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# Effects of wetland restoration on the amphibian community in the Narew River Valley (Northeast Poland)

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**Abstract.** Habitat restoration is a mitigation tool often proposed in conservation biology, however, our knowledge about its effectiveness is still limited. Here we evaluate the effects of a large-scale drainage and habitat restoration project on the amphibian community in the Narew River Valley, Poland. We used visual encounter surveys, manual calling surveys, and dip-netting to record species presence/absence and breeding status. Data were then compared with a previous study that was conducted during the restoration process. We found a general increase in breeding activity and three species were found for the first time in the study area. Amphibians bred most frequently in ephemeral ponds on wetland meadows. Anthropogenic water bodies contained a similar number of species as natural sites did. Our results suggest that the increase in the amount of water in the river valley has had a positive effect on the local amphibian community.

Key words. Amphibia, wetland, habitat restoration, breeding success.

## Introduction

Wetlands are very sensitive ecosystems that play a crucial role in sustaining the lives of diverse groups of animals as well as man (Mitsch & Gosselink 2000, Baker et al. 2006). Today, though, wetlands are one of the most rapidly declining and altered habitats worldwide (Revenga et al. 2005). For many years, large-scale drainage works and riverbed reconstruction have been carried out to support agriculture and urban development, as well as to prevent flooding. This has resulted in the destruction of different habitats and caused changes in hydrological dynamics (Jenkins et al. 2003, Blann et al. 2009, Denton & Richer 2013). Because of this, the total area of wetlands around the world has declined significantly at a faster rate than that of other habitats (e.g., Mitsch & Gosseling 1993, Tamisier & Grillas 1994, Fasola & Ruiz 1996).

Declining wetland areas have serious consequences for amphibians, one of the most endangered groups of vertebrates on a global scale (Green 2003, Stuart et al. 2004, Pounds et al. 2006, Becker et al. 2007). It is predicted that at least one-third of all amphibian species could become extinct in the near future (Johnson 2006, Wake & Vredenburg 2008). One of the main reasons for the global decline of amphibian populations is the loss of their natural habitats (Pechmann & Wake 2005, Denton & Richer 2013). For example, oxbows, which serve as breeding places for water frogs of the genus *Pelophylax*, often become overgrown with reeds and shrubs as a result of land drainage and as a consequence unsuitable for the frogs (Berger 2008). Drainage also affects the hydroperiod (the time when wetlands are flooded), which is also the time when tadpoles and larvae complete their metamorphosis. The hydroperiod is often the primary wetland characteristic associated with amphibian species occupancy (Snodgrass et al. 2000, Babbitt et al. 2003).

In particular, amphibians are sensitive to changes in floodplains along rivers, as they are one of the most diverse, complex, and dynamic wetland ecosystems (Tockner et al. 2010) that sustain amphibian populations worldwide. This diversity is due to the heterogeneous structure of the river-floodplain ecosystem, which is itself shaped by unpredictable waterflows and flood regimes (Walker et al. 1995, Ocock et al. 2014). This allows floodplains to sustain various amphibian species with different habitat requirements. Unfortunately, floodplains are often used for agriculture or commercial purposes, which leads to a significant decline in amphibian populations (Cayuela et al. 2015). However, various restoration projects show that it is possible to recreate damaged wetland ecosystems and improve habitat conditions for amphibians and other wildlife (Chovanec et al. 2000, Lehtinen & Galatowitsch 2001, Pedersen et al. 2007).

The Narew River is one of Europe's few braided rivers, forming a precious river valley wetland ecosystem. It comprises several riverbeds that form a unique mosaic of river networks separated by braid bars. Historical data show that before the 1970s, the Narew had not been modified in any way (Suchowolec 2012). Unfortunately, large-scale drainage works destroyed natural wetland habitats in the 1970s and 80s. This caused a huge decline in local biodiversity, i.e., many bird and fish species native to this area became extinct (Banaszuk 1996). However, we lack data specifically regarding amphibian populations from before the time of these drainage works.

