ECRR

CIRF

European Centre for River Restoration

Centro Italiano per la Riqualificazione Fluviale

PROCEEDINGS

IV^th ECRR International Conference on
RIVER RESTORATION 2008

Venice, San Servolo Island - 16/19 June 2008

IV^th ECRR International Conference on RIVER RESTORATION

VENICE EDITOR

PROCEEDINGS

EDITED BY: B. GUMIERO, M. RINALDI, B. FOKKENS

4th ECRR Conference on River Restoration
Italy, Venice S. Servolo Island
16-21 June 2008

REFLECTION OF HYDROMORPHOLOGICAL CONDITIONS IN A MOUNTAIN RIVER SUBJECTED TO VARIABLE HUMAN IMPACT IN THE ABUNDANCE AND DIVERSITY OF FISH FAUNA

Wyżga B.[1], Zawiejska J.[2], Amirowicz A.[1], Radecki-Pawlik A.[3]*

[1] Institute of Nature Conservation, Polish Academy of Sciences, Poland
[2] Institute of Geography, Pedagogical University of Kraków, Poland
[3] Agricultural University of Kraków, Poland
* Corresponding author, e-mail: j_zawiejska@o2.pl

ABSTRACT

The Czarny Dunajec River, Polish Carpathians, has been considerably modified by channelization or channel incision and varies in morphology from single-thread, incised or regulated channel to unmanaged, multi-thread channel. Hydromorphological river quality was assessed for 12 cross-sections with 1-4 flow threads and compared with the abundance and diversity of fish fauna determined by electrofishing. The variation in depth, velocity and bed material size in each cross-section was also determined. Values of hydromorphological quality for the surveyed cross-sections ranged between 1.08 and 3.96, with the cross-sections with heavily island-braided morphology representing high status conditions and those located in channelized river sections falling into Class 4. The increasing number of low-flow channels in a cross-section was associated with increasing variation in depth, velocity and bed material size. Single-thread cross-sections hosted only 2 fish species and 13 specimens on average, whereas 3-4 species and 82 specimens on average were stated in the cross-sections with four low-flow channels. The reduced abundance and diversity of fish fauna typified single-thread river sections located both upstream and downstream of the multi-thread channel reach. The number of both fish species and specimens increased linearly with increasing variation in depth within a cross-section and exponentially with improving hydromorphological quality. This study shows that the simplification of flow pattern and the resultant aggravation of hydromorphological river quality, caused by human disturbances, is reflected in remarkable impoverishment of fish communities. This indicates a need for increasing morphological complexity and improving hydromorphological quality of the river to recover the abundance and diversity of its fish fauna.

Key words: mountain river, hydromorphological quality, human impact, fish fauna

1. INTRODUCTION

In the 20th century many mountain rivers in Europe were largely modified due to human activity, with the resultant loss of vertical stability of their channels and a dramatic decrease in the biodiversity of riverine and riparian ecosystems (Habersack & Piégay, 2008). Similar detrimental changes occurred also along most rivers in the Polish Carpathians (Bojarski et al., 2005). Channelization works resulted in considerable shortening of the rivers and transformation of their former multi-thread channels into straight, artificial channels with highly increased transport capacities (Wyżga, 2008). Moreover, some Carpathian rivers underwent intense gravel mining from their channels (Rinaldi et al., 2005). The increase in transport capacity of Carpathian rivers together with bed material deficit resulting from gravel mining have led to rapid incision of their channels, which amounted to 0.5-3.8 m over the 20th century (Wyżga, 2008). To prevent bed degradation of the rivers, concrete weirs were constructed in their channels; however, this has disrupted continuity of the rivers for fish (Bojarski et al., 2005).

