STUDIA GEOMORPHOLOGICA CARPATHO-BALCANICA
VOL. XXXVII KRAKÓW 2003 PL ISSN 0081-6434
LANDFORM EVOLUTION IN MOUNTAIN AREAS

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THE COARSE WOODY DEBRIS DAMS IN MOUNTAIN STREAMS OF CENTRAL EUROPE, STUCTURE AND DISTRIBUTION

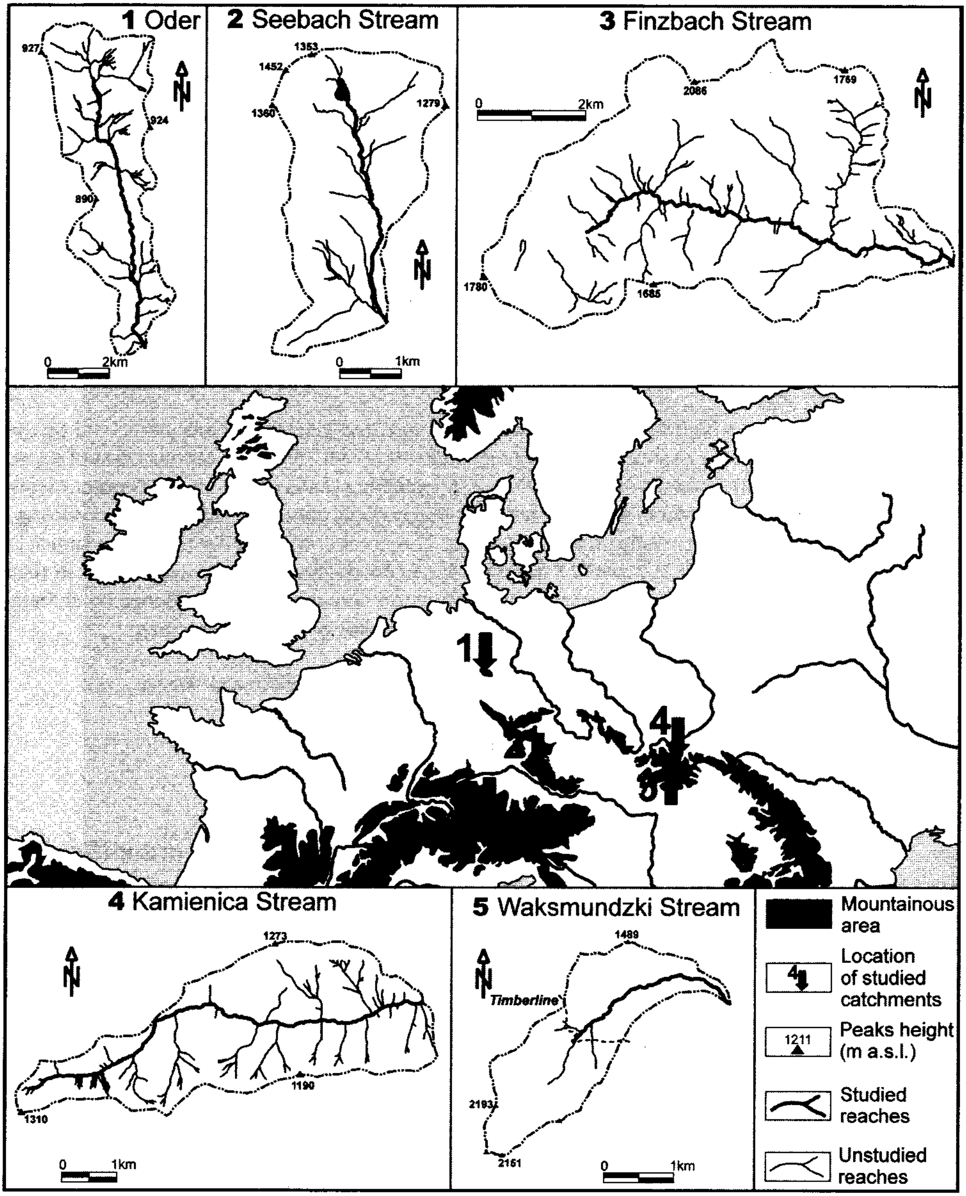
Abstract. The streams which flow within mountainous forested catchments are influenced by the fallen trees delivered to the channel. These organic matter is able to compose various types of dams. Five streams (2nd to 4th Strahler's order) in different mountainous areas of Poland and Germany were compared. The quantity of coarse woody debris and woody dams depends on the river morphology, riparian forest condition and mostly on human impact. The number of CWD dams was the largest in Polish Carpathians streams (108.7 and 57.3 dams per km of the river course) and the smallest in Harz Mts., Germany (1.3 dams per km of river course). Active dams with the greatest influence on channel morphology, are rather rare in each case (0.7–6.3 dam per km of the river course).

Key words: coarse woody debris, dams, channel morphology, mountainous stream

INTRODUCTION

The research concerned on five streams, second to fourth order (Strahler cl.) in different mountainous areas of Central Europe (Fig. 1). The investigated streams represent different types of Central European mountainous landscapes. The physiography and intensity of human impact are differentiated within the discussed catchments. The streams are located in the upper parts of the fluvial systems, where the debris output as an effect of erosion and rapid transportation is a dominating process (Schumm 1977; Kaszowski and Krzemień 1999). One of the main factor, which limits erosion in these forested catchments (apart from the resistance of the bedrock) are the tree trunks delivered to the stream channel. The main role of coarse woody debris (CWD) is to create dams and stimulate the storage of the mineral and organic debris. Although numerous researchers work on the problem of CWD dams role in mountain streams (Keller and Swanson 1979; Bisson et al. 1987; Bilby and Ward 1991; Gregory et al. 1993; Nakamura and Swanson 1993;

Richmond and Fausch 1995; Piegay and Gurnell 1997; Elosegi et al. 1999), not enough research is being conducted in Central Europe (Hering and Reich 1997; Kaczka 1999).



