Island development in a passively restored mountain river: the Raba, Polish Carpathians

Restauration passive des îles fluviales dans une rivière de montagne: Le Raba, dans les Carpates polonaises

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RÉSUMÉ

L'abandon des structures de canalisation dans un tronçon de 2,3 km de la rivière Raba, dans les Carpates polonaises, a entraîné un élargissement considérable du canal et le développement d'îles dans le canal élargi. Les résultats des études morphologiques et botaniques des îles sur une période de 7 ans et la modélisation hydraulique unidimensionnelle des flux de crue dans le tronçon élargi et les tronçons canalisés adjacents sont utilisés pour décrire les premières étapes du développement des îles dans une rivière de montagne restaurée passivement. L'âge moyen, le nombre d'îles et leur superficie moyenne et totale dans le tronçon ont augmenté de manière significative au cours de la période d'étude, mais l'augmentation a été modérée par l'érosion des îles par les flux de crue, l'établissement des îles peu de temps après les grandes inondations et la coalescence des îles dans les années sans ces inondations. Les valeurs plus faibles de la profondeur moyenne de l'eau, de la vitesse d'écoulement et de la puissance unitaire du courant dans le tronçon élargi par rapport aux tronçons adjacents canalisés favorisent le dépôt de bois flotté vivant sur les barres du canal, initiant le développement des îles, et réduisent la probabilité d'érosion des îles existantes. Le nombre total d'espèces végétales sur les îles a fortement varié au cours de la période d'étude, indiquant une contribution diverse des îles à la richesse globale en espèces des communautés végétales dans le corridor fluvial aux premiers stades du rétablissement des îles dans la rivière.

ABSTRACT

Abandonment of channelization structures in a 2.3-km-long reach of the Raba River, Polish Carpathians, resulted in considerable channel widening and the development of islands in the widened channel. Results of 7-year long morphological and botanical surveys of the islands and one-dimensional hydraulic modelling of flood flows in the widened reach and the adjacent channelized reaches are used to describe early stages of island development in a passively restored mountain river. Average age, number of islands and their average and total area in the reach markedly increased over the study period but the increase was moderated by island erosion by flood flows, island establishment shortly after major floods and island coalescence in the years without such floods. Lower values of mean water depth, flow velocity and unit stream power in the widened reach in comparison to the adjacent channelized reaches promote deposition of living driftwood on channel bars, initiating island development, and reduce the probability of erosion of existing islands. Total number of plant species on islands varied highly over the study period, indicating diverse contribution of islands to the overall species richness of plant communities in the river corridor at early stages of island re-establishment in the river.

KEYWORDS

erodible river corridor, hydraulic parameters, plant species, river island, mountain river

1 INTRODUCTION

Investigations of islands in an undisturbed reach of the Czarny Dunajec in the Polish Carpathians indicated that islands are very dynamic landforms and greatly contribute to the overall plant diversity of the River corridor (Mikuś et al., 2013). This was the basis of the hypothesis that re-establishment of islands may be an important factor in the restoration of hydromorphologically degraded mountain rivers. This hypothesis was verified in a study of the Raba River, Polish Carpathians. In the 20th century the Raba was heavily channelized and incised deeply in its mountain course (Wyżga, 2008), but about 10 years ago an erodible river corridor was established in its 2.3-km-long reach (Wyżga et al., 2021). Abandonment of channelization structures and the passage of two large floods in 2010 and 2014 resulted in up to a threefold increase in channel width, re-establishment of a multi-thread channel pattern and island development in this reach.

2 STUDY METHODS

Morphological and botanical surveys were conducted annually between 2011 and 2017 to determine the processes and patterns governing development of islands and their floristic complexity in the reach subjected to passive restoration. Morphometric parameters of islands were measured with Trimble R4 GPS receiver. Standard dendrochronological dating was applied to determine the age of particular islands. An inventory of vascular plant species on the islands was carried out in the middle of each summer. In some years, plant species were also surveyed on 10 plots of riparian forest adjacent to the channel in the reach. Moreover, hydraulic conditions promoting establishment and persistence of islands were determined with one-dimensional hydraulic modelling of flood flows for 8 unmanaged river cross-sections with islands and 8 cross-sections in the adjacent channelized reaches. Data about cross-sectional river morphology, channel slope and roughness of particular parts of river cross-sections were used as input data to the hydraulic modelling.

3 RESULTS

Observations indicated that the formation of pioneer islands in the freely developing river reach is connected to the occurrence of major flood events, but evolution and expansion of already existing islands takes place also during the years with low and medium flood flows. Pioneer islands originate as a result of vegetative regeneration of living driftwood. Before the start of our investigations, numerous large wood accumulations were deposited on gravel bars in the reach during a large flood in 2010, giving rise to many pioneer islands. A generally stable pattern of bars and low-flow channels in the reach during the next 3 years allowed the survival of these initial islands; during that period, the number and the average and total area of islands increased significantly. This development of islands was the effect of germination of seeds of herbaceous plants in the hydraulic shadow of existing islands as well as of re-sprouting of willow and poplar driftwood deposited by smaller floods. In 2013 a rapid growth of grey alder seedlings took place around the oldest building island, leading to a considerable increase in its area. However, these young seedlings were completely destroyed by a large flood in 2014. This flood delivered to the reach much living willow, poplar and alder driftwood, the re-sprouting of which resulted in the development of numerous new islands.