At the beginning of the 1990s, a restoration project was initiated in order to repair the damaged river system and restore the valuable natural marsh ecosystems of the Narew National Park and its buffer zone. During the later part of the restoration project, a herpetofaunal inventory survey was conducted (Sidoruk 2005), which provided the first view of the status of the local amphibian community after the drainage works.

Our study had two objectives: (1) to conduct an inventory survey of the amphibian fauna in an area where restoration works were conducted, and (2) compare the results of the current survey with the historical data from the earlier part of the restoration project in order to evaluate the longer-term effects of the restoration works on the amphibian community.

## Materials and methods

### Study area

Our study was conducted in the northeastern part of the marshy Narew River Valley (Podlaskie Voivodeship, Northeast Poland, 53.145029° N, 22.888573° E). The study area lies within the Narew National Park (NNP) buffer zone and borders the NNP on its northeastern side (Fig. 1). The NNP, as well as its buffer zone, is protected by the European Union's Nature 2000 Habitats Directive (PLB200001) and the RAMSAR Convention (RAMSAR ID: 1564). Our study site of about 1,500 ha was located within the borders of the NNP buffer zone where restoration works were conducted. It included riverbeds, oxbows, ephemeral floodplains on meadows of different agricultural uses and intensities, natural and anthropogenic water bodies, crop fields, and urban areas. The study area was divided into six plots (Fig. 1). This allowed us to compare our results with those of a previous survey, for which only qualitative data from plots I, IV, V, and VI of the NNP buffer zone were available (Table 1, Sidoruk 2005).

### Restoration works

Large-scale drainage works in the Narew River Valley were carried out in the 1970s and 80s. The restoration project aimed at restoring the river network system to its predrainage state (for details see Mioduszewski 1999, Suchowolec 2012). Land works were started between 1995

