Ecological Engineering 106 (2017) 263–272

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Research Paper

Effect of a baffled chute on stream habitat conditions and biological communities

Aneta Bylak[a,*], Krzysztof Kukuła[a], Karol Plesiński[b], Artur Radecki-Pawlik[b,c]

[a] Department of Ecology and Environmental Biology, University of Rzeszow, ul. Zelwerowicza 4, 35-601 Rzeszów, Poland
[b] Department of Hydraulics Engineering and Geotechnic, University of Agriculture in Krakow, al. Mickiewicza 21, 31-120 Krakow, Poland
[c] Institute of Structural Mechanics, Faculty of Civil Engineering, Cracow University of Technology, ul. Warszawska 24, 31-155, Kraków, Poland

ARTICLE INFO

Article history:
Received 22 December 2016
Received in revised form 9 May 2017
Accepted 29 May 2017
Available online 9 June 2017

Keywords:
Aquatic invertebrates
Barriers to fish migration
Froude number
Ichthyofauna
Peterka type baffled chute
Reynolds number

ABSTRACT

Despite the occurrence of many low head hydraulic structures in rivers, such as drop hydraulic structures or boulder ramps, there is still a lack of information on how these structures influence stream habitat conditions and biological communities. This lack of knowledge especially applies to baffled chutes, which, to date, have not been the subject of any hydrobiological studies. Our study examined a baffled chute on the Lubenka stream in Poland that was constructed in the early 1970s and rebuilt in 2015 with European Union financial support. We analysed the influence of that particular ramp hydraulic structure on the biological conditions upstream and downstream, looking into the quality and abundance of fish and benthic invertebrates. The Peterka-type baffled chute interfered with the ecosystem of the stream and fundamentally changed the conditions for the organisms in a relatively long section. In the area of the direct impact of the chute, hydraulic parameters changed drastically, which entailed the formation of three new distinct habitats with associated biological communities. The presence of the baffled chute resulted in transformations to the stream's biological communities over relatively long sections. It disrupted the natural balance between deposition and erosion, with the former dominating above the chute and it acted as a barrier to the general movement or migration of aquatic fauna. The Lubenka chute seems to be an example of an ill-considered human intervention that has adversely affected the ecosystem for several decades. Despite this, it was decided to incur large costs for the renovation of the chute rather than opt for its removal or at least to build a fish pass. Given the data presented in this paper, the chute seems to be a clear example of a bad management practice. The application of these solutions (baffled chute) should be limited to artificial wastewater canals. In streambeds, the chute causes drastic and practically irreversible changes.

1. Introduction

Aquatic ecosystems are often subject to anthropogenic stresses that interfere with the biology of many species (Allan and Castillo, 2009). One such example is river channel management, which influences the morphological processes in riverbeds and indirectly affects aquatic fauna (Bylak and Kukuła, 2017; Bylak et al., 2009; Wyżga et al., 2014). The most significant in this regard are weirs (Gibson et al., 2005; Kukuła, 2006), which reduce the possibility of upstream movement of fish and invertebrates, particularly during low water levels. Therefore, they obstruct valuable spawning, and forage habitats (Garbe et al., 2016; Shaw et al., 2016). Hydraulic structures have a profound impact on the stream ecosystem: they change the hydraulic characteristics, disrupt the natural balance between deposition and erosion, and affect the water temperature and dissolved oxygen concentration (Gosset et al., 2006; Januchowski-Hartley et al., 2013; Vaughan, 2002). All these factors directly affect the animal and plant organisms and shape the biocoenosis within the stream (Allan and Castillo, 2009). In the Carpathians, many weirs have disrupted the ecological continuity of rivers and significantly altered the natural communities of fish and invertebrates in the watercourses (Kukuła, 2003). For over 100 years, river channel management of large and small tributaries of the upper Vistula accelerated erosion and lowered water levels due to the use of check dams and drop hydraulic structures (Hennig, 1991).

At present, in line with the Water Framework Directive, river channel management is often based on the use of ramp hydraulic

* Corresponding author.
E-mail address: abylak@ur.edu.pl (A. Bylak).

http://dx.doi.org/10.1016/j.ecoleng.2017.05.049
0925-8574/

structures made of natural stones, whose artificial roughness is used to stabilize smaller streams (Oertel and Schlenkhoff, 2012; Pagliara et al., 2017; Plesiński et al., 2015; Radecki-Pawlik, 2013). However, older types of ramps can also be found, e.g., the Peterka baffled chute, popular in the USA (Rhone, 1977), but much less so in Europe, where it was mainly used to limit erosion above wastewater canals of water reservoirs, as well as to prevent the cutting of riverbeds into the substrate, or to strengthen the support structures of bridges (Kisyński and Stasiak, 1971).

A considerable number of baffled chutes have been in use for many years, showing satisfactory performance and high practicality. They are used to dissipate the energy of the water flow, most often at canal wasteways or drops. In general, conditions a Peterka-type baffled chute is constructed on an excavated slope, 1:2 or flatter, extending below the channel bottom. Backfill is placed over one or more rows of the baffles to restore the original streambed elevation. There are many examples of such constructions in the USA, e.g., in the Culbertson Canal and Helena Canal within the Missouri River Basin projects, both fed by water from reservoirs (Peterka, 1963). Other examples of Peterka baffled chutes can be found in the Santa Ana Creek (Robles-Casitas canal) and in Idaho (Main East Chanel). Rhone (1977) described Peterka structures built in the Marble Bluff Dam Diversion in Nevada. In Poland, Peterka-type baffled chutes were constructed in the early 1970s (e.g., the studied Lubenka chute) and were described in detail by Kisyński and Stasiak (1971). Laboratory measurements of those structures were made by Majewski et al. (1967).

