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Fish recolonization of a lowland river with non-buffered storm water discharges but with abated pollution from a large municipality

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ABSTRACT

Water pollution from industrial Metro Łódź (ML), Poland, made the Ner River almost fishless in its middle-lower course for most of the 19th and 20th century. The new sewage treatment plant of ML and reduction of industry have caused pollution abatement there since the 1990s. As a result, the Ner became repopulated, which was shown by fish samples collected along its course in 2000–2012. Multivariate statistical methods helped distinguish unpolluted (I and II, in the upper course), and recovered (III, IV and V, in the middle-lower course) sections of the river. Historical and present data indicated that section III (downstream of ML) recovered least, both before and during the study. Section V (outflow one) recovered most and its fish fauna (almost exclusively native) now displays high and stable biomass, abundance and species richness, including those of obligatory riverine species. Non-native Prussian carp's dominance followed the river degradation gradient, i.e. was highest in section III, and in section V declined to almost absence. This study shows that the revival of native fish fauna seems to be a method of restricting the dominance of this highly tolerant species. Despite the abatement, storm events are very harmful to fish (mostly in section III), because the Ner discharge may then increase manifold and all storm water is drained by the ML combined sewer system to the Ner in several hours. Other stressors are numerous dams and desorption of pollutants from sediment in the middle Ner, and perhaps pollutant inflow from agriculture or local urban areas. Some moderation of storm impact on water entering the Ner from ML by constructing buffer reservoirs would probably cause further fish recovery in section III.

1. Introduction

Water pollution is a frequent man-made disturbance that stresses fish in rivers (Lewis et al., 1982; Yount and Niemi, 1990). It may be of pulse character, when a disturbance is short, or "chronic, with the duration longer than the life-span of the longest-lived species in a community" (Detenbeck et al., 1992). The latter type is more harmful, because fish may survive short periods of severe pollution, but may not long periods of milder pollution (Jones, 1964; Lewis et al., 1982; Alabaster and Lloyd, 1984; Penczak and Koszalińska, 1993). Besides, effects of chronic pollution include accumulation of toxicants in benthic sediments (Mosiej et al., 2007b; Penczak et al., 2010), and in groundwater (Hamilton, 2012), which then harm fish long after the original pollution has abated. Chronic pollution stress started affecting fish in Europe and elsewhere with the onset of Industrial Revolution and related increase in abundance of human populations. In some of the rivers the stress continues today (Adams et al., 1992; Wolter and Vilcinskas, 1997; Boët et al., 1999; Gafny et al., 2000).

Fortunately, the growing awareness of pollution impact on ecosystems, cleaner industrial technologies and better wastewater purification have resulted in pollution abatement in many rivers of developed countries in recent decades (Penczak, 1996; Raat, 2001; Neumann, 2002; Alexander and Smith, 2006). The abatement usually allowed for recovery of fish assemblages there (but see Aarts et al., 2004) and numerous such cases were analyzed in Niemi et al. (1990), Yount and Niemi (1990), Detenbeck et al. (1992), and later studies. In rivers described, however, sources of pollution were numerous, which made causes and patterns of fish population and community revival obscure (Lewis et al., 1982). In addition, respective analyses usually concerned a single fish species (or a fish family), took place in North American rivers, and, last but not least, were rarely compliant with informative environmental monitoring (Hunsaker, 1993; Eklöv et al., 1998; Chovanec et al., 2000; Penczak et al., 2000, 2004a,b, 2006, 2012, 2014; Siligato and Bohmer, 2001; Kruk and Penczak, 2003, 2013; Penczak, 2009; Hued et al., 2010;

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Ryon, 2011; Głowacki, 2012; Głowacki and Penczak, 2012, 2013; McClelland et al., 2012; Jażdżewski et al., 2014; Radtke et al., 2015), such that rigorous quantitative sampling is carried out using uniform methodology, applied to all fish species in similar sites and at similar time intervals.

The pursuit of the causes and patterns might be easier if abatement concerned a single major pollution source (e.g. Antal et al., 2013), because abatement impact on fish recovery would be more explicit. An analysis of whole fish communities would put the recovery of given species into wider ecological context, and thus supply more convincing explanations of the way and extent of species revival. The restitution of European fishes might be different, as a result of different fish pre-degradation community compositions, from those of North American fishes. Finally, spatially and temporally exhaustive and standardized monitoring might produce more complex and reliable results than the usual pre- and post-disturbance assessment.

Infrequent studies met one or two of the above four criteria, but only Dauba et al. (1997) fitted all of them, describing, along a French river, a gradual fish recovery that followed the abatement of a 20-year long pollution input from a headwater chemical factory. The river we presently analyze is similar to that in Dauba et al. (1997), yet the degrader was an entire larger and much older municipality of Łódź City (ML), Poland. Over its bicentennial history, ML was a mill town, and for decades a leading textile production centre in the world. The centre declined after World War I, and many companies were liquidated during a politically-induced transition of Poland's economy in the 1990s. Yet, the population of ML grew to 1.2 million today. Because most of ML area is the south-western slope of the Łódź Upland drained by the Ner River, most of wastewater and surface run-off from this area is deposited into the upper course of the river.