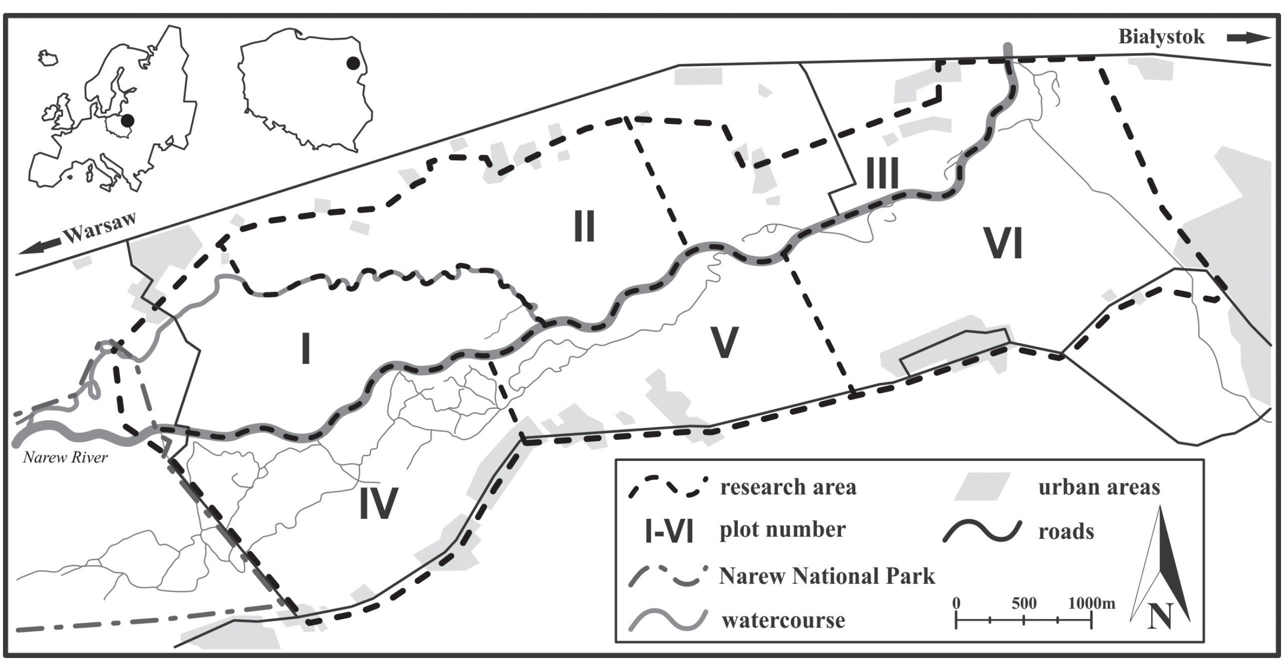


Figure 1. Study area in the Narew National Park buffer zone.

and 96. Two dams were built in the mouths of two old riverbeds that lead into the Narew in the SW part of the buffer zone (Fig. 2, squares). This slowed the outflow of water into the main Narew bed and allowed the land to sustain a nearly natural water level. In the next phase, riverbeds and oxbows were dug up and de-sludged – their regeneration played a significant role in the restoration project. Reconstruction of the river network system allowed larger volumes of water to flow through the valley. This was necessary to start renovation of the levee that connected the villages of Rzędziany and Pańki (Fig. 2, black line). In 2003, the flow of water was increased by replacing small pipe culverts buried within the levee with three wooden bridges on the riverbeds. During the next stage in 2007, two weirs were built near the village of Radule in the NNP (Fig. 2, rectangles). This diverted larger volumes of water from the main Narew bed towards the levee and into riverbeds in the northern and southern parts of the buffer zone (Fig. 2, arrows). It also increased the amount of water flowing through the old main riverbed located in the NW part of the buffer zone (Table 2). The increased flow of water regenerated riverbeds and oxbows, as well as increased the water level and inhibited marsh formation in the river valley (Suchowolec 2012). In addition to the reconstruction of the river network, work was carried out that allowed for extensive agricultural usage of the river valley and so considered the needs of local farmers. Water holes for livestock were created in the meadows to promote pastures for the traditional Polish red cattle. Studies of the effects of the restoration works suggest that the redirection of water to old riverbeds has restored damaged parts of the Narew Valley ecosystem (Jekatierynczyk-Rudczyk 2012, Suchowolec 2012).

## Survey methods

A herpetofaunal survey was conducted during the amphibian breeding season in 2011. Inventory techniques were selected to mirror those of previous studies conducted between 2000 and 2004 (Sidoruk 2005). We sampled the amphibian communities of all natural and anthropogenic water bodies, which were grouped into three habitat categories: (I) ephemeral ponds on meadows, (II) riverbeds and oxbows, and (III) anthropogenic water bodies (Fig. 3). We used three terrestrial and aquatic inventory techniques (Dodd 2010) to assess species presence/absence and the number of individuals as well as their breeding activity. (1) Visual encounter surveys (VESs) – we used this method to count all mature amphibians in the water bodies (to two metres from shoreline). Specifically, this involved one person searching for amphibians that were active on the surface in a particular area for half an hour each. VESs were conducted on three occasions, in April, May, and July.

