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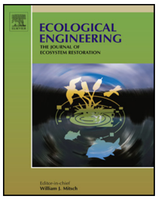

Temporal changes in the abiotic/biotic drivers of selfpurification in a temperate river

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ABSTRACT

Riverine selfpurification regulates concentrations of phosphorus (P) and suspended matter (SM) in rivers, thus determine water quality in the rivers, downstream reservoirs and estuaries. This study tests a hypothesis, that ecohydrological dynamics of aquatic ecosystems, including their selfpurification, are controlled by two top-drivers: hydrological characteristics and temperature. The paper proposes a model explaining the changing hierarchy of these two top-drivers in a temperate river (Pilica, Poland), which supplies an eutrophication-sensitive lowland reservoir with accidents of toxic cyanobacterial blooms. Statistical analyses of the 4-year observation of the P and SM dynamics at the inflow to the reservoir, in a matrix of high/low discharge and high/low temperature ranges show that the hydrological drivers regulate nutrient concentrations stronger during cold months. During summers, temperature seriously disturbs this pattern. The effect of the rapid rise in discharge (24 h ΔQ) is also weaker in the growing season when compared to winters. The results indicate that the general management strategies for nutrient control, especially in the face of climate changes, should differ seasonally: they should focus on enhancement of physical selfpurification processes (e.g. discharge control by floodplains rehabilitation) in the winters, and enhancement of temperature-dependent selfpurification processes (including biological trapping) during growing seasons. Both strategies are based on green infrastructure, ecological engineering and ecohydrology concepts, and enhance supporting ecosystem services of catchments.

1. Introduction

In the second half of the 20th century, the export of phosphorus (P) from landscapes to water has been more regulated by humans than by natural forces (Anthropocen; Crutzen, 2002). The erosion rates and resulting yield of sediment (suspended matter; SM), an important carrier of P (Ballantine et al., 2009), has seriously and progressively increased (by as much as an order of magnitude) as a result of intensification of land clearing and use (Morgan, 1986). Data for the Baltic Sea basin show that, out of 92–97% of waterborne total P load, at least 45% of the loads originate from diffused anthropogenic sources (HELCOM, 2011). Point-source pollution discharging directly into the Baltic Sea in 2006 amounted only to about 8% of the total P load (HELCOM, 2011; Kiedrzyńska et al., 2014a). As a consequence of this process, the global riverine P concentration is estimated to have doubled, or even increased by 10–50 times, in regions with high human populations and high energy consumption, compared to its natural level (Meybeck, 1982). These processes result with eutrophication of rivers, other freshwater ecosystems (e.g., man-made reservoirs – more sensitive to P overloads than rivers) and coastal waters, and seriously impedes their ability to deliver ecosystem services (TEEB, 2010). One of the most common and most damaging example of these processes is an overgrowth of toxic cyanobacteria, which causes adverse human health effects (Codd et al., 2005; Mankiewicz-Boczek et al., 2011) and hampers water abstraction and purification (Jurczak et al., 2005), forcing investments in alternative water infrastructures (Wagner-Łotkowska et al., 2004), lowering the productivity of fisheries (Colby et al., 1972) and restricting recreation, leading to considerable economic losses (Steffensen, 2007; McGregor et al., 2012).

Instream riverine concentrations of phosphorus and suspended matter are determined by a number of biotic and abiotic (physical and chemical) processes. Their export from the catchment is the result of the interplay between the P sources and sinks at all scales (Haygarth et al., 2005a,b) and depends on the catchment-specific conditions, such as geological and climatic characteristics, land use structure, terrestrial ecosystem succession stages, the