1 Oder

2 Seebach Stream

3 Finzbach Stream

4 Kamienica Stream

5 Waksmundzki Stream

Fig. 1. Location of study areas in Central Europe. The investigation was led in the main steams of the catchments. In two cases the entire course of the stream was investigated; Waksmundzki, Seebach Stream. In the Finzbach, Kamienica and Oder Streams the research was led in the upper course where the conditions are natural or seminatural

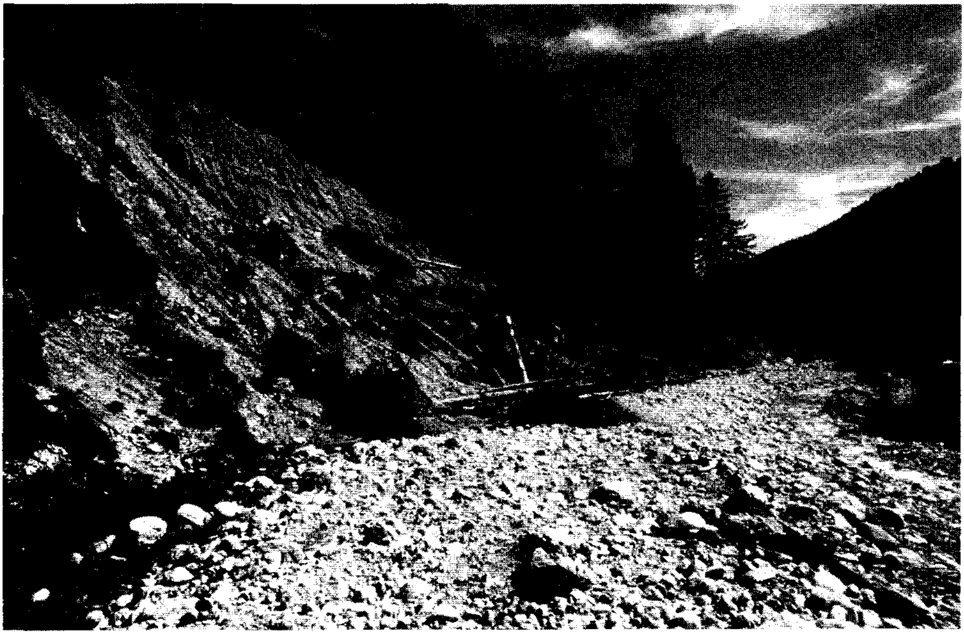


Photo 1. Riverbank undercuted during high water stage resulted from the spring thaw creates a source of trees delivery. Upper course of the Finzbach Stream, Bavarian Alps, Germany

The purpose of this research was to define the distribution and structure of CWD dams and their dependence on the quantity of cwd and geomorphological character of the channel in various natural and seminatural mountainous environments.

The secondary purpose was to define the influence of coarse woody debris dams constructors on a mountain stream channel.

THE STUDY AREA

The catchments are characterised by varied physiographic features and different transformations caused by human activities (Table 1). All of the investigated streams, except the Finzbach Stream, a moderately managed catchment, are located within the National Parks. In Germany and in Poland, like in other European countries, (Gregory et al. 1993; Hering and Reich 1997; Piegay and Gurnell 1997; Piegay et al. 1999; Gurnell et al. 2000) CWD is removed from streams. The only exceptions can be observed in some National Parks and Preserves.

The Finzbach and the Waksmundzki Streams represent catchments of high fluvial energy. This results from high channel and catchment gradient and average annual precipitation (Table 1). In the Finzbach Stream the main channel has a low

Table 1

Morphological characteristics of the investigated streams and the main physiographic parameters of their cachments

River	Waksmundzki Stream	Finzbach	Seebach	Kamienica	Oder
Location	Tatra Mountains	Bavarian Alps	The Bavarian Forest	Gorce Mountains	Harz Mountains
Order (Strahler cl.)	2	4	3	4	4
Average altitude of catchment [m a.s.l.]	1,191	1,118	926	1,006	575
Average annual sum of precipiration [mm]	1,721	1,320	1,339	1,230	1,540
Riparian forest (predominant species)	Upper subalpine forest, spruce, alder	Subalpine forest, spruce, pines	Lower subalpine forest, planted spruce	Subalpine forest, spruce	Lower subalpine forest, planted spruce
Catchment area [km^2]	4.5	28.6	6.3	15.4	20.7
Lenght of investigated reach [km]	2.9	8.7	4.4	7.9	10.77
Average gradient of investigated reach [m/m]	0.141	0.027	0.066	0.052	0.039

gradient but all its tributaries are steep. The discharge of the streams is often very high as an effect of summer rainfall (Waksmundzki Stream) (Kotarba 1998) or spring thaw (Finzbach Stream). Traces of numerous high water stages are visible as a bank undercuts which create the source of CWD delivery (Photo 1). The Finzbach Stream channel drains an area of limestone and dolomite. The stream dissects the glacial and fluvial deposits. The channel changes its character from cascade and step-pool system in the source area to plane-bed in the middle part. In its lower part (at a length of about 3 km) dominate the bedrock channel. The Waksmundzki Stream channel is filled with gravel and crystalline boulders, it is cascade and step-pool type. In its lower section, close to its mouth, the channel is dry — the water disappears into a course grained alluvial fan. The entire catchment is located in the Tatra National Park and has been under strict protection since 1954.

The Seebach Stream begins from in a moraine-dammed lake. Downstream it flows through gaps in successive moraines (cascade channel type). In the lower course it has a stabilised course and few traces of bank erosion (plane-bed type of channel). Seebach Stream draines the Bavarian Forest National Park, which was established in 1970.