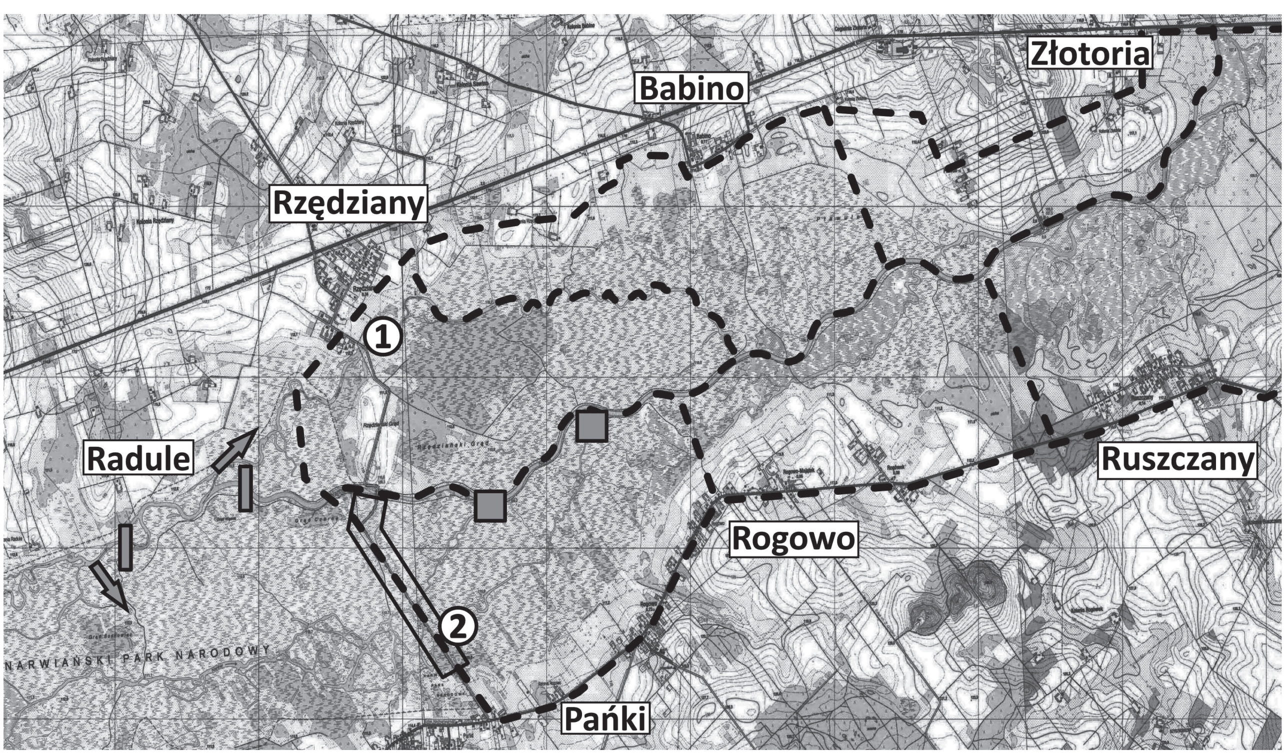


Figure 2. The Narew River Valley after drainage works, with locations of land restoration works marked. Map represents the local area after 1996 (date of creation of the Narew National Park). Dashed line – research area and plot borders; 1, 2 – points of water flow measuring; solid black outline – the reconstructed Rzędziany-Pańki levee; squares – dams; rectangles – weirs; arrows – change in the direction of water flow.

(2) Manual calling surveys (MCSs) – this method consisted of listening for the vocalisations of male anurans near water bodies. The MCSs were conducted on three occasions in May and June at night, from half an hour after sunset until midnight. We used MCSs only for qualitative reasons, i.e., to detect species presence/absence in a particular area. (3) Dip-netting – we used this method to capture anuran tadpoles, newt larvae, and adult newts of particular species in order to record species presence/absence. Dip-netting was performed on three occasions, in June and July.

We conducted surveys in weather conditions that were favourable for observing amphibians, i.e., on warm and humid days. We defined breeding sites as water bodies in which we observed evidence of breeding activity of any amphibian species: spawn, larvae, juvenile individuals, calling males, or mating individuals. Considering the difficulties inherent in identifying the spawn, tadpoles, and juvenile individuals of species belonging to the genera *Rana* and *Pelophylax* (Berger 2000), we assigned them to groups as brown frogs (BF, genus *Rana*) or green frogs (GF, genus *Pelophylax*). We computed the percentage of breeding sites (S) for each species according to the formula

$S = (BSs/BS) \times 100\%$,

where *BSs* was the number of breeding sites of a particular species and *BS* was the total number of breeding sites.

In order to properly compare our data with those of the previous survey, we adopted the same frequency of sampling. Moreover, we used only qualitative data when analysing the results of our study together with historical data (Sidoruk 2005). Thus, we compared the presence of a species and its breeding status on plots I, IV, V, and VI. We did not compare quantitative data due to the different field personnel involved in each survey.

