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Coarse woody debris in mountain streams and their influence on geomorphology of channels in the Tatra Mts.

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Abstract: Dead wood plays important function in the riverine environment. Dead trees lying in stream channels modify the speed of the current and the shape of the channel, thus have a great influence on channel morphology. Coarse woody debris (CWD) exert influence on variation in channel width and gradient as well as promote lateral channel migration and sediment storage. In this paper we study the characteristics of dead wood delivered to two mountain streams, the Waksmundzki Stream and Pyszniański Stream in the Tatra Mts. The inflow of dead trees to the stream channels was determined with the use of dendrochronological methods. In both channels, a similar number of CWD was found – ca. 60 units per 100 m. In the Waskmundzki Stream more logs were aggregated in form of dams than in the Pyszniański Stream. The distribution of diameters, decay classes, and length classes was similar for both streams. Bank erosion is the most common cause of inflow of dead wood to the stream channel. Cross-dating of the moment of death of trees lying in the stream may indicate that inflow of dead wood to the channels is a continuous process. Fragmented remains of dead trees create geomorphological formations like dams and steps, which highly modify the channels.

Keywords: Dendrochronology, CWD (coarse woody derbis), stream channel, subalpine forest, Tatra Mountains

Introduction

Studies conducted during the last decades demonstrated importance of coarse woody debris in many ecosystems (Harmon *et al*., 1986; Franklin & Spies, 1991). Dead trees lying in stream channels modify the speed of the current and the shape of the channel, thus have a great influence on channel morphology. Coarse woody debris (CWD) exert influence on variation in channel width and gradient as well as promote lateral channel migration and sediment storage (Nakamura & Swenson, 1993). Dead trees increase variability of microhabitats in valleys of streams and rivers as well as of richness of animal and plant species (Harmon *et al*., 1986; Everett & Ruiz, 1993; Gurnell *et al*., 1995). Dead wood units located in stream channels form an accumulation of organic matter, what causes increase of food for many littoral organisms (Maser & Trappe, 1984; Hoffmann & Hering, 2000). CWD in different stages of decay have large contribution to the ecosystems' biodiversity (Gregory & Davis, 1992; Phillips, 1995; Siitonen, 2001; Topp *et al*., 2006).

Dead trees get to the stream and river beds during landslides, very often caused by floods and bank erosion, but often also due to tree mortality typical for forest disturbances, like the activity of wind, insects and pathogens (Maser & Sedell, 1994). In natural conditions of forested catchments, accumulation of CWD might obtain a high level in relation to the surrounding forest (Piegay, 1993), but due to management of littoral environments and forestry practice dead wood have been often removed from such habitats. Information about the structure of CWD

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and their dynamics in stream and riverine ecosystems in European literature is rare and practically limited to the Scandinavian boreal zone (Dahlström *et al*., 2005; Dahlström & Nilsson, 2006), partly because of the lack of suitable objects for study. Most of streams and rivers have been regulated and the CWD have become a unique component of the fluvial environment. Also, only few authors tried to deal with this topic in their studies (Pawlaczyk, 1995; Kaczka, 1998; Ciapała, 2002).

The aim of this study is to analyze the structure of CWD and their inflow and dynamics over time in two streams located in well preserved, natural subalpine spruce forests in the Carpathian Mts. Dendrochronological analyzes were used to determine the inflow of dead trees to the stream channel in a time scale.

Methods

The study was conducted in two streams: the Potok Waksmundzki Stream and the Potok Pyszniański Stream in the Polish Tatra Mts., Western Carpathians. Both streams flow through well preserved subalpine spruce stands on the territory of the Tatra National Park. The area of both catchments is covered with natural spruce forests and belongs to the best preserved subalpine stands in the Polish Tatras. At least during the last several decades human activity was very limited along both streams, thus, dead trees in both channels have accumulated due to natural processes. Also, most likely, dead wood was not removed from the stream channels and the present CWD structure is caused by natural dynamic processes. The elevation of the studied sections of the stream corresponds roughly to the altitude range of subalpine spruce forest. The climate is cool and moderately wet. Annual precipitation reaches 1,800 mm yr^{-1} and the average annual temperature is 2–4°C (Hess, 1996). The bedrock of the Waksmundzki Stream is built mostly of granite and subordinately of limestone, and the bedrock of the Pyszniański Stream is built of postglacial sediments bearing clasts of metamorphic and crystalline rocks. The forests covering both catchments as well as riparian zones of both streams is distinctly dominated by Norway spruce (*Picea abies*). A small admixture of rowan (*Sorbus aucuparia* L.) appears in undergrowth. Ground vegetation is dominated by *Vaccinium myrtillus* L., *Vaccinium vitis-idea* L., and *Lycopodium annotinum* L.