The development of ML wastewater and storm water facilities much lagged behind that of the industry and human population. In the 1920–1930s a combined (and largely underground) sewer system for collecting industrial, household, and storm water was completed to drain the area. Beside a sewage treatment plant it included several canals that had been tributaries of the Ner. The canals served mostly for collecting rainwater run-off from streets and roads, yet most of them possessed (and still do) combined sewer overflow devices. Water quality in the Ner continued to be very poor because sewage treatments were only bar screens and sand sedimentary tanks. Besides, the canals lacked (and still do) buffer reservoirs. Consequently, no fish in almost all the Ner polluted course (Kulmatycki, 1936; Penczak, 1969, 1975) was recorded, and the river was the most polluted in Poland for several decades since World War II (Statistical Yearbook, 1975, 1986; Kruk et al., 2003).

The liquidation of much of ML industry in the 1990s was one cause of an abrupt and decisive pollution abatement in the Ner (sewage outflow from ML decreased by about half in the 1990s). The other was the launching of a huge sewage treatment plant (STP), located on the Ner River between the storm water canals, in the mid 1990s. The STP now collects three fourths of all sewage and up to half storm water of average rain events of ML. Of all water entering the STP, 100% has been mechanically treated since 1995, 50% biologically treated since 1998, and 90% since 2001 (Mosiej et al., 2007b). The biological and chemical treatment lines of the STP have been expanded in later years to be able to reduce phosphorus and nitrogen compounds amounts to levels similar to those in the river's most upper, unpolluted section (GOŚ, 2015). No essential change in other important factors affecting fish life in the Ner has occurred in the recent decades.

The fish fauna of the Ner was sampled along its course in 2000–2012 and is herein presented. Multivariate analyses were applied to the biomass data of fish samples obtained for the present study. They produced a typology of fish samples and sites that helped us to divide the Ner into sections of specific biomass structure characteristics and enabled distinguishing their indicator species. An analysis of similarities and differences between these sections and comparison with historical data allowed us to determine: (1) the degree of fish recovery by the start and by the end of our study, (2) the degree of similarity of fish recovery in different (natural and recovered) sections of the river, including that of facultative riverine species (FRS) and obligatory riverine species (ORS) (Penczak and Kruk, 2000; Kruk, 2006), both before and during the study, (3) the possibility and factors of future fish recovery, (4) the presence, spread or decline of non-native species in the Ner, (5) the impact of Ner discharge fluctuation on fish in the river.

2. Study area

The Ner River is 124.1 km long (Czarnecka, 2005) (Fig. 1), its sources are located at 210 m a.s.l., and the outlet to the middle Warta River is at 94 m a.s.l. (Penczak, 1975). The average slope of the river is 1.07‰, and long-term average discharge ranges from a quarter of a cubic metre at site 1 to 11 m^3 at the outlet to the Warta River, increasing most abruptly at the inflows from ML, between sites 4 and 6 (Fig. 1). The Ner's catchment is 1866 km^2, and its shape is elongated and generally symmetrical.

Between 2000 and 2005 fish were sampled along the Ner at 10 sites (sites in parentheses in Fig. 1). The sites were not then distributed at similar spatial intervals, because earlier research and information obtained from anglers, local people and fragmentary pilot samplings indicated that an about 20 km long section of the Ner downstream of ML was fishless (Penczak, 1975; Penczak et al., 2010). Three new sites were added to the former 10 in the middle Ner section in the 2008 sampling (present sites 6, 7 and 10; Fig. 1). Still another site (present site 3) was added in the 2010 and 2012 samplings (Fig. 1). Site 3 is located just downstream of a cascade of two recreational reservoirs on the Ner.

The 20 km headwater section of the Ner (present sites 1–3) has always been little affected by humans and not by industry (Penczak, 1969, 1975), except for the cascade of shallow reservoirs (2 and 10 ha in area, at km 107–108), the downstream (larger) one of which is always emptied for winter (Photo S1), and the upstream one has not been emptied for at least the recent twenty years. The Ner section with abated pollution begins at the outlet of the first storm water canal from Łódź City (USWC, km 104.38 (Fig. 1)) (Photos S2–S4), where the discharge is about 1 cubic metre per second. Subsequent outlets are the Dobrzynka Stream, from the Pabianice town (MSWC1 in Fig. 1, km 98.98), and MSWC2 (km 97.25). The outlet from the STP is at km 97 and adds (on average) about 2 $m^3\,s^{-1}$ to the discharge (GOŚ, 2015; personal communication from the STP). The outlets of the lower storm water canals from ML are at km 94.21 and 92.11 (LSWC1, LSWC2 (Fig. 1)). The canals and STP drain most of ML, which is about 500 hundred square kilometres in area. The STP is located at the lowest point of ML (163 m a.s.l.), while the highest point of ML is at 284 m a.s.l. (on the north-eastern limit of Łódź City) (Wikipedia, 2015).

The middle course of the Ner (present sites 6–11) (Photo S5) has been fragmented for several recent decades by over twenty low-head dams and nine normal dams with small hydropower plants (of which only one has a fish pass). The lower course of the Ner (present sites 12–14) is not fragmented (Photo S6). The Ner water of the middle and lower courses has long been affected by numerous dairies, ungulate and poultry farms, and carp ponds located along larger Ner tributaries. Additionally, two thirds of Ner catchment area are arable fields. Ner water is used for their irrigation, but the river also receives surface run-off from such fields, and