## Results

We made a total of 2,561 observations of mature amphibians, representing twelve species that occupied 397 water bodies (221 were classified as breeding sites). Amphibians were observed mainly in the ephemeral ponds on meadows (N = 226, 56.9% of observations), while riverbeds/oxbows and anthropogenic water bodies were inhabited less frequently (N = 129, 32.5% and N = 42, 10.6%, respectively). Eleven species were observed in the ephemeral ponds on meadows, ten in anthropogenic water bodies, and eight within riverbeds and oxbows.

We encountered 1110 mature brown frogs (genus *Rana)*, which accounted for 43.3% of all amphibians observed. Only mature frogs could be identified to species level. *Rana temporaria* and *Rana arvalis* comprised 10.7 and 6.2% of all brown frogs, respectively. We found 82 brown frog breeding sites (S = 37.0% of all amphibian breeding sites, Fig. 4), of which 58 were situated on ephemeral ponds, mainly in plots I, II, III, and VI. Breeding of *R. temporaria* in plots IV and VI was confirmed for the first time, while attempted breeding (mating calls) was observed in plot I (Table 1). In plot V, only adult individuals were observed, as had been reported in historical observations (Table 1). The breeding status of the *R. arvalis* population also improved compared to the previous study, in which only adult individuals had been observed. We confirmed breeding in plot I and attempted breeding was observed in plots IV and V, whereas

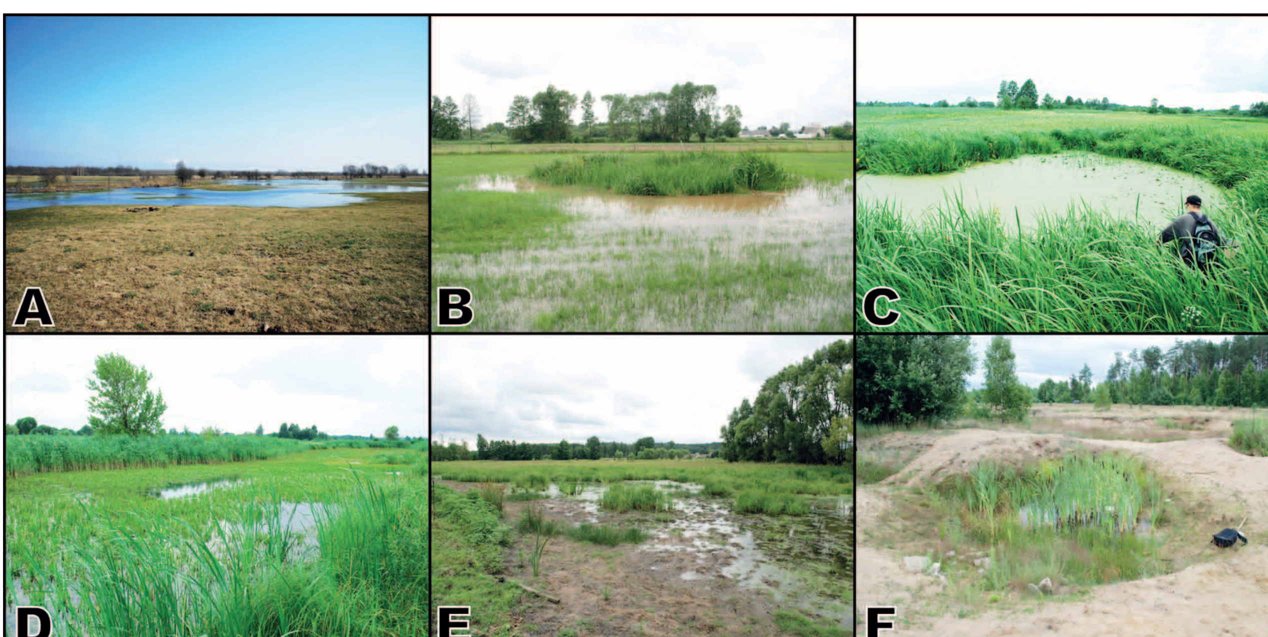


Figure 3. Examples of amphibian breeding sites. (A) Ephemeral pond in April; (B) ephemeral pond in June; (C, D) Narew River oxbows; (E) anthropogenic water body; (F) anthropogenic water body in a gravel pit.

