Przegląd Naukowy – Inżynieria i Kształtowanie Środowiska nr 70, 2015: 400–411
(Prz. Nauk. Inż. Kszt. Środ. 70, 2015)
Scientific Review – Engineering and Environmental Sciences No 51, 2011: 400–411
(Sci. Rev. Eng. Env. Sci. 70, 2015)

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Regulation of mountain streams versus ecological balance as illustrated by the example of the upper Vistula basin (part II)
Regulacja potoków górskich a równowaga ekologiczna na przykładzie dorzecza górnej Wisły (część II)

Key words: Carpathian watercourses, hydraulic stuctures, hydrobionts, renaturization
Słowa kluczowe: cieki karpackie, zabudowa hydrotechniczna, hydrobionty, renaturyzacja

The influence of watercourse regulation on hydrobionts

Abiotic and anthropogenic factors exercise a multidirectional impact on river biotic communities, which results, among other things, from the volume and velocity of the flow (Wood et al., 2007; Poff and Zimmerman, 2010), transport of debris and the shape of the bottom and channel (Wyżga et al., 2011) as well as presence of natural and artificial obstacles (Kajak, 1992).

Hydromorphological changes in the watercourse channel and river valley, which are caused by both natural and anthropogenic factors, lead to changes in ecosystems. Biotic communities living in regulated watercourses usually lose some of their species and their population diminishes (Bylak et al., 2007; Dukowska and Grzybkowska, 2007; Mazurkiewicz-Boroń and Starmach, 2009; Żelazo, 2009; Kukuła and Bylak, 2011). The changes in watercourse hydromorphology mentioned above decrease the biodiversity of habitats. They can be generally described as changes caused by disruption of the river continuity (Vannote et al., 1980; Lampert and Sommer, 2001; Thorp and Covich, 2001). Hydraulic structures also affect riverine plant communities. As a result, natural communities disappear and new ones appear, frequency of their occurrence is reduced and substitute habitats are used (Koczur, 2012).

Moreover, river biotic communities are affected by changes occurring within basins (Sponseller et al., 2001; Townsend et al., 2003). This refers to changes in the use of the territory of the basin (Kopacz and Twardy, 2006; Törnblom et al., 2011), progressing urbanization and development of agricultural economy (resulting, among other things, in big loads of biogenic compounds coming from surface run-off and punctual sources of pollution (Elliot et al., 1997; Morse et al., 2003; Obolewski et al., 2009), forestry, e.g. transport of wood through channels or leaving wood chips in channels of small watercourses (Kukuła and Bylak, 2011) as well as expansion of road networks and vehicular transport (Kłonowska-Olejnik, 2010).

One of the best-known aspects of the influence exercised by watercourse regulation on biotic communities is the building of dams which are accompanied by dammed reservoirs. This disrupts the river continuity. In consequence, river sections above and below the dam differ in the volume of the flow, velocity of the current, amount of the debris transported, water temperature and chemical composition of water and sediments (Baxter, 1977; Majewski, 1992; Greenwood et al., 1999; Bergkamp et al., 2000; Fjellheim and Raddum, 2008; Czerniawski et al., 2010; Carolli et al., 2011). This leads to accumulation of chemical compounds in sediments of dammed reservoirs (Starmach et al., 1976). There are changes in cycles of matter and energy flow. Waters of the reservoirs, especially hypolimnion, which are let into the river section below the dam disturb thermal relations, wash away alluvia and harden the bottom (Ćerégino et al., 2002; Lessard and Hayes, 2003; Grubbs and Taylor, 2004).

Flow fluctuations disturb life cycles of fish and invertebrates, e.g. in the Dunajec river below Czorsztyn Dam (Szczęsny, 1995). Fish and invertebrate communities in the river sections in front of the dam, behind the dam and in the dammed reservoir can be very different. The greatest taxonomic impoverishment is usually observed directly behind the dam (Allan, 1998; Knutelski, 2010). Changes in fish communities above and below the obstacle lead to a change in the pressure put by predators on their potential prey, which are usually representatives of zoobenthos. The pressure exercised by fish of prey increases the intensity of drift and reduces the number of invertebrates (Kołodziejczyk, 1999). Sometimes such changes also have negative impact on the invertebrate population, which is attached by symbiotic ties to fish (Błachuta et al., 2011).

