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Research article

Restoration of a shady urban pond – The pros and cons

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A B S T R A C T

The Bzura-7 pond (Łódź, Poland) is a typical shallow and shady urban reservoir situated on the Bzura River that is exposed to pollutants introduced mainly by internal loads and the supply from the catchment. In 2010–2012, the following characteristics were observed in the pond: a high allochthonous input of organic matter, high concentration of ammonium, low concentration of dissolved oxygen and low diversity of zooplankton, dominated mainly by *Daphnia* spp. From January to June 2013, restoration measures were performed, including sediment removal, increasing light access to the pond and construction of a sequential sedimentation-biofiltration system (SSBS). The aim of the present study was to investigate how the water quality in the Bzura-7 pond was affected by the restoration process, which included reducing pollutant inflows and enhancing habitat potential, thus increasing the diversity of this ecosystem. Restoration efforts improved the chemical and physical parameters of the water. The oxygen concentration increased, and the concentrations of TN and ammonium significantly decreased. Despite the increase in pond lighting, the growth of cyanobacteria was limited. However, we observed increased abundance of green algae and diatoms but less than adequate changes in the zooplankton community structures. Although we observed a significant increase in the zooplankton species richness after restoration, this increase was related to the small-bodied groups of zooplankton, rotifers and bosminiids, characteristic of eutrophic ecosystems. In addition, a planktivorous fish – sunbleak (*Leucaspius delineatus*) – was identified as an unintended side effect of the restoration effort. Further conservation efforts in the Bzura-7 pond and monitoring of results are still needed.

1. Introduction

One of the main functions of urban ponds is landscape water retention. The ponds receive stormwater and snow melt and are used for mitigation of stormwater flows into rivers (Mitsch and Gosselink, 2000). They are usually shallow, unstratified reservoirs with short retention times and high seasonal fluctuations in water levels (De Meester et al., 2005). However, even small impoundments perform multiple ecological functions, creating habitats for many organisms and thus enriching the diversity of an urban biocenosis (Céréghino et al., 2008; Hassall, 2014). Urban ponds influence the microclimate by increasing the humidity and reducing the variability of the temperature; thus, locally, they mitigate the effect of urban heat islands (Kupryś-Lipińska et al., 2009; Wibig, 2016). Urban reservoirs are valued in cities as one of the most attractive "natural" places for recreation (Lee and Maheswaran, 2011). However, due to their rapid sedimentation, plant overgrowth or other effects of eutrophication, they are often unable to perform their recreational functions. Additionally, various human pressures on these waters, e.g., bathing, fishing, and duck feeding, cause further degradation and impairment (Faulkner, 2004). In addition, the high nutrient content of the water is enhanced by its internal load. For these reasons, restoration of the pond is necessary (Collins et al., 2010).

Typical, effective restoration efforts are the mechanical removal of sediments, inactivation of phosphorus by introducing chemicals into the water, aeration and biomanipulation (e.g., Peretyatko et al., 2012; Rosińska et al., 2017). However, due to the high costs and the temporary and limited effectiveness of these methods, it is necessary to apply solutions that will reduce nutrient inflow from the catchment (Zalewski et al., 2012; Zalewski, 2015), such as the construction of buffer zones or the construction of pre-reservoirs

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for the sedimentation process. There are also innovative systems that limit the inflow of pollutants to the reservoirs (Jurczak et al., 2018). A few of these systems were demonstrated as ecohydrological approaches within the LIFE project "Ecohydrologic rehabilitation of recreational reservoirs "Arturówek" (Łódź) as a model approach to rehabilitation of urban reservoirs" (EH-REK) (LIFE08 ENV/PL/000517, 2008; Jurczak et al., 2012). This ecohydrological approach has resulted in significant improvements in the water quality of the restored urban reservoirs in the city of Łódź (Szulc et al., 2015; Jurczak et al., 2018).

One of the ecohydrological approaches in the framework of the LIFE project was the adaptation of the Bzura-7 pond to intensify its water self-purification process. Constructing the sequential sedimentation-biofiltration system (SSBS) to reduce the pollutants flowing into the reservoir along with additional activities, such as the removal of the bottom sediments and increasing access to sunlight, were used to achieve water quality improvement. This pond is small in size and has relatively high internal homogeneity due to substantial shading. The low availability of sunlight has resulted in low productivity and the heterotrophic nature of this ecosystem (Verhofstad et al., 2017). In these types of water bodies, production is based on microbial loop components, especially heterotrophic bacteria, for a large part of the vegetation season (Del Georgio et al., 1999; Jasser et al., 2009). As species richness is largely associated with primary production (Korhonen et al., 2011), shaded heterotrophic ecosystems are typically characterized by low biodiversity (Biggs et al., 1994). In particular, herbivorous crustacean zooplankton, which are usually an important element of a grazing food chain in shady ponds, are represented by low numbers of taxa and low diversity (Urabe and Sterner, 1996). The exception to this rule may be species of *Daphnia* that can ingest bacteria as efficiently as they can ingest algae (Hessen et al., 1989). Therefore, despite potentially low food quality for zooplankton grazers, heterotrophic ponds are often inhabited by dense populations of daphniids (as was also observed in Bzura-7); in these ponds, the basic foods of daphniids are bacteria and protozoan plankton (flagellates and ciliates) (Mahoney et al., 1990; Yoshida et al., 2001). Additionally, in the case of shallow heterotrophic lakes and ponds, the lack of fish or their highly limited presence, in terms of both number of species and densities, is a characteristic trait (Søndergaard et al., 2005; Radtke et al., 2011; Wolnicki et al., 2011a, 2011b). However, it should be emphasized that low diversity limits the ecosystem's resistance to disturbances, which may be particularly detrimental to urban ponds that are vulnerable to anthropogenic impacts. Consequently, the goals of the restoration efforts for Bzura-7 were not only to reduce the inflow of pollutants but also to enhance habitat potential and thus increase the diversity of this ecosystem. In our study, we paid special attention to zooplankton because, as other authors argue, these animals can be an exceptionally good tool for assessing the success of pond restoration efforts (Jenkins, 2003; Olmo et al., 2012).