The Kamienica Stream is a typical river of the northern Carpathian Mountains. There are marks of bank erosion in its entire course and of the channel incision in weakly resistant flysch rocks. The upper course of Kamienica Stream is step-pool system stream. There are a lot of rocky steps (on sandstone) and of woody debris steps. The riffles and pools are the predominant forms of the channel in the lower course of investigated area. The entire studied part of Kamienica is located in Gorce National Park, which was established in 1980.

The Oder Stream is a river flowing in the low mountains. The fluvial energy here is small; this is demonstrated by a small number of erosive forms. The upper course includes cascades formed of granite boulders. The riffles and pools are the predominant forms in the lower course. Investigation was conducted from

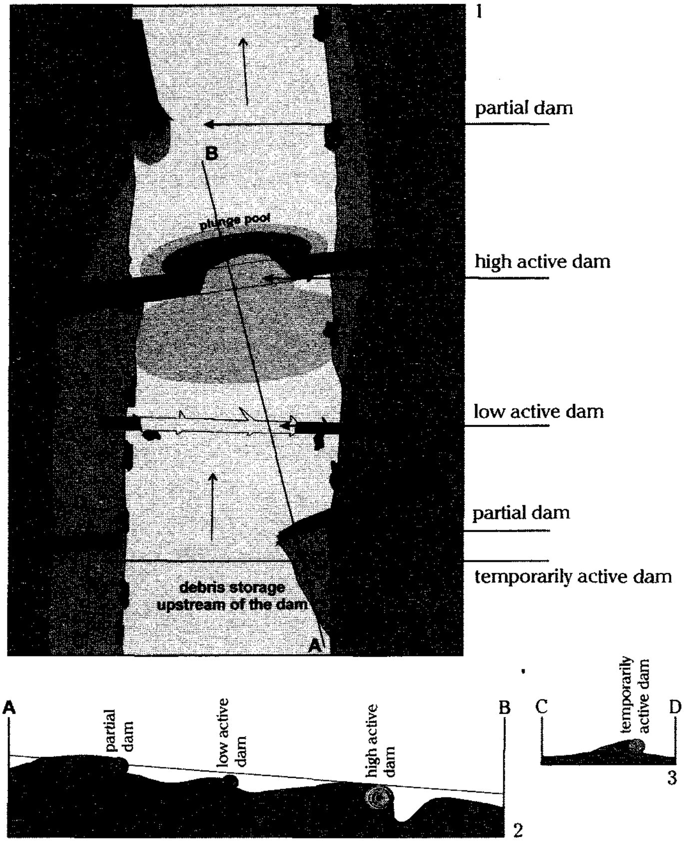


Fig. 2. Schematic diagrams of the coarse woody debris dams types.
1 — plan view, 2, 3 — longitudinal view

below the artificial dam located in the upper course of the stream, to the border of the Harz National Park (established in 1994).

METHODS

The coarse woody debris (CWD) was considered to be any piece of wood of minimal length of 1m and a diameter of at least 10 cm in the half-length of the log (Richmond and Fausch 1995; Piegay and Gurnell 1997; Gurnell et al. 2000). Measures were taken of the basic sizes (length, diameter) and the position of each CWD piece in entire investigated course.

The main features of the channel morphology (the channel structure, the width of the active channel and bottom of the valley, slope of the channel etc.) were mapped on the basis of compilation of the river channel mapping instruction by M. Kamykowska et al. (1999), and of the channel classifications by M. Church (1992) as well as D. R. Montgomery et al. (1995).

Dams were defined on the basis of the modified classification of K. J. Gregory et al. (1993). The original classification consists of four types of the woody dams based on the positions of the coarse woody debris in the channel (verbatim):

- active dams are those that completely cross the width of the channel and constitute a break in the long profile by producing a step,
- complete dams also cross the channel but do not produce a step in long profile,
- partial dams do not completely cross the channel and are accumulations that other studies have sometimes referred to as inchannel debris,
- high water dam influences channel at near bankfull discharge.

During the field study the need of modification of the classification was recognised. The changes of the definitions concern the functions and the structure of the channel forms stimulated by and containing woody debris (Fig. 2):

1. Permanently active dams — forms located in low water stage channel, always active. Their function is visible in changing the course and energy of the water, as well as in the storage of mineral and organic debris, and in the modification of the longitudinal channel profile. The intensity of that processes depends on dam construction:
    - high complete dams — the woody step higher than average diameter of the all CWD (Photo 2),
    - low complete dams — the woody step lower than average diameter of the CWD,
    - partial dams — do not completely cross the channel (Photo 3).
2. Temporarily active dams — have the same structures but are located on the bars or within dry (abandoned or secondary) channels. They are active only during high water stages. Temporarily active dams play the similar role as permanently active dams but the time of their activity is entirely.

Photo 2. High complete dams — the woody step higher than average diameter of the coarse woody debris (20 cm). Kamienica, Gorce (Poland)

Photo 3. Partial dams — coarse woody debris do not completely cross the channel. Oder Stream, Harz (Germany)

RESULTS

CHARACTERISTICS OF COARSE WOODY DEBRIS

In the analysed catchments the observed supply of CWD is connected with the following factors: the erosive activity of the river and dying forests which results from air pollution, pests and forest management (Urlich 1991). The supply caused by human impact is present in each of the investigated catchments. The CWD coming from this source dominates in seminatural catchments in Germany — like, for example in Seebach Stream 17% of all CWD originates the dead standing trees in dying forest. The comparison of the main parameters of CWD in the researched streams shows a significant variation regarding their both amount and size (Table 2). Standard deviation (SD) shows the differentiation of such CWD features as volume and dimensions. The largest load of the woody debris was noticed in Waksmundzki and Kamienica Stream. In Oder the amount of CWD was about ten times lower than in Carpathians catchments. The largest CWD pieces occur in Oder Stream (38 m) and in Kamienica (31.5 m). The biggest volume of CWD is found in the Kamienica Stream (85.36 m^3/km) despite the fact that the biggest number of logs is found in the Waksmundzki Stream.