With the increasing understanding of adverse effects of human intervention in river channels, restoration measures are increasingly being undertaken in mountain rivers in Europe (Habersack & Piégay, 2008), aiming to improve their geomorphological and ecological conditions. In the attempts to restore good ecological status of watercourses, it is essential to determine the relations which exist between the structure of river biocoenoses and the quality of hydromorphological characteristics of the habitats. This will allow to establish whether the good quality of river ecosystems can be re-attained through the improvement of physical characteristics as well as the flow and sediment regime of the watercourse (i.e. of its hydromorphological quality), or the ecosystem degradation has been caused by a decrease in water quality which would then focus restoration measures on improvement of the latter. Determining the biodiversity gradients of riverine communities and the scale of habitat modification in relation to reference (natural) conditions will indicate the range of necessary restoration measures to be undertaken.

This study presents the results of a study on the relations between the abundance and diversity of fish fauna and hydromorphological river quality in a number of cross-sections of the Czarny Dunajec in the Polish Carpathians.

2. FIELD SETTING

The Czarny Dunajec is an example of a mountain river, which has been subjected to considerable though spatially varied modification by human activity. The study area encompasses a 17 km long reach along which the catchment area increases relatively little and the river receives no major tributaries. In the upper part of the reach, up to 3.5 m of channel incision has

occurred to date in response to the sediment deficit caused by in-stream gravel mining conducted during a few past decades. In the second half of the 20th century, a 7 km long, middle part of the reach was channelized with the use of concrete weirs. This has resulted in replacement of the former multi-thread channel by a single, nearly straight one, whereas the weirs have disrupted the river continuity for fish. In the lower part of the reach, the river has remained unmanaged, showing island-braided to heavily island-braided channel pattern. At the downstream end of the study reach there again occurs a narrow, regulated channel; however, its slope has not been reduced by drop structures. It is evident from the above description that the present Czarny Dunajec in its middle course highly varies in terms of river morphology and channel management (Krzemień, 2003; Zawiejska & Krzemień, 2004; Wyżga & Zawiejska 2005). There occur channelized and unmanaged river sections, sections with single- and multi-thread channel morphology as well as those with alluvial and bedrock boundary conditions. This variability of channel types conditions high variability in physical parameters of habitats along the reach which, in turn, is likely to be reflected in the differences between local river biocoenoses.

3. STUDY METHODS

Twelve cross-sections representing a range of hydromorphological conditions present in the study reach of the Czarny Dunajec were examined. For each cross-section, detailed levelling was performed and water depth, mean flow velocity and mean grain size of surface bed material were determined at 1 m intervals within the low-flow channel(s). Mean size of gravelly sediment was established in the field by means of transect sampling, while that of sandy and silty sediment in a laboratory. For each cross-section, means and coefficients of variation of the three parameters were next calculated.

Hydromorphological quality of the river in the investigated cross-sections was assessed through scoring of channel, river banks, riparian zone and floodplain features according to their specification in the European Standard EN 14614 (CEN, 2003). The assessment was performed by four specialists in fluvial geomorphology, river engineering and hydrobiology following field site inspection as well as the analysis of river channel changes over the past decades and the presentation of channel cross-sections and river appearance at particular sites on orthophotos and ground photos. Each assessed category was scored on the scale from 1 (near-natural conditions) to 5 (extremely modified conditions). The aggregated score, averaged for the four specialists, allowed to associate each of the cross-sections with a particular class of hydromorphological quality.

Species composition of fish communities was estimated on the basis of results of single electrofishings carried out on 4 September 2006 in 10-m

wide stripes along the twelve channel cross-sections. Number and approximate total lengths of the individuals caught in particular low-flow channels were recorded. Juveniles (YOY) and subadult and adult fishes (1+ and older) were recorded separately. These age categories were distinguished taking the total length of 10 cm (brown trout) or 5 cm (other species) as the size limit.