Between and 2017 the number of islands in the studied river reach increased from 28 to 50, average island age from 2.8 to 5.9 years, total island area from 3.9 ha to 44.7 ha and average island area from 139 m^2 to 893 m^2. However, the increases in these parameters were not steady but moderated by processes of island erosion by flood flows, island establishment shortly after major floods (increasing the number and reducing the average age and area of islands) and island coalescence in the years without major floods (with the opposite effects on the island parameters).

Hydraulic modelling of flood flows indicated that significantly larger width of flood flows in the freely developing reach was accompanied by significantly lower values of mean water depth, flow velocity, unit stream power and bed shear stress than in the adjacent narrow, channelized reaches. Figure 1 presents these differences for a 33-year flood, similar in magnitude to the floods of 2010 and 2014. Such hydraulic conditions of flood flows in the erodible river corridor promote deposition of living driftwood on gravel bars, initiating island development, and reduce the probability of erosion of existing islands. A relationship between the proportion of river area covered by islands and river width was determined, indicating that islands start to develop in the Raba where its width exceeds 120% of an average width of regulated channel and that 20% proportion of islands in the river area (corresponding to the development of island-braided channel pattern) is exceeded where the river width is about three times larger than the regulated channel width.

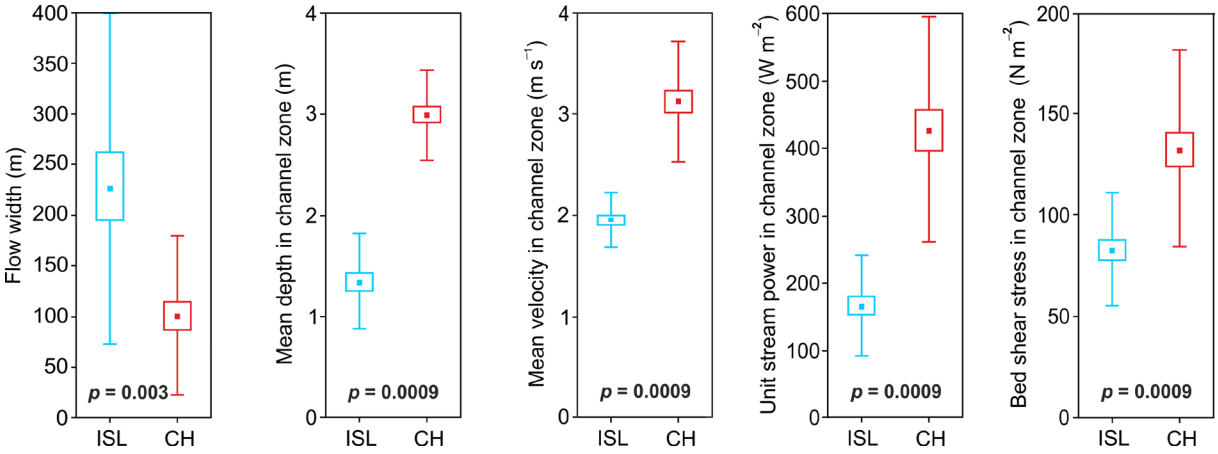

Figure 1. Range and mean value of hydraulic parameters at a 33-year flood in the 8 unmanaged cross-sections of the Raba River with islands (ISL) and the 8 channelized cross-sections without islands (CH). Range plots show mean value (squares), standard error of the mean (boxes), and extreme values (whiskers) of the parameters. Statistical significance of the difference of particular parameters between both cross-section types, determined by a Mann–Whitney test, is indicated.

Plant species inventories indicated a greater total number of vascular plant species on islands than in the riparian forest prior to the major flood of 2014 and similar numbers in both types of habitats in the years following this flood. The change in the relative species richness of islands reflected reduced numbers of herbal – perennial, biennial and annual – species recorded on islands during the surveys following the major flood of 2014. The change most likely reflected a flood-caused increase in flow capacity of the river that limited the inundation of islands and the associated propagule delivery onto their surface by floodwaters.

4 CONCLUSIONS

Observations in the Raba River confirmed the previous findings from the Czarny Dunajec River that in a highly dynamic mountain river, islands originate as a result of deposition and re-sprouting of living driftwood of willows or poplars. Hydraulic conditions of flood flows in the widened reach within the erodible river corridor facilitate deposition of living driftwood on channel bars, initiating island development, and reduce the probability of erosion of existing islands. Our results suggest that in early phases of island re-establishment in a mountain river recovering from channelization and channel incision, the contribution of islands to the overall species richness of the riparian corridor can be highly variable depending on hydraulic and hydrological conditions. This contrasts with the situation in the vertically stable, multi-thread reach of the Czarny Dunajec River where numerous established islands are an efficient source of propagules and the occurrence of a relatively shallow channel facilitates their deposition on islands by floodwaters (cf. Mikuś et al., 2013).

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LIST OF REFERENCES

Mikuś, P., Wyżga, B., Kaczka, R.J., Walusiak, E. and Zawiejska, J. (2013). Islands in a European mountain river: Linkages with large wood deposition, flood flows and plant diversity. *Geomorphology*, 202, 115–127.

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

Wyżga, B., Amirowicz, A., Bednarska, A., Bylak, A., Hajdukiewicz, H., Kędzior, R., Kukuła, K., Liro, M., Mikuś, P., Oglęcki, P., Radecki-Pawlik, A. and Zawiejska, J. (2021). Scientific monitoring of immediate and long-term effects of river restoration projects in the Polish Carpathians. *Ecohydrol. Hydrobiol.*, 21, 244-255.