The Peterka baffled chute in the Lubenka stream was designed as an independent object, as a very unusual type of impoundment in a small stream. However, no one has ever studied the effect of Peterka baffled chutes on aquatic invertebrates and fish. This is why our study aimed to investigate the ecological consequences of the chute's presence. This paper is a major contribution to the understanding of the functioning and local scale impact of the Peterka baffled chute. We highlighted it. This is why our study aimed to investigate the ecological consequences of the chute's presence. This paper is a major contribution to the understanding of the functioning and local scale impact of the Peterka baffled chute. We highlighted its potential to affect both the physical and ecological conditions of river systems. Relatively small, compared to large dams, chutes and other hydrotechnical constructions have negative effects on the ecosystem, particularly at a local scale (Bylak and Kukuła, 2017; Gordon et al., 2004; Petts, 1984). In small streams, however, often with several, or even dozens of similar structures, this effect would likely be multiplied. That justifies why knowledge about the ecological effects of technical interference in watercourses is so important. Although Peterka chute is rarely constructed in natural streams, the assessment of its impact on river ecosystems is more universal, and can be used to predict the impact of other small hydraulic structures on lotic environments.

The detailed aims of this study included an analysis of a Peterka baffled chute on the morphological and hydraulic parameters of a small Carpathian stream and, consequently, on the invertebrate and fish fauna. We hypothesized that the benthic invertebrates and/or ichthyofauna inhabiting the baffled chute and stream sections immediately upstream and downstream of the chute would differ from those at a non-transformed site.

2. Material and methods

2.1. Study area

The study was conducted in an ~500 m long section of the small upland Lubenka stream (16.5 km long, catchment area of 48 km^2). The Lubenka stream flows into the Wisłok River, a left-bank tributary of the San River (the Vistula catchment basin). The catchment area of the Lubenka stream includes a fragment of the Dynowskie Foothills and the studied section was located at an altitude of ~220 m asl. The area is agricultural land, with buildings of the Lubenia village along the stream's channel. In 1970, the lower part of the Lubenka stream was divided by a Peterka baffled chute, 22 m long and 4 m tall. Baffles were alternately arranged in 7 rows, 3 or 4 in each row. The height of each baffle was 1.2 m, with 2.4 m spaces between baffles. Laboratory measurements and calculations showed that the chute was suitable for a flow of $Q_{1\%} = 80\,m^3 \cdot s^{-1}$, a considerable excess for such a small stream (Kisyński and Stasiak, 1971; Majewski et al., 1967).

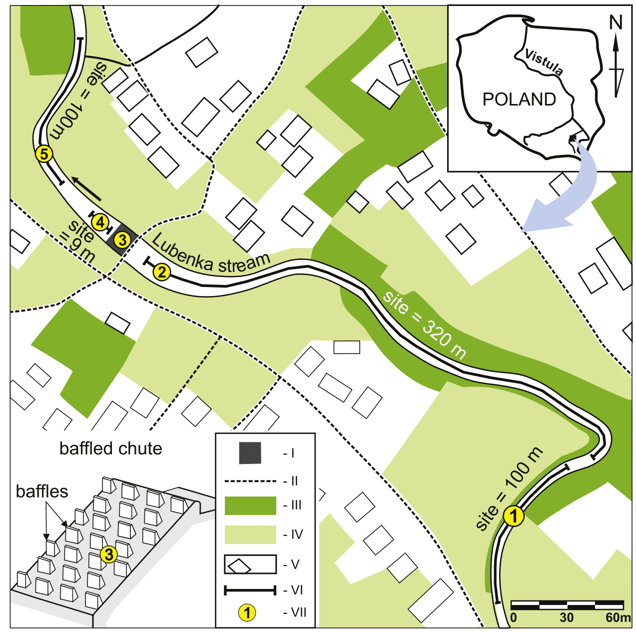

Fig. 1. Map of the study area showing the collection sites in the Lubenka stream; baffled chute (I), roads (II), woodlots (III), grassy area (IV), buildings and gardens (V), electrocatching sections (VI), and sampling sites (VII).

The analysed section of the Lubenka stream was divided into 5 parts (sites) differing in the extent and nature of anthropogenic alterations (Fig. 1). Site 1 was located in the upper part of the section, where the stream had maintained an almost natural character and the depth did not exceed 0.5 m. The bottom was covered with stones and gravel and the water flow was quite fast (Table 1). Site 2 was an ~300 m long section, with a reduced water speed and depth often exceeding 1 m. The bottom consisted of fine mineral sediments. Aquatic macrophytes were absent. Site 3 was the Peterka-type baffled chute. Site 4, a short section directly below the chute, had a depth that did not exceed 0.8 m and a slow water speed. The stream bed mainly consisted of sand and gravel. Site 5 was a 100 m long section, with a gravel-stone bottom and a fast water speed.

2.2. Data collection

Measurements were made at site 1, at the baffled chute (site 3) and in the areas of its direct influence (sites 2, 4 and 5) (Table A.1, Fig. A.1, Fig. A.2). Site 1 was used as the reference. The morphometric, physicochemical, granulometric and hydrodynamic parameters of each sampling site were measured. Data on biological communities were also collected. Fish were collected once (August), while benthic samples and other data were collected three times at 1 month intervals, at moderate and low water levels (4.08.2015, 7.09.2015 and 12.10.2015). One-period sampling permits the evaluation of