STUCTURE OF CWD DAMS

The height of complete dams is differentiated (Fig. 3). The highest dams occur in Waksmundzki Stream (max. height 1.8 m), the lowest in Oder (max. 40 cm). Mean values differ slightly (from 0.3 m on Finzbach and Oder to 0.65 m in

Table 2

Main parameters of coarse woody debris within investigated streams

Streams	Number of CWD pieces	Number of CWD pieces per 1 km of channel length	Total volume of CWD [m^3]	Volume of CWD pieces per 1 km of channel length [m^3/km]	Mean length of CWD pieces [m] ±SD	Mean diameter of CWD pieces [cm] ±SD	Mean volume of CWD pieces [m^3] ±SD
Waksmundzki	718	247.6	120.7	41.6	4.0 ±2.9	19.5 ±8.1	0.2 ±0.2
Finzbach	1,136	130.6	173.0	19.9	3.8 ±3.4	19.7 ±8.9	0.2 ±0.3
Seebach	670	152.3	121.4	27.6	4.5 ±4.3	18.3 ±7.6	0.2 ±0.3
Kamienica	1,649	208.7	674.4	85.4	7.6 ±6.4	19.6 ±8.6	0.4 ±0.7
Oder	291	27.0	171.2	15.9	7.5 ±8.3	23.9±11.7	0.6±1.2

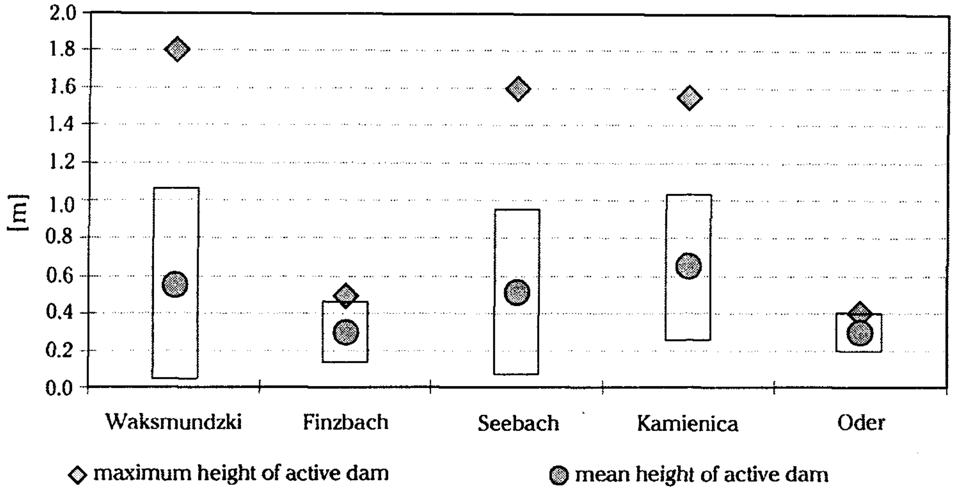


Fig. 3. Height of complete dams in the investigated streams. The boxes show the values of standard deviation

Kamienica). High complete dams are often constructed of large amount of CWD. The highest complete dam in the Waksmundzki Stream contain of 32 CWD pieces and plenty of fine organic material. Not each of CWD pieces was possible to measure. In Seebach the highest dam is constructed of 7 CWD, in Kamienica also of 7 CWD. In Finzbach all complete dams is created on single CWD. In Oder only 1 of that dam consists of more than one CWD (4 logs).

DISTRIBUTION OF CWD DAMS

The number of dams and their distribution in the studied catchments differs considerably (Fig. 4). The highest number of dams occur in Waksmundzki Stream (108.7 dams/km). The fewest dams occur in Oder Stream (1.3 dams/km). The lowest diversity of dam types is present in Seebach and the highest in Finzbach (Fig. 4). Temporarily active dams (Photo 4) numerously occur in Finzbach (73%) and Waksmundzki (66%) Streams.

The similar frequency of partial dams occurs in the Kamienica and Waksmundzki Streams (35.2 and 26.8 dams/km). In the other streams this type of dams is less common (2.2 in Finzbach; 4.5 in Seebach). The comparable amount of low complete dams occurs in all streams (from 3.5 to 5.8 dams/km) except Oder. High complete dams (Photo 2) are most common in Seebach (39%) and Kamienica (11%). In high mountain streams — (Waksmundzki and Finzbach) the amount of dams of this type is significantly lower (4% and 2%).

In the Finzbach Stream high complete dams are concentrated in the lower course (Fig. 5) where the channel is narrow and limited by rock walls. There are numerous boulders here, facilitating the CWD getting stuck and the steps formation. In Seebach Stream the high complete dams are cumulated in the

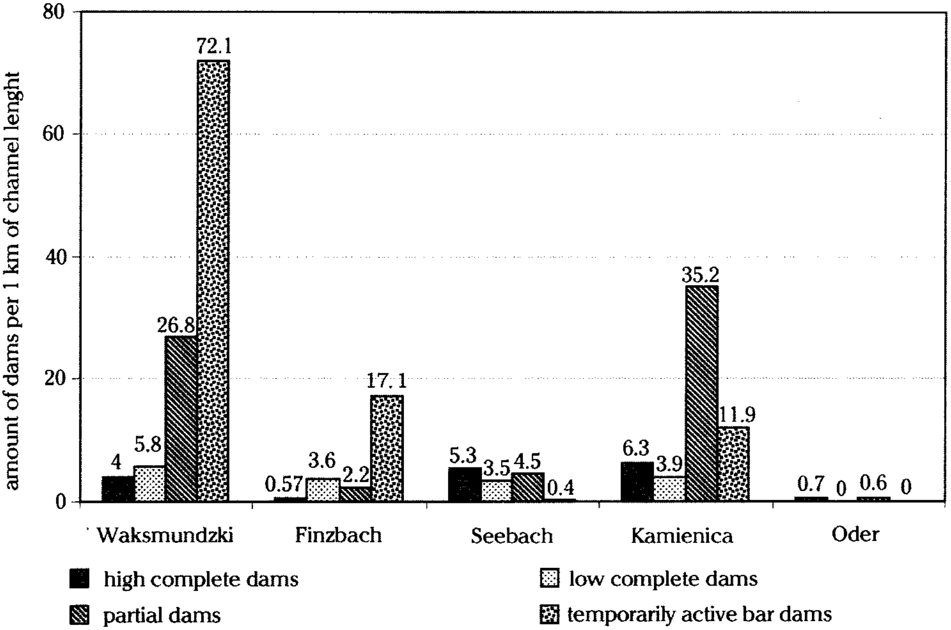


Fig. 4. The number of the particular types of debris dams per unit of channel length in the investigated streams

