Changes to the functioning of a mountain stream following installation of boulder riffles and check-dam lowering: Krzczonówka Stream, Polish Carpathians

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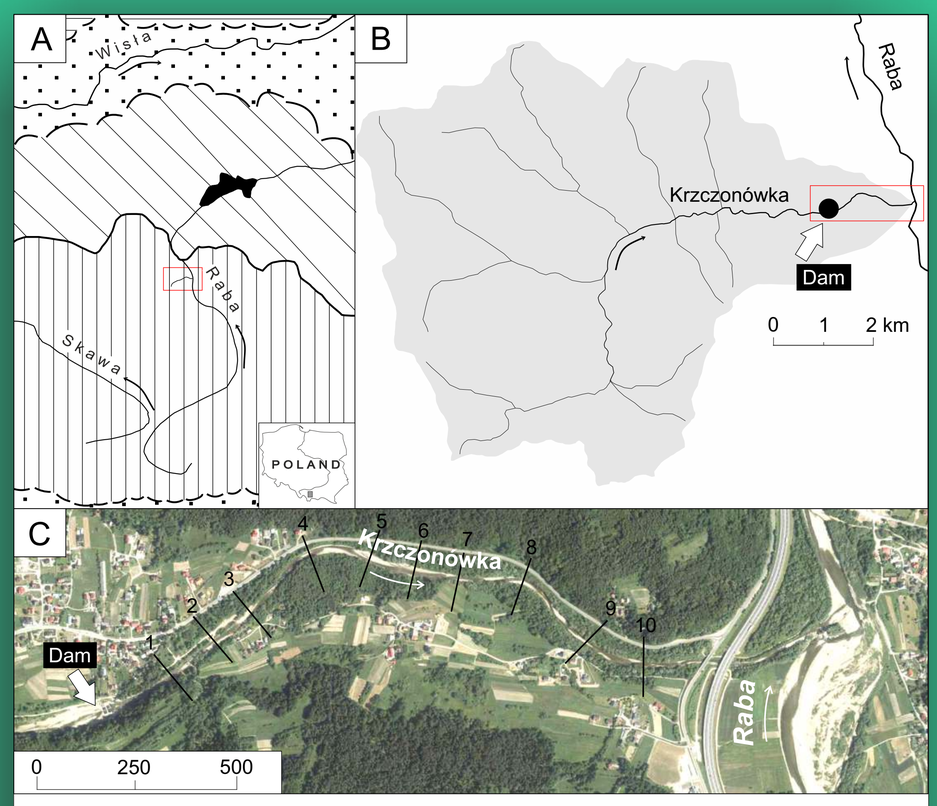
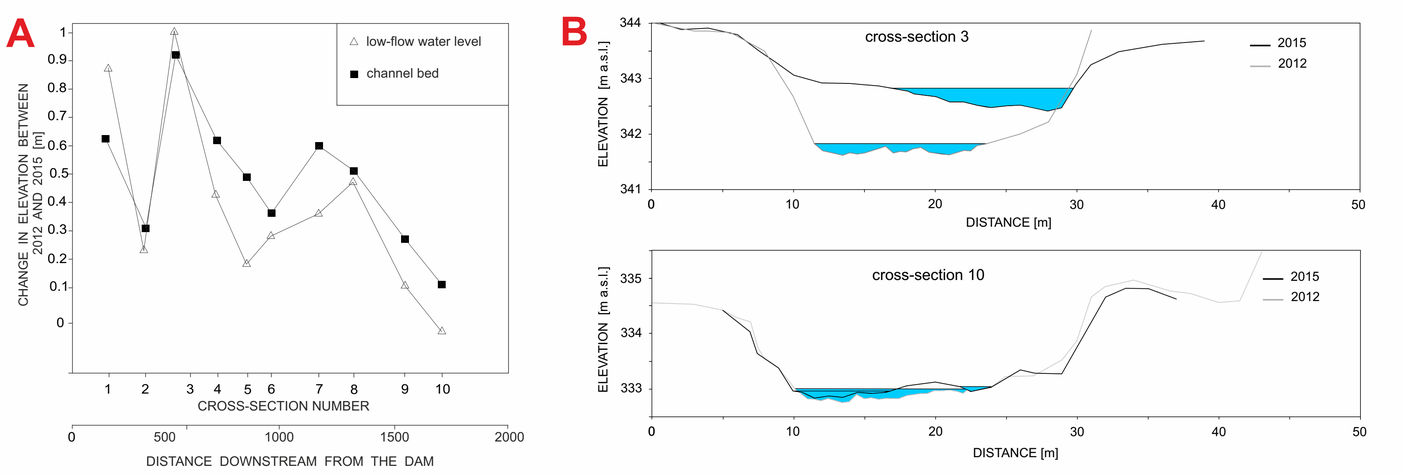
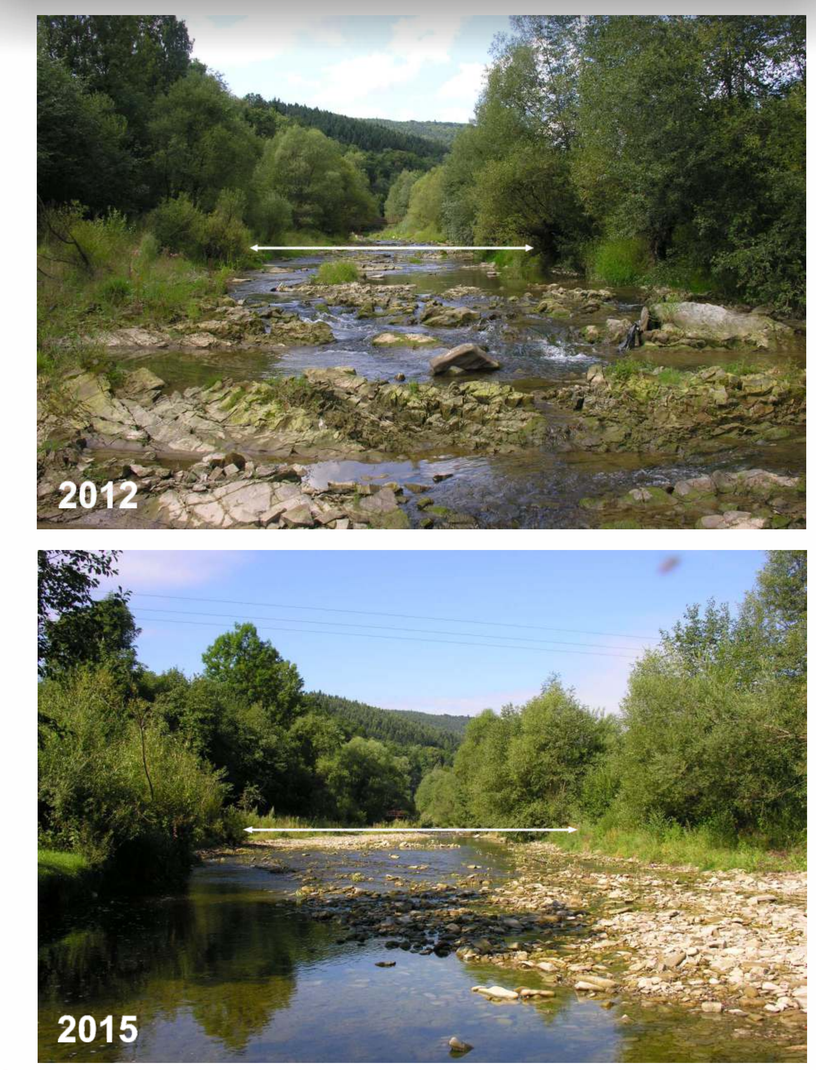
An increasing number of dams and check-dams are removed from rivers all over the world to re-establish their longitudinal continuity for biota migration and sediment transport. Because of long-lasting sediment starvation, channel reaches downstream of the dams are typically deeply incised and thus the sediment flushed out from the demolished dams may not be trapped in these reaches but is transported far downstream. To enable entrapment of sediment in such a deeply incised channel, artificial boulder riffles were constructed before check-dam lowering in Krzczonówka Stream, Polish Carpathians **(1)**. Changes in channel morphology **(2-4)**, hydromorphological conditions **(3-4, 8)**, and fish **(5)** and macroinvertebrate communities **(6-7)** in the stream were investigated over the period 2012-2016 encompassing the conditions existing prior to restoration activities (2012), after the installation of boulder riffles but with still unchanged check-dam (2013), during (2014), and after the check-dam lowering (2015, 2016). A change in the ecological state of the stream **(7)** over the period was also analysed.



