al. 2001). Because the alder reference curve could not be created either, the two alder samples were also dated using the oak reference curve.

Out of the 35 samples taken at the second site, 34 were spruce, one sample was poplar. The average tree-ring curve created on the basis of selected tree-ring curves of these trunks was dated using the average tree-ring curve of the reference spruce samples. In total, 17 samples, the exact half of the collected spruce samples, could be dated. Seven samples contained fewer than 40 tree-rings which are usually considered the minimum number of tree-rings necessary for reliable dendrochronological dating. Only two out of these seven samples (28 %) could be dated. A trunk with 40 tree-rings at this site would have to have 12 cm in diameter on average. In contrast to the species with diffuse-porous wood structure, the species with ring-porous wood structure and conifers are considered very well datable by dendrochronology (Schweingruber 1993).

To be able to establish the exact year when the trees stopped growing (the time when the trunks probably came to the river channel), the dated samples have to contain the terminal ring. If the samples do not retain such a ring, it is only possible to determine the year after which the trees stopped growing. Since only four samples from the Morávka River could be dated and only two of them contained the terminal ring, the results cannot be used to establish the temporal dynamics of the woody debris input. On the other hand, out of the 17 samples dated dendrochronologically on the Černá Opava River, fourteen retained the terminal ring. Most of these samples fall within the period between autumn or winter 2006 and spring 2008. The last large flood, with maximum flow of 76.6 $m^3.s^{-1}$, was recorded in september 2007 (the average flow at the Mnichov Station is 0.76 $m^3.s^{-1}$ (Wistuba 2009)). Other possible ways in which the stem could get into the river channel are human activity and windthrow.

CONLUSSIONS

Out of the 29 samples taken at the first site, 79 % were species with diffuse-porous wood structure. This group of wood species is the most difficult to date dendrochronologically. As a result, only four samples could be dated. For this reason, the temporal dynamics of the woody debris input in the Morávka River could not be established. Out of the 35 samples taken at the second site, 97 % were spruce. In total, 17 samples from this site could be dated. As most of the dated samples fall within the period between autumn 2006 and spring 2008, in which only one large flood was recorded – in september 2007, we can assume that the woody debris came to the river channel at this time.

We can conclude that wood species with diffuse-porous structure are very difficult to date by dendrochronological methods on the basis of Pressler borer cores. Unless it is possible to take cross sections from the trunks and carry out measurements in several radial directions, these species can hardly be dated. On the other hand, the sites with conifers are easily datable, especially if the trunks contain more than 40 tree-rings. Therefore, it is recommendable from the dendrochronological point of view to avoid the sites where the dominant species have the diffuse-porous structure and to concentrate on the sites with coniferous species or species with the ring-porous wood structure.

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