Measurements of CWD were conducted on 2,650 m long section of the Waksmundzki Stream and 2,200 m long section of the Pyszniański Stream, in respective elevation intervals of 1,360–1,050 m a.s.l. and 1,270–1,100 m a.s.l. The upper limits of these sections were established where streams flowed in the close canopy forest. Sections were divided into 25 meters fragments, and all units of coarse woody debris were recorded in them. As CWD, we treated all units of wood longer than 1 m and of diameter larger than 10 cm. Diameters of all units were measured at the ticker end. For the simplification of measurements in the field, three length classes of CWD units were distinguished:
L – long logs (longer than 10 m),
M – medium logs (length between 5 m and 10 m),
S – short logs (shorter than 5 m).

For each unit a decay class was determined. We used 5 degree classification, modified after classifications used for describing CWD decay in forest. Our modification aimed at considering also mechanical abrasion caused by fluvial activity. The following decay classes were distinguished:

1. freshly fallen trees, bark and all, even small, branches present;
2. lack of bark, only branches thicker than 1 cm present, surface of bole smooth;
3. crevices ca. 1 cm deep in bole, remains of branches present ;
4. whole surface of bole eroded, crevices 1–5 cm deep, lack of branches;
5. crevices over 5 cm deep, large loss in outer layer of bole.

Units of local origin (IN-SITU) and transported from the upper part of the stream (EX-SITU) were distinguished. Groups of logs in a form of dams were recorded. As a dam, we regarded a group of at least 5 logs, which were in direct contact with each other.

To reconstruct the inflow of dead trees to the stream channel we used dendrochronological cross-dating of randomly selected logs. Cross-sections were extracted from basal parts of chosen logs, possibly with remains of bark. Wood samples were then dried and polished with a belt sender. For the construction of a local reference chronology, 30 living spruces were cored in the forest surrounding the Waksmundzki Stream within altitudinal gradient of 1,100–1,300 m a.s.l. Selected trees belonged to the dominant layer and were free from visual signs of mechanical abrasions, like broken tops or other damages. Each tree was cored twice in perpendicular directions. Ring widths of all wood samples and cores were then measured with a resolution of 0.01 mm using LIN-TAB system produced by the Frank Rinn Company, Heidelberg, Germany (Rinn, 1996). The validity of tree-ring measurements was checked with COFECHA (Holmes, 1983). Two measurements from living trees were averaged and used for construction of the reference chronology. Ring series from dead trees were then fitted against the reference chronology to cross-date the calendar year of the last formed ring, using standard parameters with TSAP program (Rinn, 1996), and to determine a year of tree's death (Dynesius & Jonnson, 1991). The correctness of the cross-dating was verified with the sequence of pointer years (Schweingruber *et al*., 1990). The year of tree's death was determined for 72 logs in the Waksmundzki Stream and 38 logs from the Pyszniański Stream.

Results

In the whole section of the Pyszniański Stream 1,121 units of CWD were found, what constituted ca. 60 units per 100 m of the stream length. In the Waksmundzki Stream the density of logs was almost the same – 62 units per 100 m of stream length. In the upper part of the Pyszniański Stream, logs appeared as single units and did not create concentrations in a form of dams. Only in the lower part, beneath 1,700 m of its length, 8 dams were recorded. Most of the dams consisted of small number of 8–18 units, and only one dam at a distance of 1,925 m consisted of 40 logs. Beginning with 1,975 m of the stream length, a decrease in the number of logs was observed. In the Waksmundzki Stream the density of logs increased with the decrease of elevation. The number of dams was higher than in the Pyszniański Stream – 18 dams, and they were more abundant in dead wood units. The largest dam consisted of 86 fragments of CWD (Fig. 1).