4. RESULTS

The analysis of hydromorphological conditions in river cross-sections with different number of low-flow channels showed that complexity of flow network affects the formation of fish habitats. Multi-thread cross-sections were typified by significantly greater aggregated width of low-flow channels than single-thread cross-sections (Fig. 1). However, the most striking difference between these types of cross-sections was their distinct variation of abiotic characteristics of fish habitats (Fig. 1). Single-thread cross-sections showed significantly lower variation in flow depth (Mann-Whitney test, $p=0.01$), velocity ($p=0.02$) and mean size of bed material ($p=0.02$) than the cross-sections with four low-flow channels. In the former, only gravelly bed occurred whereas in the latter, the dominating gravelly parts of the bed were accompanied by those covered with sand or mud (Fig. 1).

Performed evaluation of hydromorphological quality of the river indicated its considerable variation among the surveyed cross-sections, with the values ranging between 1.08 and 3.96 (Fig. 2). For all cross-sections with four low-flow channels, the river has been classified as representing high status (reference) conditions, with two cross-sections showing heavily island-braided morphology (I and J) considered to be only slightly modified by human activity. In turn, single-thread cross-sections with regulated channel (D–F and L) fell into Class 4. This reflected radical modification of channel geometry in the cross-sections, the lack of erosional and depositional forms, disturbance of fish migrations by weirs, loss of hydraulic connectivity of the river with its floodplain and lateral channel stabilisation. Finally, unmanaged cross-sections A–C (two single-thread ones and one with three low-flow channels) with deeply incised channel were considered to represent good hydromorphological conditions (Class 2).

In total, 1463 fishes (1010 juveniles and 453 older) were recorded in the investigated cross-sections. They belong to four species, i.e. brown trout, *Salmo trutta* L. (16 and 40, respectively), Alpine bullhead, *Cottus poecilopus* Heckel (38 and 92), Eurasian minnow, *Phoxinus phoxinus* (L.) (953 and 316) and stone loach, *Barbatula barbatula* (L.) (3 and 5). Brown trout and Alpine bullhead occurred in all cross-sections, while Eurasian minnow were found in five, and stone loach in only two cross-sections (Fig. 2). The number of both species and older individuals was greater in multi-thread channels (Fig. 2). Single-thread cross-sections hosted 2 species and 4-22