Dams and dammed reservoirs affect significantly invertebrate macrofauna of watercourses. Increased velocity of the current and disruption of the bottom structure (e.g. below dams) result in the intensification of drift as well as decline in the number and diversity of invertebrates (Wróbel and Szczęsny, 1983; Casas et al., 2000; Cortes et al., 2002; Armitage 2006; Käiro et al., 2011). Regulation works produce adverse effects in communities of zooplankton and zoobenthos, which provide the elementary food basis for fish (Bylak et al., 2007; Czerniawski et al., 2010). The biodiversity of species is dimished – the dominating species are Diptera, Oligochaeta and mollusks which form numerous populations (Grzybkowska et al., 2001; Puczyńska and Skrzypski, 2007; Głowacki et al., 2011). In the river section in front of the dam certain taxons disappear, the number of some decreases and the number of others grows, whereas new species appear which have not been observed before (Jones, 2011). Such a phenomenon was described by Kutelski (2010) after the Czorsztyn reservoir in the basin of the upper Vistula was filled.

Changes in abiotic and anthropogenic factors which are caused by small hydraulic riparian structures affect in various ways particular communities of hydrobionts. Biological effects of partitioning watercourses with such structures are best known in case of ichthyofauna, e.g. in the basin of the upper Vistula and Dunajec river. This concerns mainly migrations of anadromous and catadromous fish as well as changes in species and domination structure in communities (Augustyn et al., 2006; Jędryka, 2009; Augustyn, 2010; Murat-Błażejewska and Sojka, 2011). An insurmountable obstacle for most species of fish is a structure a few dozen centimetres high, whereas in case of young specimens and some Cyprinidae a structure even as low as 20–30 cm is too high (Kukuła, 2006; Mokwa, 2007; Czerniawski et al., 2010).

Small crosswise hydraulic structures also have an environmental impact on benthos (Fleituch, 2003; Santucci et al., 2005; Tiemann et al., 2005; Vallania and Corigliano, 2007; Brown et al., 2010; Bellucci et al., 2011). They change most abiotic factors in the environment of flowing waters (Negishi et al., 2002; Adynkiewicz-Piragas and Lejcuś, 2009; Kłonowska-Olejnik, 2009). Structures of this type change the velocity of flow. It is one of the main factors which determine the character of fauna communities within and beyond the channel (Wood et al., 2007). Apart from this, organisms can be washed away from the river bed, especially directly behind the structure (Collier et al., 1996; Mazurkiewicz-Boroń and Starmach, 2009). It seems that the increase in flow velocity is correlated with the size of drift (Imbert and Perry, 2000; Bond and Downes, 2003; Gibbins et al., 2007; James et al., 2008). The velocity of flow and bottom erosion affect the structure of bottom substrate, deposition of organic matter and as a result, microhabitats and food basis of many bottom invertebrates (Small et al., 2008). Thus, the structure of flow is reflected by the structure of microhabitats and communities living in them (Thorp and Covich, 2001; Parasiewicz, 2003). This influences the distribution of rheophilic species and those living in calmer environments as well as those choosing specific types of the river bed (Starmach et al., 1976; Davy-Bowker et al., 2006). The degree of granulation of the bed and the presence of organic matter in mineral substrate affect the density and distribution of benthos on the bottom of the stream (Thorp and Covich, 2001; Wood et al., 2007). Another important factor which influences colonization of the bed by invertebrates is its stability (Jowett, 2003). The presence of small crosswise hydraulic structures causes new channel forms to develop, e.g. evorsion potholes or heaps of wooden debris (Harmon et al., 1986). Insignificant swellings of water on small watercourses and slowing down of the flow can cause local accumulation of sediments containing nutrients and pollutants (Kajak, 1992). Disorders in hydromorphological processes in watercourses also manifest themselves by disorders in biological processes, including fish and zoobenthos migration (Kołodziejczyk, 1999; Kukuła, 2006; Mochizuki et al., 2008; Petterson and Smokorowski, 2011).