In the diameter distribution, the thinnest units of CWD dominated in both streams. Most CWD units were in the middle decay stages (Fig. 2). Units in decay class 3 constituted 43% in the Pyszniański Stream and 39% in the Waksmundzki Stream. The percentage in decay class 2 was almost the same for both streams and equaled 27% and 28%, respectively. The fresh logs as well as those in the most advanced decay stage were in much lower percentage. Decay stage was related with the length of logs. In both streams, decay class 1 was represented by long and medium-long logs. In the Pyszniański Stream, beginning with decay class 3, an increase in the number of shortest logs was observed. In this decay class the shortest logs started to prevail. In successive decay classes, a decrease of long logs and increase of short logs were still visible. In the Waksmundzki Stream an intensive fragmentation of dead trees began already in decay class 2, where shortest units started to dominate. In both streams the most advanced in decay class 5 was represented only by the shortest logs and few medium-length logs (Fig. 2).

The CWD susceptibility for transportation down the stream was also associated with the length of logs. Among logs transported (ex-situ) those of the smallest dimensions dominated, and only small percentage of long logs was moved from the place of uprooting. Respectively, among logs not transported (in- situ), long and medium-long logs were dominant. The distribution was almost identical for the two streams (Fig. 3).

In both streams, the dead trees got to the channels successively at least during the least two decades due to bank erosion. The highest amount of uprootings was created in 2002 and 1997 in the Pyszniański Stream, and in 1997, 1999 and 1993 in the Waksmundzki Stream. Single uprootings were created in the meantime, as well (Fig. 4).

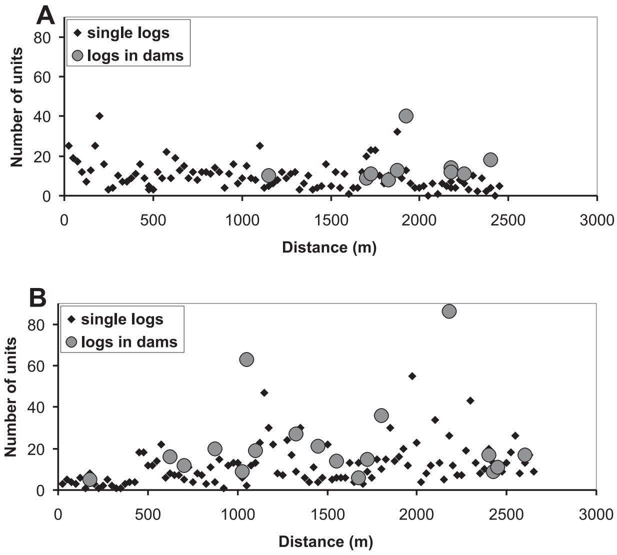

Fig. 1. Number of logs in 25 m long sections of streams. Aggregation of logs in dams marked with circles: A) Pyszniański Stream, B) Waksmundzki Stream

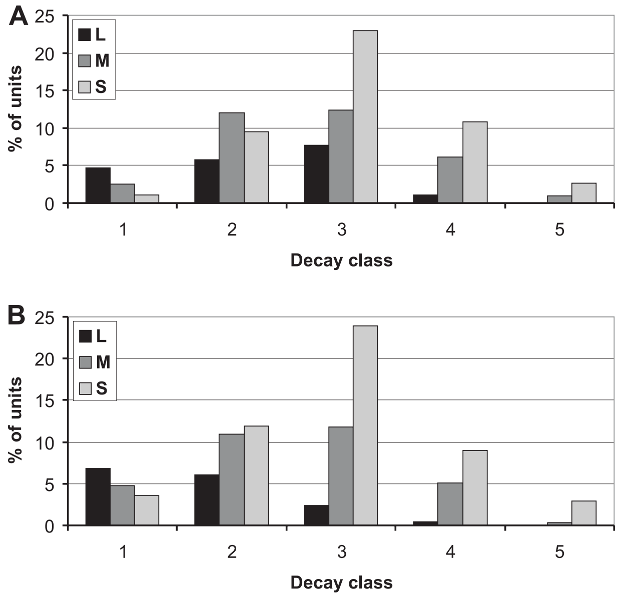

Fig. 2. Percentage of logs in decay classes depending on their length. L – above 10 m long, M – between 5 and 10 m long, S – below 5 m long; A) Pyszniański Stream, B) Waksmundzki Stream