Photo 4. Temporarily active dam — have the same structure as high complete dam but is located in dry (abandoned) channel. Finzbach Stream, Bavarian Alps (Germany)

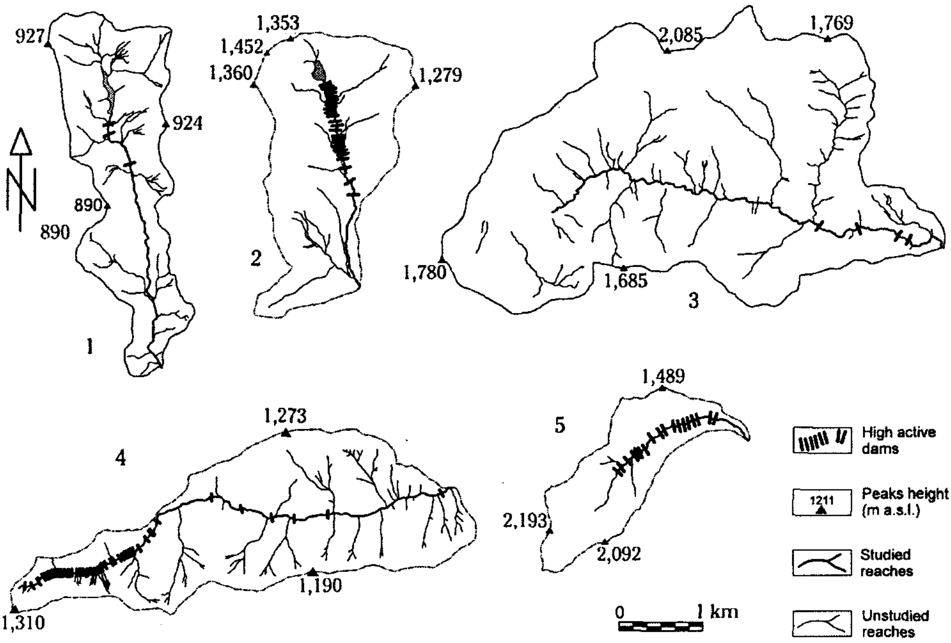


Fig. 5. Generalised distribution of active dams. 1 — Oder, 2 — Seebach Stream, 3 — Finzbach Stream, 4 — Kamienica Stream, 5 — Waksmundzki Stream

upper part of the reach (Fig. 5). In the middle course a big number of dams has been found in the section with a steeper slope, where the stream flows through a gorge in the moraines. In the lower course the number of dams decreases. In the Waksmundzki Stream the high complete dams occur below the forest line where the trees grow at the riverbanks. In the lower course, in the dry channel, the dams do not occur (Fig. 5).

There are very few dams in the Oder Stream in comparison to the other streams. Only nine dams were examined in the entire watercourse. With such a small number of examples, an analysis of their variation seems to be unjustified. In the Kamienica Stream, high complete dams are most numerous in the upper section (Fig. 5). This is an effect of the flood in July 1997. Numerous active dams noticed along the entire course of the stream during observations conducted prior to this flood were destroyed by the extremely high water level during the flood. The development of new high complete dams in the lower section was observed after 1997. Between 1997 and 2000 their number increased by 20%. In the other catchments similar observations were not conducted.

DISCUSSION

The abundance of CWD is much more significant in the Carpathian catchments. It refers as to the number — Waksmundzki, as the volume — Kamienica. The character of investigated catchments in Germany is seminatural. The human influence on the CWD number is the strongest there. Nowadays the Seebach is the stream with the slightest management. The intensive supply is connected with the forest dying. The foresters do not carry out the CWD what causes that the CWD is here numerous. In other cases CWD is removed with various intensity.

Average abundance of CWD in investigated European catchments is lowest that was noticed on Western Coast of the Northern America (Keller and Swanson 1979; Harmon et al. 1986; Nakamura and Swanson 1994). It is confirmed by the other European researchers (Piegay et al. 1999; Gurnell et al. 2000). In Carpathian streams the number and volume of CWD is comparable to 2nd and 3rd order old growth streams in Colorado (Richmond and Fausch 1995) and to none or moderate harvested forests of Western Washington (Ralph et al. 1994). The features of German streams are similar to 2nd order disturbed catchment in Colorado (Richmond and Fausch 1995) and to moderate and intensive harvested forests of Western Washington (Ralph et al. 1994). The dimensions of CWD investigated as well as the other CWD studied in Europe (Piegay and Gurnell 1997; Elosegi et al. 1999; Gurnell et al. 2000) are usually smaller than those on Western Coast (Bilby and Ward 1991).