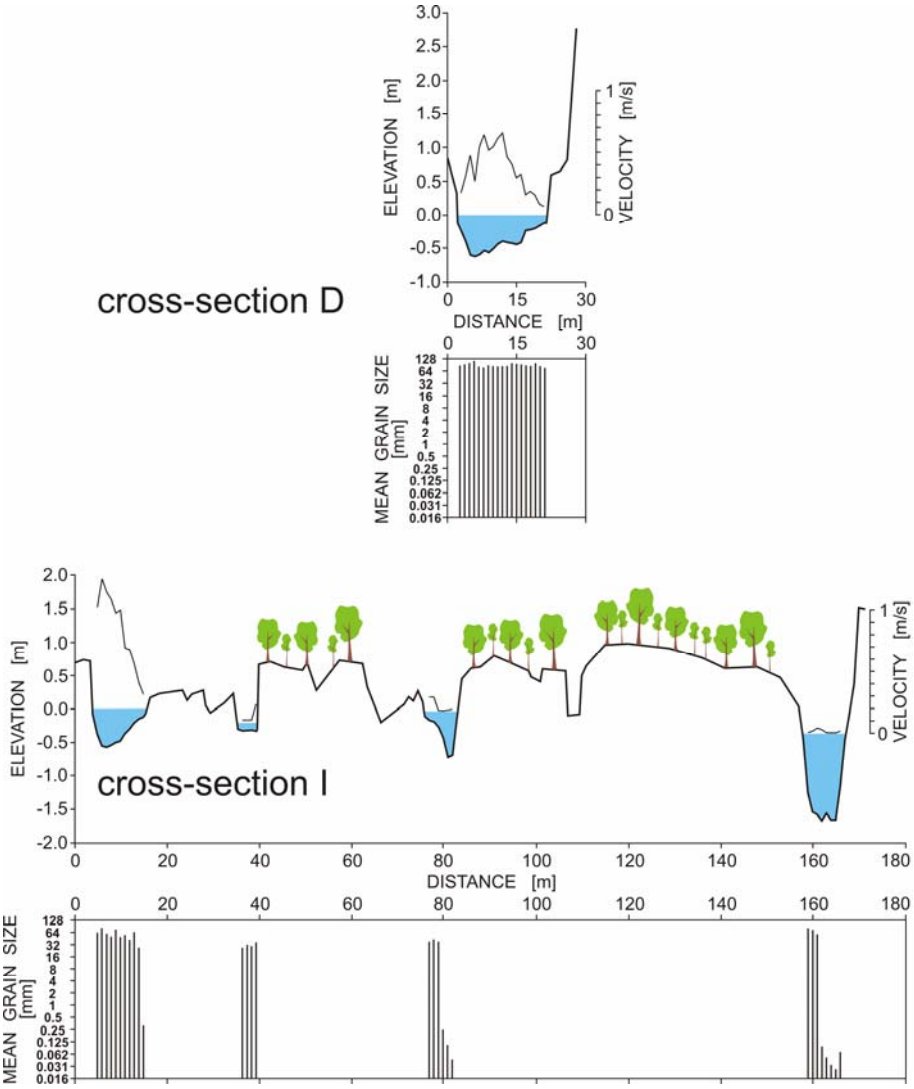

Figure 1 – Examples of cross-sectional morphology of the Czarny Dunajec River in channelized reach (upper) and unmanaged reach (lower). For low-flow channels, mean size of the sediment on bed surface and mean flow velocity are indicated at 1m intervals. A scale for the velocity is movable, with its beginning located on the water surface at each low-flow channel.

specimens (13 on average), whereas 3–4 species and 36–119 specimens (mean: 82) were recorded in the cross-sections with four low-flow channels, and these differences were statistically significant (Mann-Whitney test, $p=0.01$ for both species and specimens). The occurrence of two-species