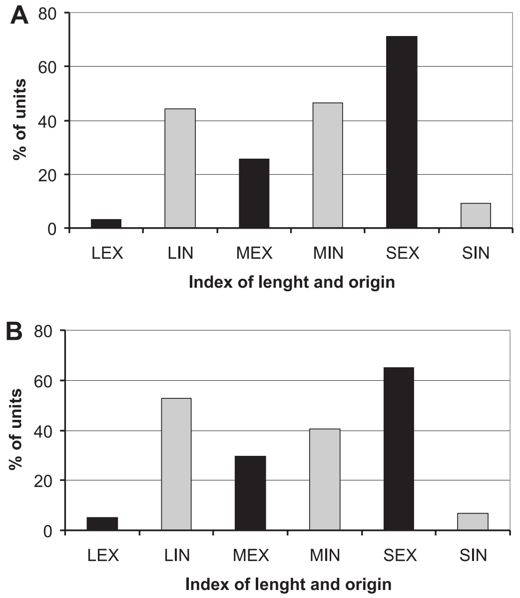

Fig. 3. Percentage of logs in relation to their origin: IN (in situ) – grey, EX (ex situ) – black and length category; A) Pyszniański Stream, B) Waksmundzki Stream

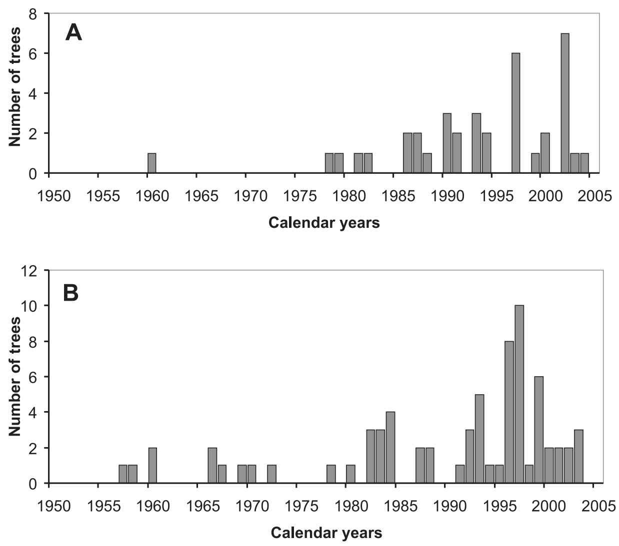

Fig. 4. Inflow of dead trees to the stream channel in calendar years, based on dendrochronological cross-dating; A) Pyszniański Stream, B) Waksmundzki Stream

Discussion

The amount of CWD recorded in the studied streams (60–62 logs/100 m) was relatively high and similar to the results obtained from the other undisturbed riparian habitats. For example, Dahlström and Nilsson (2006) noted 64 units of CWD in a stream channel located in old growth boreal forest, while Christensen *et al*. (1996) recorded 555 logs/km of shoreline of temperate lakes. Although both streams contained similar amount of dead wood, its distribution along the stream channels was slightly different. More variable amount of CWD units among 25 sections of the Waksmundzki Stream might be explained with more rocky stream bed and higher gradient. Large stones located in the stream channel created obstacles, which caused aggregation of transported fragments of wood. This may explain also larger number of dams and higher amount of units cumulated in dams in the Waksmundzki Stream.