The number of dams in Carpathian Mts. streams is comparable to this in USA (Bilby and Likens 1980; Likens and Bilby 1982; Sedell and Swanson 1984; Heede 1985; Hedin et al. 1988) or higher (Marston 1982; Potts and Anderson 1990; Webster et al. 1990). The number of dams in other streams is similar to mountainous streams in western costal zone of USA or low gradient

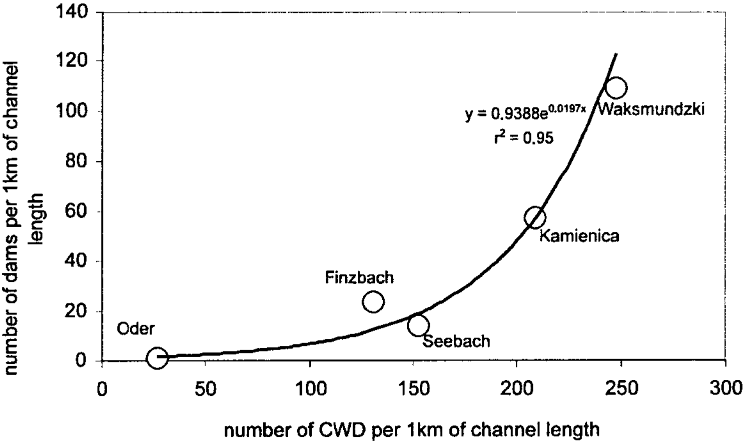


Fig. 6. Relationship between the average number of coarse woody debris and of CWD dams per unit of channel length in the investigated streams

streams in harvested forests in England (Gregory et al. 1985; Webster et al. 1990; Gregory et al. 1993). The most numerous dams exist in Carpathian streams as well as the biggest number of CWD. This suggests the connection between the number of CWD and the possibility of dam creation (r^2 = 0.87, t = 0.0038). The bigger amount of CWD affects the increase of dams number (Fig. 6). This could be the explanation of such low number of dams in Oder Stream. The width of wet and active channels is also the important factor. The narrower is channel the more of CWD stuck in the channel (Bilby and Ward 1989; Piegay et al. 1999; Fetherston et al. 1995).

A small number of dams exist in Finzbach. Wet and active channels of the Finzbach Stream are wide (mean 11 and 70 m) but the CWD size is not significant (length 3.8 m ±3.4 SD).

The number of low complete dams is the slightest differentiated in all streams. The largest quantity of partial dams occur in catchments reach in CWD. In contrary the number of partial dams depends rather on the CWD volume (r^2 = 0.92, t = 0.01) than on the number of CWD pieces (r^2 = 0.8, t = 0.006).

High complete dams play the more important role in shaping the channel since they alter the longitudinal profile. The highest complete dams occur in the high gradient reaches of streams. In the steeper, upper sections of streams active dams occur more often (Fig. 6). In contrary in Finzbach all dams are located in lower course (Fig. 5). Dams were created on the CWD trapped by the boulders in narrow, rocky section of the channel. The dams develop on spanning CWD (Photo 2). Such forms originate as a result of the accumulation of a large amount of mineral and fine organic debris on the distal side of the CWD. On the proximal side, falling water forms plunge pools (Keller and Swanson 1979). The number of CWD creating active dams differs (Gregory et al. 1993). The dams not higher that the mean height of dam (0.5 m) consist usually of single CWD. The higher active dams often consist of a group of CWD pieces oriented similarly (Piegay et al. 1999). Transported fragments of tree trunks, branches and leaves are trapped by CWD pieces, which are permanently anchored (Nakamura and Swanson 1993). This improves the efficiency of the dam. The increasing mass of wooden and mineral material influences the stabilisation of these forms. The structure of active dams could rise by trapping next CWD. In effect the age of CWD in one dam differs (Kaczka 2001). In streams with numerous boulders in wet channel there was observed that high complete dams are often created by single CWD. Dam is created by CWD anchored by boulder. In such situation the height of dam depends on the boulders dimensions and not on number and size of CWD (eg. in Seebach and Waksmundzki exists the dams 1–1.5 m high consist of single CWD anchored on boulders). The quantity of mineral debris as more resistant material determines the time of dam existence (Fig. 7).

In those catchments in which occure episodes with very high water levels, the CWD transported at the time of largest discharge is deposited on bars and than the CWD pieces themselves enforce a deposition of mineral debris as the

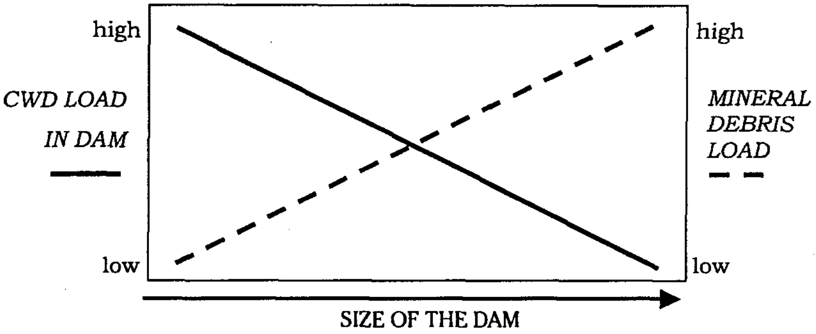


Fig. 7. Schematic representation of the general trend of the effects of coarse woody debris abundance in dam on the dam size

flood wave falls. This kind of dams could store debris during next flood period. At the time of low and medium discharge, this CWD is inactive. Numerous forms of this type — high water dams are found in streams of high fluvial energy character: Waksmundzki, Finzbach Streams and Kamienica Stream. In those catchments, in which high water level episodes are relatively rare, these forms of debris retention are rare — the Oder Stream and Seebach Stream represent this type.

CONCLUSIONS

1. In mountainous areas of Central Europe the forest management affects the abundance of CWD in the streams. Mountainous streams located in highly developed countries (for example: the Finzbach, Oder and Seebach in Germany) are affected by human activities. Even if the streams retained or regain their quasi-natural character, the number of logs and what follows the presence of CWD dams in the channels is smaller than in streams with a natural character (the Waksmundzki Stream, Kamienica Stream in Poland). The number and importance of CWD dams in natural streams is comparable with the situation in the forests of West Coast of USA.

2. Considerable abundance of CWD in a stream favour a quantity of forms connected with their presence in the channel — Kamienica Stream, the Waksmundzki Stream.

