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Influence of stormwater runoff on macroinvertebrates in a small urban river and a reservoir

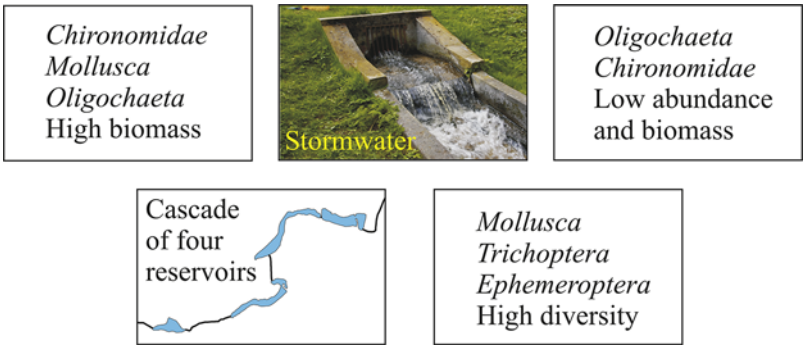
Ryszard Gołdyn [a,*], Barbara Szpakowska [b], Dariusz Świerk [b], Piotr Domek [a], Jan Buxakowski [a], Renata Dondajewska [a], Danuta Barałkiewicz [c], Adam Sajnóg [c]

[a] Department of Water Protection, Faculty of Biology, Adam Mickiewicz University, Poland
[b] Department of Landscape Architecture, Poznań University of Life Sciences, Poland
[c] Department of Trace Elements Analysis by Spectroscopy Method, Faculty of Chemistry, Adam Mickiewicz University, Poland

HIGHLIGHTS

- Stormwater caused marked transformation of benthic macroinvertebrates composition.
- Abundance and biomass of benthic organisms were also strongly influenced.
- Particularly sensitive were Ephemeroptera, Trichoptera and Mollusca.
- Impact on macroinvertebrates in the reservoir was more pronounced than in the river.
- Reservoirs improve water quality and composition of organisms in outflowing river.

GRAPHICAL ABSTRACT



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ABSTRACT

The impact of stormwater on benthic macroinvertebrates was studied in two annual cycles. Five small catchments drained by stormwater sewers to a small urban river and a small and shallow reservoir situated in its course were selected. These catchments were located in residential areas with single-family houses or blocks of flats as well as industrial areas, i.e., a car factory, a glassworks and showroom as well as the parking lots of a car dealer and servicing company. In addition to the five stations situated in the vicinity of the stormwater outlets, three stations not directly influenced by stormwater were also established. Macroinvertebrates were sampled in every season, four times per year. Both abundance and biomass were assessed. Stormwater from industrial areas associated with cars, whose catchments showed a high percentage of impervious areas, had the greatest impact on benthic macroinvertebrates. This was due to a large amount of stormwater and its contamination, including heavy metals. Stormwater outflow from residential multi-family houses exerted the least influence. Macroinvertebrates in the water reservoir were found to undergo more extensive changes than those in the river. The cascade of four reservoirs resulted in a marked improvement of water quality in the river, which was confirmed by species composition, abundance and biomass of macroinvertebrates and indicators calculated on their basis for the stations below the cascade in comparison to the stations above and in the first reservoir. These reservoirs replaced constructed wetlands or other measures, which should be undertaken for stormwater management prior to its discharge into urban rivers and other water bodies.

* Corresponding author at: Department of Water Protection, Faculty of Biology, Adam Mickiewicz University, Umultowska 89, 61-614 Poznań, Poland.
E-mail address: rgold@amu.edu.pl (R. Gołdyn).

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1. Introduction

The quality of stormwater is determined to a large extent by the type of catchment area, season of the year, type of road surface and traffic intensity (Shirasuna et al., 2006). Stormwater can contain combustion products of fuel, ingredients derived from industrial emissions, mineral and organic parts of the soils, etc. (Ki et al., 2011). Several chemical elements and substances can be present, e.g. compounds of arsenic, mercury, chromium, lead, cadmium, nickel, zinc and many others (Barałkiewicz et al., 2014; Szpakowska et al., 2014). Urban runoff with stormwater affects not only the physical and chemical variables of water quality in the receiver but also organisms living in the water column and at the bottom (DOE 1997; Johnson et al., 2011). It negatively affects ecosystem processes and reduces biodiversity. Smucker and Detenbeck (2014) stated that biodiversity in urban streams was 47% less than that in reference streams. They found that ecological communities, habitats and rates of nutrient cycling were negatively affected as well.