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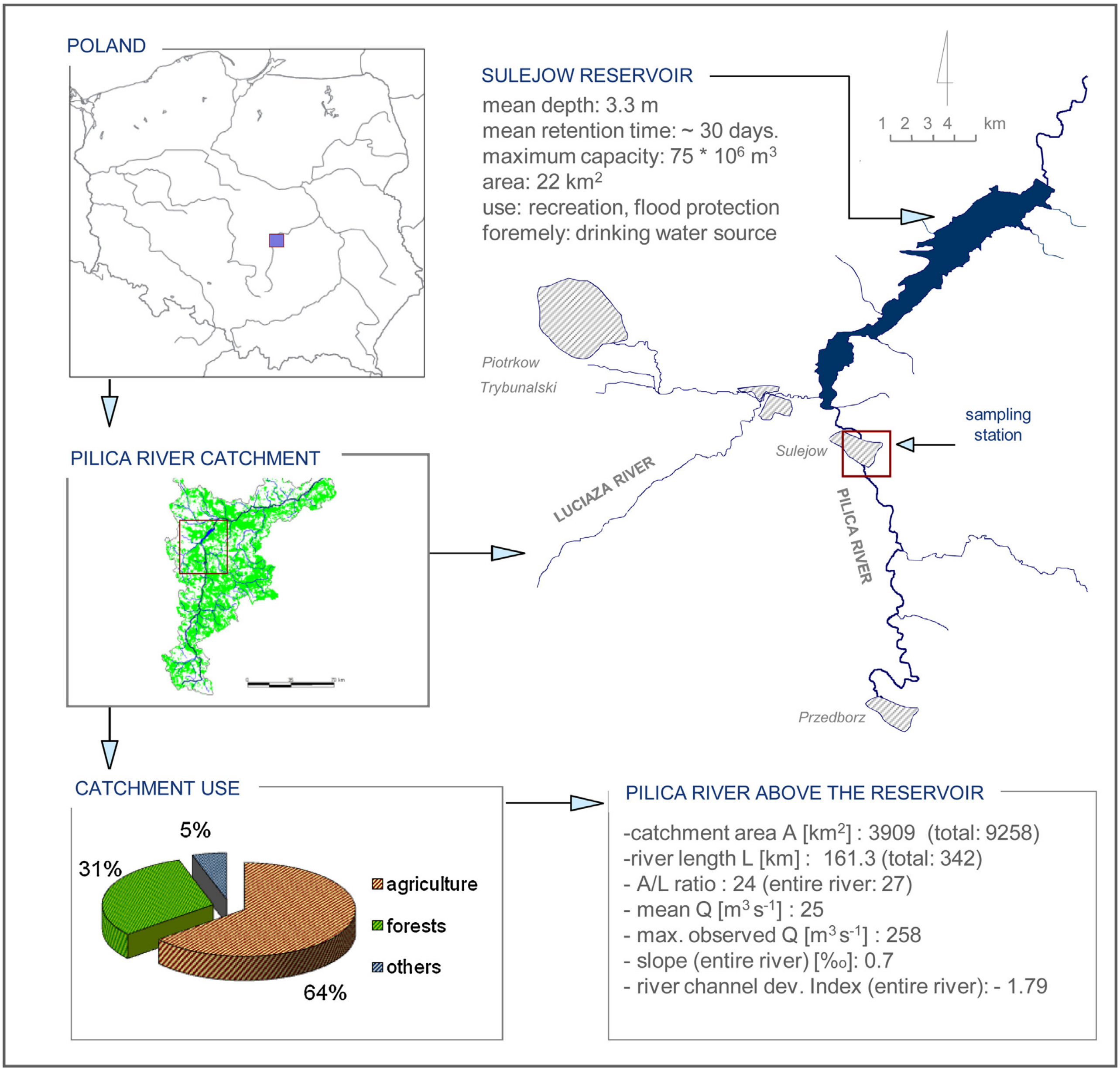

SULEJOW RESERVOIR
mean depth: 3.3 m
mean retention time: ~ 30 days.
maximum capacity: 75 * 10^6 m^3
area: 22 km^2
use: recreation, flood protection
foremely: drinking water source

PILICA RIVER ABOVE THE RESERVOIR
-catchment area A [km^2] : 3909 (total: 9258)
-river length L [km] : 161.3 (total: 342)
- A/L ratio : 24 (entire river: 27)
- mean Q [$m^3 s^{-1}$] : 25
- max. observed Q [$m^3 s^{-1}$] : 258
- slope (entire river) [‰]: 0.7
- river channel dev. Index (entire river): - 1.79

Fig. 1. Location and characteristics of the Pilica River and its catchment.

presence of transitioning ecosystems between land and water, and management strategies for nutrient control (Uusitalo et al., 2000; Vörösmarty et al., 2003; Mitsch et al., 2005; Doody et al., 2012). The P concentration within a river changes according to such aspects as its uptake/release, adsorption/desorption, precipitation/dissolution, and advection/diffusion, and have considerable capacity to process P and regulate its downstream delivery (House, 2003; Withers and Jarvie, 2008). Finally, P also changes with phases of flood formation, antecedent hydrological conditions and temporal (long-term and seasonal) dynamics of climate and hydrological patterns of rivers (Fraser et al., 1999; Zalewski et al., 2000; Macrae et al., 2010). All these processes determine rivers' selfpurification potential (Ostroumov, 2005).

The kinetics of the individual physical and biological processes determining selfpurification, and thus, P concentration in rivers, was studied for several decades in order to advance the understanding of particular elements of the P cycle and show the complexity of the issue (Meybeck 2002a,b; Heckrath et al., 2007; Withers and Jarvie, 2008). However, integration of this knowledge into a more general pattern and/or a comprehensive decision making framework is a challenge. Haygarth et al. (2005a), in an effort to integrate the science of different disciplines, described general difficulties resulting from insufficient cooperation, and objective barriers such as using incomparable methodologies or confining one's own views to different scales of focus, typical for particular disciplines.

According to the concept of ecohydrology (Zalewski et al., 1997; Zalewski, 2002), the complexity of the processes regulating riverine P concentrations are ultimately top-controlled by two drivers: hydrological characteristics in a catchment-river system (including precipitation, runoff formation, river hydrological dynamics −discharges patterns, timing, and intensity) and temperature.

(i) *Hydrological characteristics* determine the physical pathways and timing of nutrient transfer at different scales. On the catchment scale, the transportation of SM and sediment-associated P via surface runoff due to intense precipitation has long been recognized as a major hydrological pathway for P delivery to surface waters (Ernstberger et al., 2004; Ballantine et al., 2009;