1 (A) Location of Krzczonówka Stream in relation to physiogeographic regions of southern Poland. 1 – high mountains; 2 – mountains of intermediate and low height; 3 – foothills; 4 – intramontane and submontane depressions; (B) Krzczonówka Stream catchment, (C) orthophoto from 2009 showing the studied reach and the location of surveyed cross-sections.

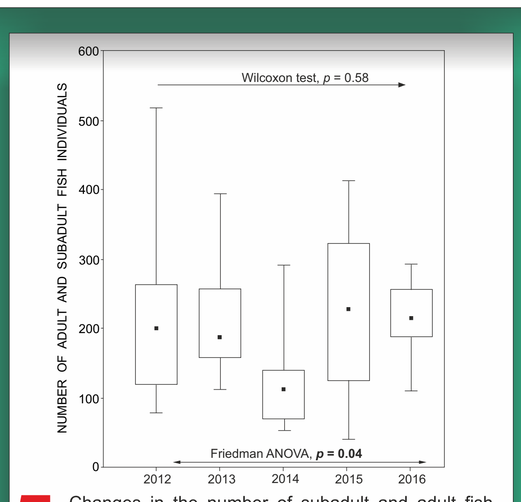


2 (A) Change in the elevation of low-flow water surface and mean elevation of channel bed in the investigated cross-sections between 2012 and 2015. (B) Examples of cross-sections in the proximal (upper) and distal (lower) parts of the sediment wave in the stream reach downstream of the lowered check dam.

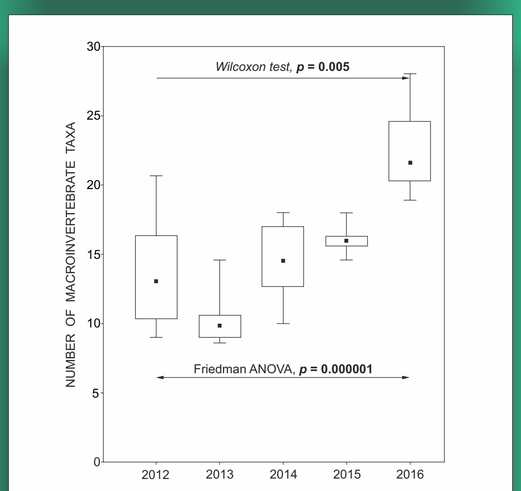


3 View of Krzczonówka Stream in the vicinity of cross-section 3 before (2012) and after (2015) the installation of boulder riffles. Visible change from bedrock to alluvial boundary conditions as a result of gravel deposition in the channel.

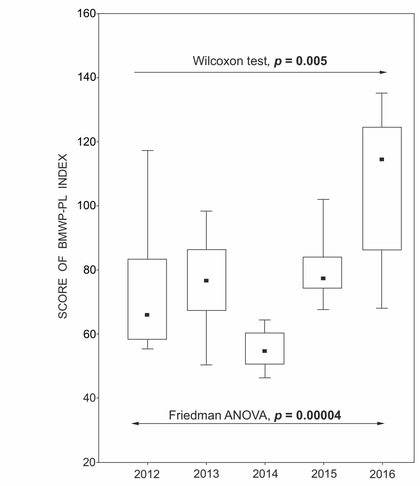
4 View of Krzczonówka Stream with an installed boulder riffle (2013) and after the passage of the flood of May 2014. Visible entrapment of considerable amount of gravel and burying of the boulder riffle.