Attempts at changing the current situation

The Hydrologic Law act (2001) states that: „During the processes of designing, building and maintenance of regulation structures the governing principle should be that of sustainable development, particularly preservation of good ecological status of waters and their characteristic biotic communities as well as preservation of the existing relief and biological relations in the water environment and floodplains" (Article 63, Act 1). Those issues are also regulated by other legal doccuments, e.g. Environment Protection Act (2004) and EU Water Framework Directive (2000). Water Framework Directive sets three basic goals of water management:

– to achieve and preserve a good hydrological status;
– to meet economic needs while using water in a sustainable way;
– to protect the population from consequences of flooding and drought.

Recommendations of Water Framework Directive, other EU directives and properly adapted Polish legislation introduce the following concepts: criteria of "goodness" in the water quality, water quantity and the hydrologic regime; criteria connected with the choice of measures which allow for simultaneous economic use of water and protection of ecosystems (e.g. modern means of protection against flooding); general planning procedures (Nachlik, 2006). Implementation of the recommendations given by Water Framework Directive first requires evaluation of the existing hydrologic situation in Poland, including the influence and effects exerted by punctual and linear hydraulic structures, e.g. drop hydraulic structures, dams, embankments etc. Evaluation of surface water status according to Water Framework Directive aims at: determining the volume and level of the flow to such an extent which corresponds with the ecological and chemical status of water, determining the ecological potential as well as the ecological and chemical status of water. The scale which is used to evaluate the status of the uniform part of waters has five degrees: very good, good, moderate, poor and bad; the ecological potential is assessed according to a four-degree scale: maximal (good or better), moderate, poor and bad. Ecological potential is evaluated in case of considerably changed water sections, where the ecological status is not assessed (Rataj, 2007; Walczykiewicz et al., 2012).

On the basis of Water Framework Directive, „so-called habitat directive and a convention for protection of biodiversity, the European Committee for Standardization has suggestedan assessment of selected hydromorphological elements of watercourses which have an impact on all biological and physicochemical processes taking place in surface waters (Ilnicki, 2006; Szoszkiewicz et al., 2007; Szoszkiewicz et al., 2009; Ilnicki, 2011). The quality of these elements influences the diversity of biotic communities. One of the hydromorphological parameters which are listed by

Water Framework Directive (WFD) and describe the watercourse channel, waterside areas and floodplains is the influence of hydraulic structures on the continuity of the river or stream. The evaluation process which is a part of the actions undertaken during the implementation of WFD should include an estimation of the impact of of hydraulic structureson migration of water organisms and transport of debris. Two other parameters directly connected with this are the flow evaluation and erosion and deposition evaluation (Grela et al., 2009).

Evaluation of those and other parameters should make it possible to assess effects of human interference in channel and fluvial systems as well as lotic ecosystems. Among adverse effects there are e.g. decrease in the volume of flow as a result of irreclaimable water consumption, introduction of polluted or heated up/cooled down water into watercourses, physical and behavioural partitioning of channels, disturbing of self-purification processes in water etc. Implementation of Water Framework Directive is directly connected with the realization of resolutions contained in two other EU directives – so-called habitat directive (1992) and so-called nitrate directive (1991). The habitat directive imposes requirements for the protection of habitats (including fresh lotic water and stagnating water) and species of fauna and flora (including amphibians, fish and water invertebrates as well as vascular plants and plants inferioir to them).