In both streams, small units of CWD dominated distinctly in respect to length and diameter. This indicates that dead logs are fragmented relatively fast. Fall of tree to the hard rocky channel might cause breakage of the stem (Lienkaemper & Swanson, 1987). Also, the decay process seems to be relatively fast compared to the wood decomposition inside the forest. In the forest floor, the decomposition of logs is manifested mostly by the loss of wood density (Næsset, 1999) and gradual disappearance of peripheral parts of boles with time (Zielonka, 2006). Logs in a stream channel are exposed to mechanical damages additionally due to flow and impact of rocky debris and other objects transported down the stream. Outer parts of logs, which are already softened by decomposition, have been removed by friction against rocky bedrock of stream channel during transportation with the flow. The scale of decomposition used for this study reflects in fact also a mechanical abrasion, accepting typical decomposition of wood in the forest conditions. Thus, we did not take compactness of the wood as a feature of decay, which is usually used in decay classifications. In the Waksmundzki Stream fragmentation begins already in decay class 2, what is manifested in prevalence of medium length fragments over long trees, which got to the channel. In the Pyszniański Stream short logs start to dominate slightly later, starting from decay class 3. In the Waksmundzki Stream a fragmentation of laying logs is accelerated by granite bedrock and rocky debris, which fills the bottom of the channel, while the Pyszniański Stream's bedrock is built of much softer post-glacial sediments, which likely cause less mechanical abrasion. In both streams fragments of dead wood create geomorphological formations, like dams and steps, which highly modify the channels (Figs. 5–6).

Bank erosion is the most common cause of inflow of dead wood to stream channels. Lateral migration of the stream results in washing out the root system, while usually asymmetric crowns of trees, extended to the direction of canopy opening above the channel, causes the fall in the direction of the stream. Uprooting of spruce trees due to bank erosion was observed in both streams during the last two decades and in case of the Waksmundzki Stream also earlier. Relatively equal distribution of CWD over time may

Fig. 5. Spruce stem uprooted due to bank erosion creates a step which retains the debris in the stream channel. Dendrochronological cross-dating of the year of tree's death allows the determination of the maximal age of this formation

Fig. 6. The dam consisting of tens of logs and filled with debris transported by the stream. Cross-dating of the log at the base indicated that this formation was established after 1966

indicate that the inflow of dead trees is a continuous process. The highest number of uprootings in 1997 in both streams is probably related to a large flood event observed in July in the whole southern Poland due to unusually high rainfall in midsummer period. However, the inflow of dead trees to the stream channel does not seem to be caused by large flood events only. The reconstruction of inflow of dead trees in the time scale longer than two decades is loaded with an error caused by difficulties with cross dating of older logs. After this period, the outer parts of logs are usually decayed and eroded, and the outermost, last ring indicating the year of tree's death cannot be precisely dated.

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References

Christensen, D.L., Herwig, B.R., Schindler, D.E. & Carpenter, S.R., 1996: Impacts of lakeshore residential development on coarse woody debris in north temperate lakes. *Ecological Applications*, 6 (4): 1143–1149.

Ciapała, S., 2002: Role of landslides and accumulative forms in diversity of vegetation on the Kamienica Łącka River valley in the Gorce National Park. In: Denisiuk, Z. (Ed.), *A strategy of landscape and biological diversity conservation in valuable nature areas*, *affected by flood disaster*. Kraków.

Dahlström, N., Jönsson, K. & Nilsson, C., 2005: Long-term dynamics of large woody debris in a managed boreal forest stream. *Forest Ecology and Management*, 210: 363–373.

Dahlström, N. & Nilsson, C., 2006: The dynamics of coarse woody debris in boreal Swedish forests are similar between stream channels and adjacent riparian forests. *Canadian Journal of Forest Research*, 36 (5): 1139–1148.

Dynesius, M. & Jonnson, B.G., 1991: Dating uprooted trees: comparison and application of eight methods in boreal forest. *Canadian Journal of Forest Research*, 21: 655–665.

Everett, R.A. & Ruiz, G.M., 1993: Coarse woody debris as a refuge from predation in aquatic communities – an experimental test. *Oecologia*, 93 (4): 475–486.

Franklin, J.F. & Spies, T.A., 1991: Composition, function and structure of old-growth Douglas-fir forest. *USDA Forest Service General Technical Report* PNW-GTR-285.