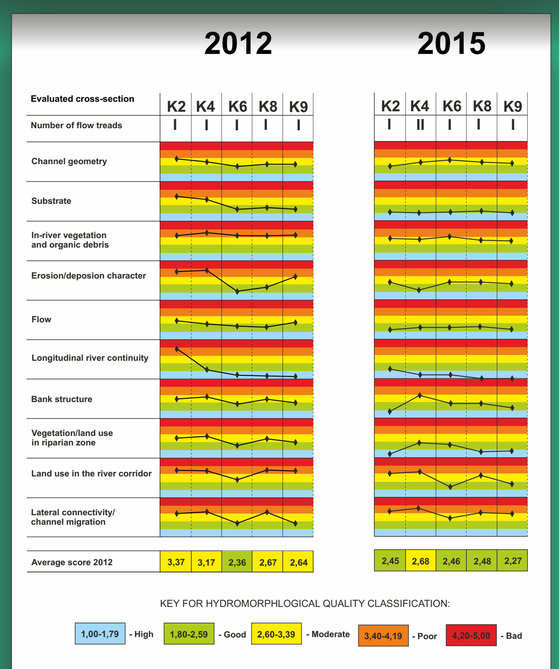
5 Changes in the number of subadult and adult fish individuals caught in the surveyed cross-sections of Krzczonówka Stream in the years 2012-2016. Statistical significance of the differences between all study years is indicated by Friedman ANOVA and those between 2012 and 2016 by Wilcoxon test.



6 Changes in the number of macroinvertebrate taxa in the surveyed cross-sections of Krzczonówka Stream in the years 2012-2016. Statistical significance of the differences between all study years is indicated by Friedman ANOVA and those between 2012 and 2016 by Wilcoxon test.



7 Changes in the scores of macroinvertebrate-based BMWP-PL index calculated for the surveyed cross-sections of Krzczonówka Stream in the years 2012-2016. Statistical significance of the differences between all study years is indicated by Friedman ANOVA and those between 2012 and 2016 by Wilcoxon test.



8 Hydromorphological quality of Krzczonówka Stream before (2012) and after (2015) the installation of boulder riffles and lowering of the upstream check-dam.

RESULTS

The material delivered to the lowest reach of Krzczonówka Stream by the flood of May 2014 was efficiently trapped by the installed boulder riffles which became buried on the distance of ca. 1.2 km from the check dam, whereas the sediment wave reached 1.6 km from the dam. About 14000 m^3 of bed material were retained in the stream, with an average increase in bed elevation amounting to 0.37 m. A maximum increase in the average elevation of bed surface equaled 0.72 m at a distance of 470 m from the dam, whereas a maximum increase of low-flow water surface reached 1 m.

The assessment of hydromorphological quality of the stream performed in 2012 and 2015 indicated its improvement in 4/5 of the evaluated cross-sections, reflected in a shift to a higher quality class for 3/5 of the evaluated cross-sections. The average number of fish individuals, especially juveniles, in a stream cross-section decreased in the years with the installation of boulder riffles, lowering the check dam, and the large flood (2013-2014) but returned to the initial values in 2015. The average number of macroinvertebrate taxa in a cross-section decreased in the year with the works to lower the check dam and the large flood, but since 2015 it has increased to a greater number than before the restoration works.

CONCLUSIONS

This study demonstrated effectiveness of boulder riffles in the entrapment of bed material in the incised channel. It also showed that the restoration works only initiated the change in physical structure of the mountain stream that may lead in future to the significant improvement of its biocoenosis and hydromorphological quality.