Apart from traditional hydraulic structures, the structures which have been getting more and more popular in recent years are more nature-friendly. Ecological reinforcements of river channels and biotechnical structures are used in regulation processes, the reconstruction of already existing structures, widely understood processes of renaturization, rehabilitation and watercourse restoration as well as in the implementation of protective measures (Popek, 1992; Ratomski, 1992; Begemann and Schiechtl, 1999; Nachlik, 2006; Jędryka, 2007; Obolewski et al., 2009; Malkiewicz, 2011). The aim is to restore the dynamic balance of the watercourse, increase the natural flood water retention and improve the ecological status through the use of hydraulic and protective treatments. Eco-friendly hydraulic structures can be divided into several basic categories: reinforcements ofescarpments and escarpment bases, regulation structures and low-head dams as well as passes for fish and other organisms (Begemann and Schiechtl, 1999; Jędryka, 2007; Bednarczyk and Duszyński, 2008; Radecki-Pawlik, 2012). Biotechnical structures are usually well integrated into the landscape and do not hinder the migration of organisms along the watercourse. Moreover, they are a source of refugia for amphibians, fish and benthic invertebrates, influencing the growth of biodiversity (Merz and Chan, 2005; Sundermann et al., 2011). As part of the revitalization and renaturization of watercourses it becomes necessary to reconstruct or demolish many low-head dams (Maloney et al., 2008; Orr et al., 2008; Hansen and Hayes, 2011). Structurally unsuitable drop hydraulic structures can be replaced e.g. by artificial riffles (Gore et al., 1998; Bojarski et al., 2005; Litvan et al., 2008). These can replace existing river bars and drop hydraulic structures, especially in streams and smaller rivers, reducing channel erosion and slowing down the flow, promoting better oxygenation of water, restoration of sandbars and natural channel sinuosity, enabling migration of organisms, providing refugia and spawning sites, while harmonizing well with the landscape (Ratomski, 2006; Litvan et al., 2007; Radecki-Pawlik, 2009). Yet, effects of renaturization treatments require long-term monitoring and evaluation (Suren et al., 2005; Jähnig et al., 2008; Kail and Hering 2009).

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Summary

Regulation of mountain streams versus ecological balance as illustrated by the example of the upper Vistula basin (part II). Streams of the Polish Carpathians are characterized by a high gradient as well as a great changeability of their volume and velocity of flow. The processes which take place in these streams are those connected with lateral, bottom and channel erosion. In order to reduce those types of erosion, various methods of channel regulation are used. In mountain streams these are mainly: river bars, drop hydraulic structuresand anti-debris dams. Regulation works (straightening of the stream channel and hydraulic structures), changes in the use of the river basin, reduction in debris supplies and exploitation of river alluvia have led to a significant deepening of channels. This increases the risk of flooding associated with higher flows. Regulation works conducted within the channels and anthropogenic pressure in the areas adjacent to watercourses exert a negative effect on biotic communities. In most cases, changes in the structure of flows, in the stability of the river bottom and in the variety of habitats as well as disruption of the river continnum affect living conditions and diversity of vertebrates and invertebrates. The attempts at improving the ecological status of Carpathian watercourses through changes in hydromorphological conditions are connected with the implementation of European Union directives. Such actions include, among other things, replacement of traditional hydraulic structures by biotechnical ones, which are more eco-friendly. Their usefulness, however, still requires long-term monitoring.

Streszczenie

Regulacja potoków górskich a równowaga ekologiczna na przykładzie dorzecza górnej Wisły (część II). Potoki polskich Karpat odznaczają się znacznym spadkiem oraz dużą zmiennością objętości i prędkości przepływu wody. W ciekach tych zachodzą procesy erozji korytowej, bocznej i dennej. Aby je ograniczyć, stosuje się różnorodne metody regulacji koryt. W potokach górskich są to głównie: progi, stopnie wodne i zapory przeciwrumowiskowe. Prace regulacyjne (wyprostowanie koryt i zabudowa hydrotechniczna), zmiany w charakterze użytkowania zlewni, zmniejszenie dostaw rumowiska i eksploatacja aluwiów rzecznych spowodowały znaczne pogłębienie koryt. Jest to przyczyną wzrostu ryzyka powodziowego, towarzyszącego większym przepływom. Prace regulacyjne w obrębie koryt i presja antropogeniczna na terenach przyległych do cieków wywołują negatywne skutki w biocenozach rzecznych. Zmiany w strukturze przepływów, stabilności dna, zróżnicowaniu siedlisk, przerwanie conti-

nuum rzecznego w większości przypadków rzutują na warunki życia oraz różnorodność fauny bezkręgowej i kręgowej. Próby poprawy stanu ekologicznego cieków karpackich, poprzez zmianę warunków hydromorfologicznych, podejmowane są w związku z wdrażaniem dyrektyw Unii Europejskiej. Do działań takich zalicza się m.in. zastępowanie tradycyjnych konstrukcji hydrotechnicznych przez budowle biotechniczne, przyjazne naturze. Ich przydatność wymaga jednak jeszcze wieloletniego monitorowania.

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