It has been known for some time that metropolitan areas are responsible for changes in habitat quality, water chemistry, hydrology, and the benthic community structure of rivers (Hynes, 1975; Harding et al., 1998; Slye et al., 2011). Historically, this was primarily associated with the discharge of municipal sewage or sewer overflows and industrial effluents, often untreated or insufficiently treated. The problem of these kinds of pollution is well recognized and in many countries it has been solved. Nowadays, however, other factors can cause more concern, including stormwater runoff, which often has the greatest impact (Gresens et al., 2007; Slye et al., 2011). Recently, this problem has grown as a result of the increasingly more frequent strong storm events associated with global climate change. However, urban stormwater has a different composition, depending on the land use, catchment size, proportion of catchment covered by impervious surfaces, type of industry and type of building (Barałkiewicz et al., 2014). Little is yet known as to how the various factors determine the abundance and richness of macroinvertebrates in urban rivers. E.g. Bellucci et al. (2013) stated that the macroinvertebrate data were best fitted by impervious land cover, wetlands metric, and catchment slope. Obolewski et al. (2011) stated that benthic macroinvertebrates in urbanised sections of river fall under the strong influence of anthropogenic pollution, and to a lesser extent seasonality and microhabitats, such as vegetation or bottom substrates. Gresens et al. (2007) stated that the negative influence of the percentage of an impervious area (PIA) is recognised at a value of 5–8% and that probably at such low levels of PIA chemical constituents in stormwater runoff may be more important than physical disturbance as a cause of decline in the biological integrity of streams.

The aim of this study was to determine whether or not the stormwater runoff from small catchments of different land use, such as residential buildings, blocks of flats and industrial areas, which influence the stormwater quality, have varying effects on the composition, abundance and biomass of bottom macroinvertebrates occurring in the urban section of a small river and in a reservoir.

2. Material and methods

2.1. Study area

The study was carried out along the lower section of the River Cybina, which is the right tributary of the River Warta, crossing the city of Poznań in West Poland. The multi-year average of water discharge is 0.67 $m^3 s^{-1}$. Four small reservoirs are found within this river section, created or restored in the 1980s, whose principal role is to intensify the process of self-purification of the river water (Gołdyn, 1994; Gołdyn et al., 2009).

To study the impact of runoff on a small urban river five catchments drained by stormwater sewers were selected. These sewers discharge water to the upper reaches of the analysed section of the River Cybina, to the first small water reservoir, known as Antoninek, and to the river downstream of a cascade of four reservoirs (Fig. 1). Catchment area No. 1, which drains the residential surroundings of single family houses, has an area of 42.7 ha, of which impervious areas occupy 28.9%. Before the sewer outlet there is a settling tank with a hydrocarbon separator for stormwater pre-treatment. Catchment area No. 2 covers the area of the car factory with parking for workers' cars. It occupies 56.8 ha, of which 51.6% is impervious. Before reaching the river stormwater is treated in an Imhoff tank, adapted from a former sewage treatment plant. Surface No. 3 mainly covers the area of the glassworks. Its area is 4.78 ha, of which 88% is impervious. Stormwater is discharged into Antoninek Reservoir. Catchment No. 4 comprises an area of workshops, a showroom and the parking lots of a car dealer and servicing company. Its area is 4.33 ha, of which 76% is impervious. Stormwater is also discharged into the Antoninek Reservoir. Surface No. 5 covers the area of a small estate of blocks of flats. Its area is 7.37 ha, of which 26.7% is impervious.

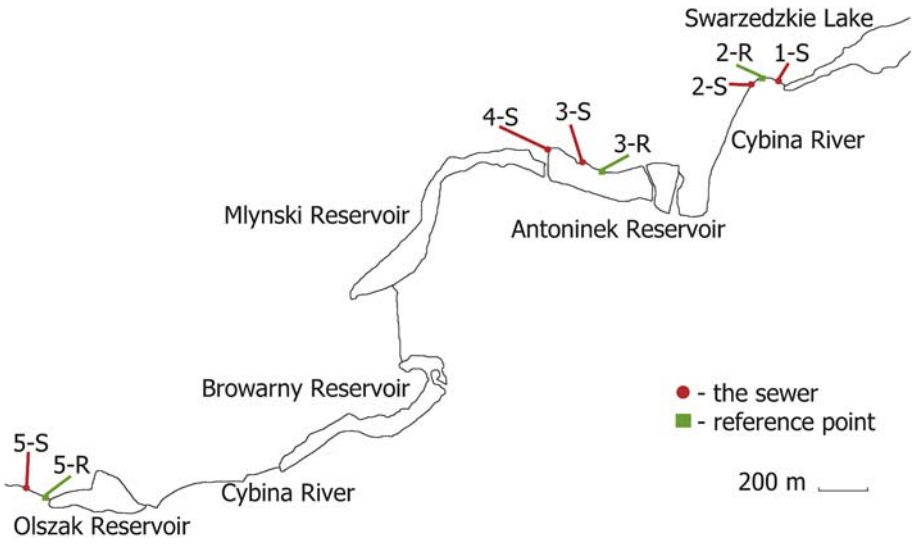

Fig. 1. Map of sampling stations.