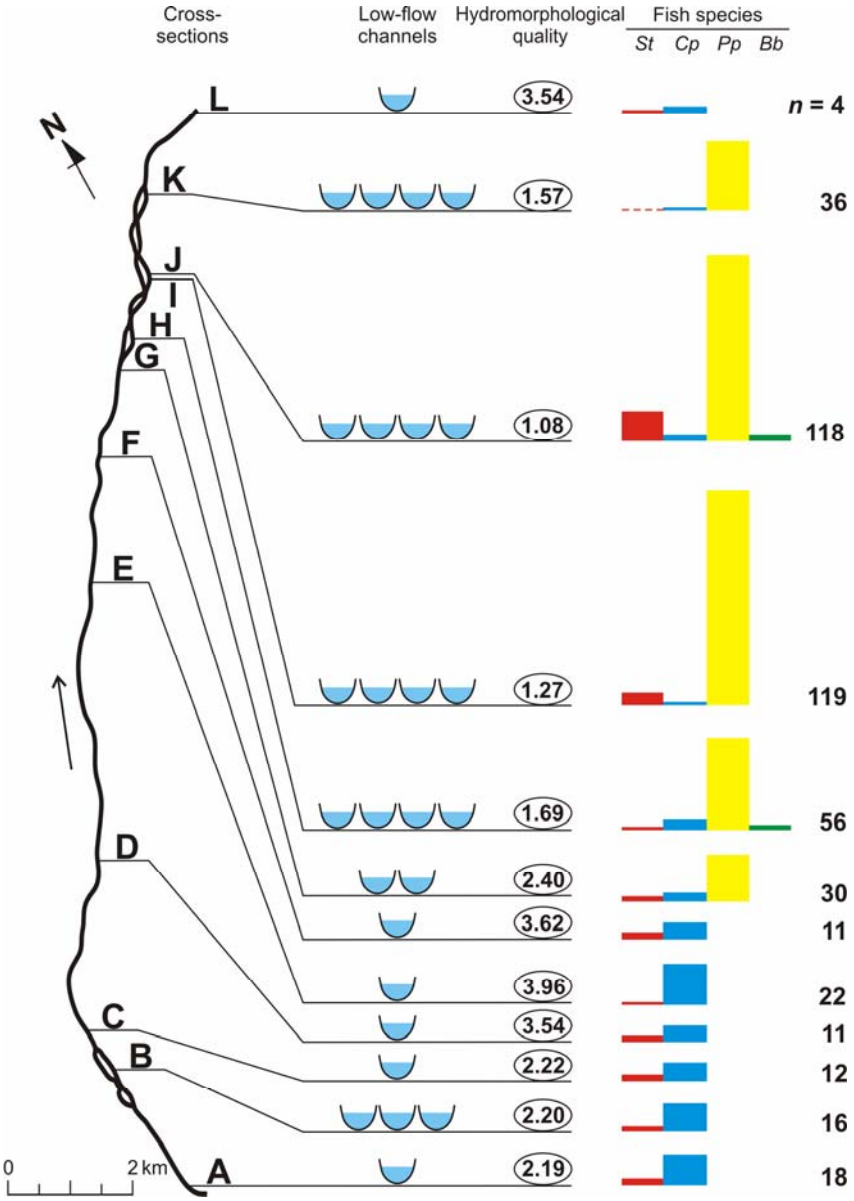

Figure 2 – Comparison of the number of low-flow channels, the assessment of hydromorphological quality and the results of electrofishing carried out in 12 cross-sections of the Czarny Dunajec: *St – Salmo trutta* L., *Cp – Cottus poecilopus* Heckel, *Pp – Phoxinus phoxinus* (L.), *Bb – Barbatula barbatula* (L.), n – total number of subadult and adult (≥ 1 year old) individuals caught; dashed line indicates the occurrence of juveniles (YOY) only.

fish assemblages with low numbers of individuals was characteristic of single-thread cross-sections situated both upstream and downstream of the unmanaged, multi-thread river reach (Fig. 2).

Regression analysis of the relations between abiotic characteristics of the studied habitats and the diversity and abundance of fish assemblages indicated the number of both species and specimens to increase linearly with increasing variation of water depth in a cross-section (species: R=0.75, p=0.005; specimens: R=0.71, p=0.009) and exponentially with improving hydromorphological river quality (species: R=–0.76, p=0.000001; specimens: R=–0.94, p=0.000001) (Fig. 3). Especially large increase in the number of specimens occurred with relatively small improvement in the hydromorphological quality of the river that was associated with the change from its island-braided to heavily island-braided morphology. The number of fish specimens increased also with increasing variation of the size of bed material in a cross-section (R=0.58, p=0.047).

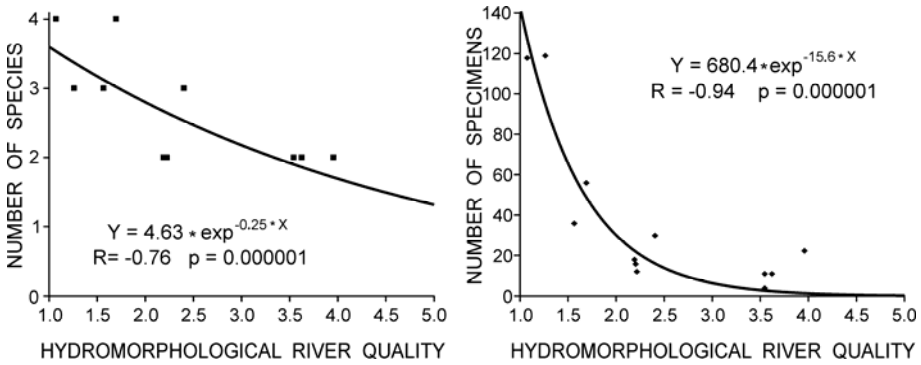

Figure 3 – Scatter plots and estimated regression relationships between the number of fish species (left diagram) and subadult and adult fish specimens (right diagram) caught in the investigated cross-sections of the Czarny Dunajec, and the hydromorphological river quality in the cross-sections.