Gurnell, A.M., Gregory, K.J. & Petts, G.E., 1995: The role of coarse woody debris in forest aquatic habitats – implications for management. *Aquatic Conservation-Marine and Freshwater Ecosytems*, 5 (2): 143–166.

Gregory, K.J. & Davis, R.J., 1992: Coarse woody debris in stream channels in relation to river channel management in woodland areas. *Regulated Rivers*: *Research and Management*, 7: 117–136.

Harmon, M.E., Franklin, J.F., Swanson, F.J., Sollins, P., Gregory, S.V., Lattin, J.D., Anderson, N.H., Cline, S.P., Aumen, N.G., Sedel,l J.R., Lienkaemper, G.W., Cromack, K. & Cummins, K.W., 1986: Ecology of coarse woody debris in temperate ecosystems. *Adv*. *Ecol*. *Res*., 15: 133–302.

Hess, M., 1996. Climate. In: Mirek, Z. (Ed.), *The nature of the Tatra National Park*. Tatrzański Park Narodowy, Zakopane–Kraków: 53–68. (in Polish with English summary)

Hoffmann, A. & Hering, D., 2000: Wood-associated macroinvertebrate fauna in Central European streams. *International Review of Hydrobiology*, 85 (1): 25–48.

Holmes, R.L., 1983. Computer assisted quality control in tree-ring dating and measurement. *Tree-Ring Bull*., 43: 67–78.

Kaczka, R., 1998: *Rola kłód w systemie fluwialnym i kształtowaniu biocenoz z nim związanych. Kamienica Łącka w Gorcach*. Praca magisterska. Wydział Nauk o Ziemi. Uniwersytet Śląski (unpublished Ph.D. thesis, in Polish).

Lienkaemper, G.W. & Swanson, F.J., 1987: Dynamics of large woody debris in streams in old-growth Douglas-fir forests. *Canadian Journal of Forest Research*, 17 (2): 150–156.

Maser, C. & Trappe, J.M., 1984: The seen and unseen world of fallen tree. *USDA, General Technical Report* PNW-GTR-164.

Maser, C. & Sedell, J.R., 1994: *From the forest to the sea: the ecology of wood in streams, rivers, estuaries and oceans*. St. Lucies Press, Delray Beach, Fla.

Nakamura, F. & Swenson, F.J., 1993: Effects of coarse woody debris on morphology and sediment storage of a mountain stream system in Western Oregon. *Earth Surface Processes and Landforms*, 18 (1): 43–61.

Næsset, E., 1999: Decomposition rate constants of Picea abies logs in southeastern Norway. *Canadian Journal of Forest Research*, 29: 372–381.

Pawlaczyk, P., 1995: Ochrona procesów generowanych przez rzeki jako podstawa ochrony przyrody w ich dolinach. *Przegląd Przyrodniczy*, 6 (3–4): 235–255.

Phillips, E.C., 1995: Associations of aquatic Coleoptera with coarse woody debris in Ozark streams, Arkansas. *The Coleopterists Bulletin*, 49 (2): 119–126.

Piegay, H., 1993: Nature, mass and preferential sites of coarse woody debris deposits in the lower Ain Valley (Mollon Reach), France. *Regulated Rivers-Research & Management*, 8 (4): 359–372.

Rinn, F., 1996. *TSAP Version 3.0. Reference Manual*. Heidelberg, Germany.

Schweingruber, F.G., Eckstein, D., Serre-Bachet, F. & Bräker, O.U., 1990: Identification, presentation, and interpretation of event years and pointer years in dendrochronology. *Dendrochronologia*, 8: 9–37.

Siitonen, J., 2001: Forest management, coarse woody debris and saproxylic organisms: Fennoscandian boreal forests as an example. *Ecological Bulletins*, 49: 11–41.

Topp, W., Kappesa, H., Kulfan, J. & Zach, P., 2006: Distribution pattern of woodlice (Isopoda) and millipedes (Diplopoda) in four primeval forests of the Western Carpathians (Central Slovakia). *Soil Biology & Biochemistry*, 38 (1): 43–50.

Zielonka, T., 2006: When does dead wood turn into a substrate for spruce replacement? *Journal of Vegetation Science*, 17: 739–746.