3. The dams dimensions depend on the amount of CWD present in the channel. The Waksmundzki Stream abounds in not large CWD pieces but CWD dams in this stream are bigger than in Oder Stream in which, on the contrary, large but sparse CWD create small dams.

4. The example of the Oder Stream catchment suggests that there exists certain number of logs, above which the role of logs in channel modelling decreases drastically.

5. In the streams of high fluvial dynamic the CWD dams contain also numerous mineral debris.

ACKNOWLEDGEMENTS

I would like to thank to Prof. Michael Reich for help at the time of my research in Germany. I am also very thankful to the authorities of Bavarian Forest National Park, Gorce National Park, Harz National Park and Tatra National Park for the permission for leading the research within the preserved areas.

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REFERENCES

Bilby R. E., Likens G. E., 1980. *Importance of organic debris dams in the structure and function of stream ecosystems*. Ecology 61, 1107–1113.

Bilby R. E., Ward J. W., 1989. *Changes in characteristics and function of woody debris with increasing size of streams in western Washington*. Transactions of the American Fisheries Society 118, 4, 368–378.

Bilby R. E., Ward J. W., 1991. *Characteristics and function of large woody debris in streams draining old-growth clear-cut, and second-growth forests in Southwestern Washington*. Canadian Journal of Fisheries and Aquatic Sciences 48, 12, 2499–2508.

Bisson P. A., Bilby R. E., Bryant M. D., Dolloff C. A., Grette G. B., House R. A., Murphy M. L., Koski K. V., Sedell J. R., 1987. *Large woody debris in forested streams in the Pacific Northwest: past, present, and future*, [in:] *Streamside Management: Forestry and Fishery Interactions*, eds. E. O. Salo, T. W. Cundy, Seattle, WA, University of Washington, 143–190.

Church M., 1992. *Channel morphology and typology*, [in:] *The Rivers Handbook*, eds. P. Calows, G. E. Petts, London, Blackwell, 126–143.

Elosegi A., Diez J. R., Pozo J., 1999. *Abundance, characteristics, and movement of woody debris in four Basque streams*. Arch. Hydrobilo. 144, 455–471.

Fetherston K. L., Naiman R. J., Bilby R. E., 1995. *Large woody debris, physical process, and riparian forest development in montane river networks of the Pacific Northwest*. Geomorphology 13, 1–4, 133–144.

Gregory K. J., Gurnell A. M., Hill C. T., 1985. *The permanence of debris dams related to river channel processes*. Hydrological Sciences Journal 30, 3–9.

Gregory K. J., Davis R. J., Tooth S., 1993. *Spatial distribution of coarse woody debris dams in the Lymington Basin, Hampshire, UK*. Geomorphology 6, 3, 207–224.

Gurnell A. M., Petts G. E., Hannah D. M., Smith B. P. G., Edwards P. J., Kollmann J., Ward J. V., Tockner K., 2000. *Wood storage within the active zone of a large European gravel-bed river*. Geomorphology 34, 55–72.

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., Sedell J. R., Lienkaemper G. W., Cromack K., Cummins K. W., 1986. *Ecology of coarse woody debris in temperate ecosystems*. Advances in Ecological Research 15, 133–302.

Hedin L. O., Mayer M. S., Likens G. E., 1988. *The effect of deforestation on organic debris dams.* Verhandlungen, Internationale Vereinigung Fur Theoretische Und Angewandte Limnologie 23, 1135–1141.

Heede B. H., 1985. *Channel adjustments to the removal of log steps: an experiment in a mountain stream*. Environmental Management 9, 5, 427–432.

Hering D., Reich M., 1997. *Bedeutung von Totholz für Morphologie, Besiedlung und Renaturierung mitteleuropäischer Fließgewässer.* Sonderdruck Aus Natur Und Landschaft 72, 383–389.

Kaczka R. J., 1999. *The role of coarse woody debris in fluvial processes during the flood of the July 1997. Kamienica Łącka Valley, Beskidy Mountains, Poland.* Studia Geomorphologica Carpatho-Balcanica 33, 117–130.

Kaczka R. J., 2001. *The age of coarse woody debris and associated channel forms in the mountain stream. Kamienica River, Poland.* Book of Abstract, Eurodendro 2001, International Scientific Conference of Dendrochronology, University of Ljubjana, Slovenia.

Kamykowska M., Kaszowski L., Krzemień K., 1999. *River channel mapping instruction. Key to the river bed description*, [in:] *River channels pattern, structure and dynamics*, eds. K. Krzemień, Prace Geogr. Inst. Geogr. UJ 104, 9–25.

Kaszowski L., Krzemień K., 1999. *Classification systems of mountain river channel*, [in:] *River channels pattern, structure and dynamics*, eds K. Krzemień, Prace Geogr. Inst. Geogr UJ 104, 9–25.

Keller E. A., Swanson F. J., 1979. *Effects of large organic material on channel form and fluvial processes*. Earth Surface Processes and Landforms 4, 361–380.

Kotarba A., 1998. *Landscape Ecology, Human Impact and Extreme Erosional Events in the Tatra Mountains, Poland*. Ambio 27, 4, 354–357.

Likens G. E., Bilby R. E., 1982. *Development maintenance and role of organic debris dams in New England streams,* [in:] *Sediment budgets and routing in forested drainage basins, U.S.* eds F. J. Swanson, R. J. Janda, T. Dunne, Forest Service Research Paper, 122–128.

Marston R. A., 1982. *The geomorphic significance of log steps in forest streams*. Annals of the Association of American Geographers 72, 99–108.

Montgomery D. R., Buffington J. M., Smith R. D., 1995. *Pool spacing in forest channels*. Water Resources Research 31, 4, 1097–1105.

Nakamura F., Swanson 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.

Nakamura F., Swanson F. J., 1994. *Distribution of coarse woody debris in a mountain stream, western Cascade Range, Oregon*. Can. J. For. Res. 24, 2397–2403.