Table 1. Occurrence and breeding status of amphibian species in the study area (2011, white background) in comparison to historical data (grey background, Sidoruk 2005). Plots according to Figure 1. No historical data exist for plots II and III. 0 – species was absent; 1 – species present but no breeding activity was observed; 2 – male advertisement calls were detected; 3 – reproduction was confirmed (i.e., spawn, larvae, individuals in amplexus, or recent metamorphs observed); *Tc* – *Triturus cristatus*; *Lv* – *Lissotriton vulgaris*; *Bo* – *Bombina bombina*; *Pf* – *Pelobates fuscus*; *Bb* – *Bufo bufo*; *Pv* – *Pseudepidalea viridis*; *Ec* – *Epidalea calamita*; *Ha* – *Hyla arborea*; *Rt* – *Rana temporaria*; *Ra* – *Rana arvalis*; *Pe* – *Pelophylax esculentus*; *Pl* – *Pelophylax lessonae*. * – reproduction confirmed by observation of amplectant individuals.

| Species | Plot | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | I | | II | III | IV | | V | | VI | |
| | 2005 | 2011 | 2011 | 2011 | 2005 | 2011 | 2005 | 2011 | 2005 | 2011 |
| *Tc* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| *Lv* | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 0 | 3 |
| *Bo* | 0 | 2 | 2 | 0 | 3 | 0 | 3 | 2 | 0 | 2 |
| *Pf* | 0 | 0 | 0 | 1 | 3 | 2 | 3 | 2 | 1 | 2 |
| *Bb* | 1 | 2 | 2 | 1 | 3 | 2 | 3 | 2 | 1 | 2 |
| Pv | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| *Ec* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| *Ha* | 0 | 0 | 2 | 0 | 1 | 2 | 3 | 2 | 1 | 3 |
| *Rt* | 1 | 2 | 3* | 3* | 1 | 3* | 1 | 1 | 1 | 3* |
| *Ra* | 1 | 3* | 2 | 1 | 1 | 2 | 1 | 2 | 1 | 1 |
| *Pe* | 1 | 2 | 2 | 2 | 3 | 3* | 3 | 3* | 1 | 3* |
| *Pl* | 1 | 2 | 2 | 2 | 3 | 2 | 3 | 2 | 1 | 2 |
| Number of species | 5 | 6 | 7 | 6 | 8 | 8 | 9 | 11 | 7 | 10 |

the situation in plot VI remained unchanged (only adults observed, no breeding; Table 1).

Green frogs (genus *Pelophylax)* were the second largest group of amphibians encountered in the NNP buffer zone. We observed 985 mature individuals, of which 34.2% were identified as *Pelophylax esculentus* and only 4.3% as *Pelophylax lessonae*. We found 62 (S = 28.0%, Fig. 4) breeding sites of both species. Green frogs bred mainly in oxbows and anthropogenic water bodies located in the southern part of the study area (Fig. 4). In contrast to previous surveys, we recorded mating calls of *P. esculentus* in plot I and confirmed breeding in plot VI (Table 1). For *P. lessonae*, though, we did not confirm breeding in plots IV and V, where it had been observed in the previous study (Table 1). However, breeding attempts of this species were recorded for the first time in plots I and VI (Table 1).

*Bufo bufo* was the most common toad in the study area, and 321 individuals were observed (12.5% of all amphibians). It reproduced at 24 sites (S = 10.9%, Fig. 4), mainly in oxbows and riverbeds. Breeding attempts of *B. bufo* were observed in plots I, II, IV, V, and VI. We did not observe breeding in plots IV and V, which had been reported in the previous study. However, the breeding situation had improved for this toad in plots I and VI (Table 1). The remaining two species of toads that we report here were observed in the study area for the first time, in plot V (Table 1). We found *Pseudepidalea viridis* in two ephemeral ponds and *Epidalea calamita* in one. The observed individuals were calling males that were located during MCSs, which suggests breeding activity.