5. DISCUSSION

With the exception of grayling, *Thymallus thymallus* (L.), which still three decades ago was recorded over most of the length of our study reach (Starmach, 1984), this study documented the occurrence of fish species reported from the Czarny Dunajec in the second half of the 19th century (Nowicki 1883) and confirmed in the years 1975-1980 (Starmach, 1984). However, the extent of stone loach and Eurasian minnow in the study reach has been considerably limited in comparison to the situation from the 1970s. In a few past decades, deep channel incision in the upper part of the study reach (cross-sections A-C) and channel regulation in its middle part (cross-sections D-F) resulted there in an almost complete elimination of multi-

thread flow pattern and shallow areas in the channel, that led to the unification of in-stream habitat conditions as well as a considerable increase in flow velocity and mean size of bed material. These changes, together with the disturbance of fish migrations by weirs constructed in the channelized river section, must have contributed to the decline of grayling as well as the reduction of the extent of stone loach (cf. Santoul et al., 2005) and Eurasian minnow in the study reach.

Most of the investigated cross-sections are presently typified by the occurrence of two-species fish assemblage (brown trout and Alpine bullhead) characteristic of mountain streams with fast water flow. In the multi-thread cross-sections, it is completed with Eurasian minnow which represents an additional environmental guild (Welcomme et al., 2006) connected with pools. The abundant occurrence of this species in multi-thread channel enhanced the disparity in fish specimens between the single- and multi-thread cross-sections.

The relations between the abundance and diversity of fish assemblages and physical characteristics of river channel, recognised in the Czarny Dunajec, probably reflect the links that exist between channel form, habitat conditions and riverine communities (Smiley & Dibble, 2005). The research performed in the river highlighted the dependence of the number of species and specimens on the variability in water depth, while their relation with an aggregated width of low-flow channels was not confimed. Therefore, the increase in fish abundance and diversity is not an effect of simple enlargement of habitat area but reflects increasing habitat diversity, especially of those habitats which are crucial for juveniles, mainly as nursery areas and refuges (Langler & Smith, 2001; Dolinsek et al., 2007). Multi-thread channel sections exhibit greater variability in many habitat parameters, such as the co-existence of patches of coarse and fine bed substrate, slow and fast water current, zones of the inflow of hyporheic water and the infiltration of riverine water into the channel bed, or zones of different water shading by tree canopy, which together are reflected in better assessment of hydromorphological river quality. As the relation between channel morphology and habitat conditions in a river is relatively strong (Smiley & Dibble, 2005), it explains the increase in the number of fish species and even more in that of specimens with increasing hydromorphological quality in the Czarny Dunajec.

6. CONCLUSIONS

The study showed that high variability of hydromorphological quality of the Czarny Dunajec, caused by spatially varied human impact, is clearly reflected in the diversity and abundance of fish fauna. More diverse and relatively abundant fish communities were recorded only in a short river reach where natural river dynamics and a multi-thread channel pattern were

preserved due to the lack of significant human intervention. This reach is typified by high variability of habitat conditions, reflected in the highly valued hydromorphological river quality in the examined multi-thread channel sections. Preservation of the undisturbed channel dynamics and the high morphological complexity of the river in the reach will be essential to preserve species diversity of fish communities in the Czarny Dunajec and to restore in the future this diversity in the modified river reaches. The dependence of the abundance and diversity of fish communities on hydromorphological river quality and the degree of variability in channel morphology, demonstrated in this study, indicates that future improvement of the ecological status of this and other mountain rivers will require a renewed increase in morphological complexity of their channels (cf. Muhar et al., 2008) and improvement of hydromorphological conditions in the rivers.