The aim of the present study was to investigate how the restoration process affected the water quality of the wooded, urban, shallow and shaded Bzura-7 pond, which is situated among a cascade of reservoirs and was exposed to pollutants introduced not only from its internal load and surrounding catchment but also from the upstream inflow.

2. Materials and methods

2.1. Sampling site

The study was conducted on an upstream stretch of the Bzura River in the north-eastern part of the city of Łódź (Poland). The Bzura-7 pond is located upstream from Wycieczkowa Street in a cascade of 17 small, shallow man-made ponds (Fig. 1) that is in the middle part of the 17th reservoir cascade on the upper part of the Bzura River (51°82′23″N, 19°49′69″E) (Fig. 1A and B). It has an area of 2850 m^2 and a water volume of 3510 m^3 (Kujawa, 2003), where a low concentration of oxygen and an elevated concentration of ammonium were observed in 2010–2012. Due to poor water quality conditions and poor ecosystem function, the Bzura-7 pond was included in the restoration project "Ecohydrologic rehabilitation of recreational reservoirs "Arturówek" (Łódź) as a model approach to rehabilitation of urban reservoirs" for which engineering efforts to restore the pond were undertaken from January to June 2013.

Restoration activities included removal of 360 m^3 of sediment, reduced shading by removal of 10 trees and reduced canopy thickness of 40 trees around the pond and the installation of an SSBS for point source inflows from the river. The constructed SSBS had an area of 165 m^2 and consisted of sedimentation (65 m^2), geochemical (19 m^2) and biological (80 m^2) parts (Fig. 1A, C, 1E). At the inlet to the Bzura-7 pond, a gabion that was 1 m wide, 1 m high and approximately 19 m in an arc shape was constructed. The barrier was made of iron mesh baskets of 6×8 cm and mesh made of wire with a diameter of 2.7 mm, and it was filled with dolomite-limestone stones with a diameter of 12–18 cm. This geochemical structure was covered with an RG17 coconut mesh mat (900 g/m^2 x 2) made of 5-cm-thick coconut cord to enhance the suspended matter retention of the gabion construction. Two PVC pipes, with diameters of 0.2 m and 0.1 m, were also installed inside the gabion to force water circulation around the island. Gabion construction divided the SSBS into two parts as follows: upper (sedimentation) and lower (biofiltration). The upper part was reinforced with concrete slabs to collect suspended matter in front of the inflow to the pond and to facilitate servicing of the SSBS. The lower part was planted with the following aquatic vegetation: *Typha angustifolia* (L.), *Carex riparia* William Curtis, *Glyceria maxima* (Hartm.) Holmb., *Iris* sp., and *Ceratophyllum demersum* (L.). These species play an important role as the biofiltration section. All the elements of the SSBS are shown in Fig. 1A, C.

Between 2010 and 2016, water samples for physicochemical (water temperature, oxygen concentration, pH, conductivity and chlorophyll *a* concentration), biological analysis (phytoplankton analyses, zooplankton analyses, fish analyses) and toxicological analysis (microcystin concentration) were collected monthly (except that in 2010, collection was every two weeks) from April to October in the following two periods: before restoration (2010–2012) and after restoration (2013–2016). For phytoplankton, chemical and toxicological analyses, water was sampled from a 1 m column of water using a 5 L Bernatowicz sampler and was transferred into a 5 L container and transported to laboratory immediately after sampling. Zooplankton were sampled twice from a 1 m column of water using a 5 L Bernatowicz sampler and transferred into a 10 L bucket. Sampled water was filtered using a 20 mm mesh net, then the samples were concentrated to 50 mL and preserved in 4% Lugol's solution (distributed by Chempur Company, Poland). For the determination of fish species composition, standardized benthic multi-mesh gillnets (prEN 14757:2005) were used, with two sets each for 2009, 2011 and 2013–2017. Gillnetting was conducted once per year, in the autumn (October–November), to avoid overfishing.

2.2. Analyses of abiotic parameters

Physical parameters were determined *in situ* during water sampling using the WTW Multi 340i (WTW, Weilheim, Germany). Water samples filtered by GF/C membranes were analysed by ion chromatography (Dionex ICS-1000, Sunnyvale, California, USA) for