Effect of Climate Change on Environmental Flow Indicators in the Narew Basin, Poland

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Environmental flows—the quantity of water required to maintain a river ecosystem in its desired state—are of particular importance in areas of high natural value. Water-dependent ecosystems are exposed to the risk of climate change through altered precipitation and evaporation. Rivers in the Narew basin in northeastern Poland are known for their valuable river and wetland ecosystems, many of them in pristine or near-pristine condition. The objective of this study was to assess changes in the environmental flow regime of the Narew river system, caused by climate change, as simulated by hydrological models with different degrees of physical characterization and spatial aggregation. Two models were assessed: the river basin scale model Soil and Water Assessment Tool (SWAT) and the continental model of water availability and use WaterGAP. Future climate change scenarios were provided by two general circulation models coupled with the A2 emission scenario: IPSL-CM4 and MIROC3.2. To assess the impact of climate change on environmental flows, a method based conceptually on the "range of variability" approach was used. The results indicate that the environmental flow regime in the Narew basin is subject to climate change risk, whose magnitude and spatial variability varies with climate model and hydrological modeling scale. Most of the analyzed sites experienced moderate impacts for the Generic Environmental Flow Indicator (GEFI), the Floodplain Inundation Indicator, and the River Habitat Availability Indicator. The consistency between SWAT and WaterGAP for GEFI was medium: in 55 to 66% of analyzed sites, the models suggested the same level of impact. Hence, we suggest that state-of-the-art, high-resolution, global- or continental-scale models, such as WaterGAP, could be useful tools for water management decision-makers and wetland conservation practitioners, whereas models such as SWAT should serve as a complementary tool for more specific, smaller-scale, local assessments.

Among the various factors that determine the health of a river ecosystem and its ability to deliver ecosystem services, discharge (flow [$m^3 s^{-1}$]) is one of the most important (Norris and Thomas, 1999) and is sometimes called a "master variable" (Power et al., 1995) that shapes many fundamental ecological characteristics of riverine ecosystems. The quantity of water required to maintain a river ecosystem in its desired state is referred to as the "environmental flow" (Acreman and Dunbar, 2004; http://www.eflownet.org/). The first environmental flows were focused on the concept of a minimum flow and were based on the idea that all river health problems are associated with low flows and that the river ecosystem will be conserved as long as the flow is kept at or above a critical minimum level. This perspective is still common in Poland, where one of the most widely used environmental flow methods sets a single value below which biological life in the river is threatened ("hydrobiological criterion") or fish survival is at risk ("fishing criterion") (Kostrzewa, 1977; Witowski et al., 2008). However, it is increasingly recognized that all elements of a flow regime, including floods and medium and low flows, are important (Richter et al., 1996; Poff et al., 1997; Poff et al., 2010).

Many of the Earth's freshwater ecosystems are under severe threat from human pressure (Vőrősmarty et al., 2010), particularly anthropogenic climate change (Kernan et al., 2010). In the northeast lowland part of Poland, many of the rivers are in a seminatural state, and surface water abstractions for agriculture, industry, and human needs are not as significant as elsewhere (Piniewski et al., 2011). Maintaining their good ecological status (as indicated in the EU Water Framework Directive) requires detailed analyses of the river–floodplain connectivity and its vulnerability to human induced changes. Assuming that there will be no direct threats to the river–floodplain morphology (e.g., building embankments or channelizing the river), flow regime alteration poses the main threat to the floodplain ecosystem. Analysis of the flow regime changes followed by the ecohydrological consideration of its possible impact on the in-stream and floodplain ecosystems should be of high priority

J. Environ. Qual.
doi:10.2134/jeq2011.0386
Received 7 Oct. 2011.
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Assigned to Associate Editor Ali Sadeghi.

Abbreviations: GCM, General Circulation Model; GEFI, Generic Environmental Flow Indicator; FII, Floodplain Inundation Indicator; IHA, Indicator of Hydrologic Alteration; RHAI, River Habitat Availability Indicator; SWAT, Soil & Water Assessment Tool; WaterGAP, Water–Global Assessment and Prognosis.