ACKNOWLEDGEMENTS

This research was financed by Research Grant 2 P04G 092 29 of the Polish Ministry of Science and Higher Education.

REFERENCES

CEN (2003) – Water quality – Guidance standard for assessing the hydromorphological features of rivers. EN-14614.

Bojarski A., Jeleński J., Jelonek M., Litewka T., Wyżga B., Zalewski J. (2005) – Zasady dobrej praktyki w utrzymaniu rzek i potoków górskich. Ministerstwo Środowiska, Warszawa.

Dolinsek I.J., Grant W.A., Biron P.M. (2007) – The effect of habitat heterogeneity on the population density of juvenile Atlantic salmon *Salmo salar* L. Journal of Fish Biology, 70, 206–214.

Habersack H. and Piégay H. (2008) – River restoration in the Alps and their surroundings: past experience and future challenges. In: Habersack H., Piégay H. and Rinaldi M. (Eds), Gravel-bed Rivers VI – From Process Understanding to River Restoration, Developments in Earth Surface Processes, Elsevier, 703–738.

Krzemień K. (2003) – The Czarny Dunajec River, Poland, as an example of human-induced development tendencies in a mountain river channel. Landform Analysis, 4, 57–64.

Langler G.J. and Smith C. (2001) – Effects of habitat enhancement on 0-group fishes in a lowland river. Regulated Rivers: Research and Management, 17, 677–686.

Muhar S., Jungwirth M., Unfer G., Wiesner C., Poppe M., Schmutz S., Hohensinner S., Habersack H. (2008) – Restoring riverine landscapes at the Drau River: successes and deficits in the context of ecological integrity. In: Habersack H., Piégay H. and Rinaldi M. (Eds), Gravel-bed Rivers VI – From Process Understanding to River Restoration, Developments in Earth Surface Processes, Elsevier, 779–807.

Nowicki M. (1883) – Przegląd rozsiedlenia ryb w wodach Galicyi według dorzeczy i krain rybnych. E. Hölzl, Wiedeń.

Rinaldi M., Wyżga B., Surian N. (2005) – Sediment mining in alluvial channels: physical effects and management perspectives. River Research and Applications, 21, 805–828.

Santoul F., Mengin N., Céréghino R., Figuerola J., Mastrorillo S. (2005) – Environmental factors influencing the regional distribution and local density of a small benthic fish: the stoneloach (*Barbatula barbatula*). Hydrobiologia, 544, 347–355.

Smiley P.C. and Dibble E.D. (2005) – Implications of a hierarchical relationship among channel form, instream habitat, and stream communities for restoration of channelized streams. Hydrobiologia, 548, 279–292.

Starmach J. (1984) – Fish zones of the River Dunajec upper catchment basin. Acta Hydrobiologica, 25/26, 415–427.

Welcomme R.L., Winemiller K.O., Cowx I.G. (2006) – Fish environmental guilds as a tool for assessment of ecological condition of rivers. River Research and Applications, 22, 377–396.

Wyżga B. (2008) – A review on channel incision in the Polish Carpathian rivers during the 20th century. In: Habersack H., Piégay H. and Rinaldi M. (Eds), Gravel-bed Rivers VI – From Process Understanding to River Restoration, Developments in Earth Surface Processes, Elsevier, 525–555.

Wyżga B. and Zawiejska J. (2005) – Wood storage in a wide mountain river: case study of the Czarny Dunajec, Polish Carpathians. Earth Surface Processes and Landforms, 30, 1475–1494.

Zawiejska J. and Krzemień K. (2004) – Human impact on the dynamics of the upper Dunajec River channel: a case study. Geograficky Časopis, 56, 111–124.