Piegay H., Gurnell A. M., 1997. *Large woody debris and river geomorphological pattern: examples from S.E. France and S. England.* Geomorphology 19, 99–116

Piegay H., Thevenet A., Citterio A., 1999. *Input, storage and distribution of large woody debris along a mountain river continuum, the Drome River, France*. Catena 35, 1, 19–39.

Potts D. F., Anderson B. K. M., 1990. *Organic debris and the management of small stream channels*. West J. Appl. For. 5(1), 25–28

Ralph S. C., Poole G. C., Conquest L. L., Naiman R. J., 1994. *Stream channel morphology and woody debris in logged and unlogged basins of western Washington*. Canadian Journal of Fisheries and Aquatic Sciences 51, 1, 37–51.

Richmond A. D., Fausch K. D., 1995. *Characteristics and function of large woody debris in subalpine Rocky Mountain streams in northern Colorado*. Canadian Journal of Fisheries and Aquatic Sciences 52, 8, 1789–1802.

Schumm S. A., 1977. *The Fluvial System.* Wiley and Sons, New York, 338 pp.

Sedell J. R., Swanson F. J., 1984. *Ecological characteristics of streams in old-growth forests of the Pacific Northwest Meehan*, [in:] *Fish and Wildlife Relationships in Old-Growth Forests: Juneau, Alaska (USA)*. American Institute of Fisheries Research Biology, 9–16.

Urlich B., 1991. *Effects of acid precipitation on forest ecosystems in Europe*, [in:] *Acid precipitation. Biological and ecological effects*, eds D. C. Adriano, A. H. Johnson, Springer Verlag, New York, Heidelberg, 189–211.

Webster J. R., Golladay S. W., Benfield E. F., D'Angelo D. J., Peters G. T., 1990. *Catchment disturbance and stream response: an overview of stream research at Coaweeta Hydrologic Laboratory*, [in:] *River Conservation and management*, eds P. J. Boon, P. J. Calow, G. E. Petts, Wiley, New York, 199–221.

STRESZCZENIE

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PROGI GRUBEGO RUMOSZU ORGANICZNEGO W POTOKACH GÓRSKICH EUROPY ŚRODKOWEJ, STRUKTURA I DYSTRYBUCJA

Badania przeprowadzono w pięciu zlewniach zlokalizowanych w różnych obszarach górskich Europy Środkowej (Fig. 1): 1. Oder (Harz); 2. Seebach (Las Bawarski); 3. Finzbach (Alpy Bawarskie); 4. Kamienica (Gorce); 5. Potok Waksmundzki (Tatry Wysokie). Badane potoki mają charakter seminaturalny. Wynika on z ochrony dolin (Potok Waksmundzki, Seebach, Kamienica, Oder) lub ekstensywnego użytkowania terenu (Finzbach). Celem badań było określenie ilości, struktury oraz dystrybucji w profilu podłużnym form korytowych związanych z grubym rumoszem organicznym (kłodami). Za kłodę (gruby rumosz organiczny) uznawano dowolny fragment drzewa o długości nie mniejszej niż 1 m i średnicy nie mniejszej niż 0,1 m. Średnicę mierzono w połowie długości. Ilość kłód w potokach jest zróżnicowana (na 1 km biegu rzeki przypada odpowiednio od 247,6 — Potok Waksmundzki do 27 — Oder). Najliczniej kłody występują w badanych potokach karpackich (Tabela 2). Ilość kłód w danym odcinku zależna jest od wielkości dostawy, transportu w niższe położenia, biologicznego i mechanicznego rozpadu drewna oraz usuwania kłód przez człowieka. W badanych potokach drzewa dostają się do koryta głównie w wyniku erodowania brzegów, łamiących się drzew z zamierającego lasu (17% kłód w badanej części zlewni Seebacha pochodzi z tego źródła). Kłody obecne w potoku modelują koryto najsilniej poprzez tworzenie progów. Analizę struktury i ilości progów dokonano w oparciu o zmodyfikowaną klasyfikację Gregorego et al. (1993): progi aktywne (całkowite, wysokie i niskie oraz częściowe) — funkcjonujące permanentnie w korycie małej wody; progi aktywne epizodycznie — zlokalizowane poza korytem małej wody, funkcjonujące jedynie podczas wezbrań; progi niskie — kłoda przegradza całkowicie koryto, nie tworzy jednak wyraźnego progu, tkwiąc w dnie lub wysokość progu jest nieznaczna (poniżej 0,2 m); ostrogi (progi częściowe) — kłoda przegradza częściowo koryto, zmieniając kierunek nurtu, nie ma znacznego wpływu na profil podłużny; formy funkcjonujące epizodycznie (suche) — generowane przez kłody poza korytem (na łachach, w korytach przelewowych, w suchych korytach bocznych). Wspólną cechą tych form jest powstanie i aktywność jedynie podczas wezbrań. Progi powstają na pojedynczych kłodach przegradzających koryto lub na ich nagromadzeniach. W zlewniach charakteryzujących się dużą dynamiką fluwialną (duży spadek, liczne wezbrania) i transportem rumoszu (Kamienica, Potok Waksmundzki, Finzbach) progi formują się stosunkowo szybko. W zlewniach, gdzie transport rumoszu jest mały (Seebach, Oder), kłody mimo podobnego usytuowania w korycie powodują powstawanie małej ilości progów. Najliczniej progi występują w Potoku Waksmundzkim i Kamienicy (Fig. 4), mimo że charakter koryt tych dwu potoków jest odmienny. Wspólną ich cechą jest duży ładunek kłód wynikający m.in. z częstej dostawy i kilkudziesięcioletniego okresu ścisłej ochrony dolin. Kłody nie są usuwane przez człowieka. Liczba progów wykształconych częściowo lub całkowicie silnie związana jest z liczbą kłód w korycie (Fig. 6).