*Bombina bombina* was also located during MCSs. This species was found at 16 sites (S = 7.2%, Fig. 4). It mainly occupied flooded meadows in plots II, V, and VI, but advertisement calls were heard also from oxbows (plots I and VI) and reservoirs (plot VI). In plots I and VI, the occurrence of *B. bombina* and its breeding attempts were observed for the first time (Table 1). Unlike the previous study, though, we did not observe breeding in plot V and failed to detect individuals of this species in plot IV (Table 1).

*Hyla arborea* occurred in flooded meadows and anthropogenic water bodies, mainly in the southern part of the study area. This species was observed at 23 sites (S = 10.0%, Fig. 4). We confirmed breeding of *H. arborea* in plot VI, while breeding attempts were noticed in plot IV (Table 1). We did not confirm breeding in plot V, where only advertisement calls were noted (Table 1).

*Pelobates fuscus* was observed during MCSs at six sites (S = 2.3%, Fig. 4), in reservoirs and floodwaters on wetland meadows in the southern part of the study area. The breeding status of this species had improved only in plot VI, where breeding attempts were noticed (Table 1). We did not confirm breeding in plots IV and V (Table 1).

Both species of newts that were recorded in our survey were observed only in reservoirs in the southern part of the study area. *Lissotriton vulgaris* reproduced at six sites, with new populations found in plots IV and VI, whereas *Triturus cristatus* bred only at one site, in plot VI, and is reported here for the first time (Table 1).

We found a general improvement in both breeding status and number of species. Comparison with the historical

Table 2. Water flow in two restored oxbows (Fig. 2) measured before (1992–1993; Mioduszewski et al. 2002) and after (2011; Jekatierynczyk-Rudczyk 2012) the restoration works. Precipitation measured at the weather station in Białystok (20 km from study area), representing total rainfall and snowmelt from January to July in a given year (Global Climate Data, Tutiempo Network. Available from http://www.tutiempo.net, accessed 10.10.2015). *W* – measurements conducted in spring (April); *S* – measurements conducted in summer (92/93 – June, 2011 – July); N/A – data not available.

| Year | Water flow ($m^3/s$) | | | | Precipitation (mm) |
|---|---|---|---|---|---|
| | Oxbow 1 | | Oxbow 2 | | |
| | W | S | W | S | |
| 1992 | N/A | 0.64 | N/A | 0.33 | 231.20 |
| 1993 | 1.58 | 1.14 | 3.94 | 0.39 | 246.94 |
| 2011 | 4.93 | 2.34 | 1.21 | 1.02 | 279.41 |

data for plot I shows that the breeding status of five species had improved and one new species was observed (Table 1). We found one new species in plot IV, but failed to detect another that had been reported in the previous study. Moreover, the breeding status of three species had improved in this plot, but declined for the three other species present (Table 1). We did not confirm breeding of five species in plot V that had been reported in the previous study (Table 1). Nevertheless, calling males of two new species and *R. arvalis* were observed in this plot for the first time (Table 1). In plot VI, the previous survey had reported the presence of only adults of seven species. We were able to confirm breeding for three of them, and noticed breeding attempts for another three (Table 1). We observed three new species in plot VI, with breeding for two of them (Table 1).

## Discussion

Our results showed a general increase in the number of species as well as improvement in their breeding status in the studied area during ongoing restoration. Two species of toads, *P. viridis* and *E. calamita*, and one species of newt, *T. cristatus,* were recorded for the first time in the study area. The breeding status of amphibians had improved in plots I and VI while species diversity had improved in three out of the four plots for which historical data exist (Table 1). Additionally, several species were observed at a larger number of sites than in the previous study. This trend was particularly pronounced for *B. bombina* and other species that breed in ephemeral ponds. In the previous

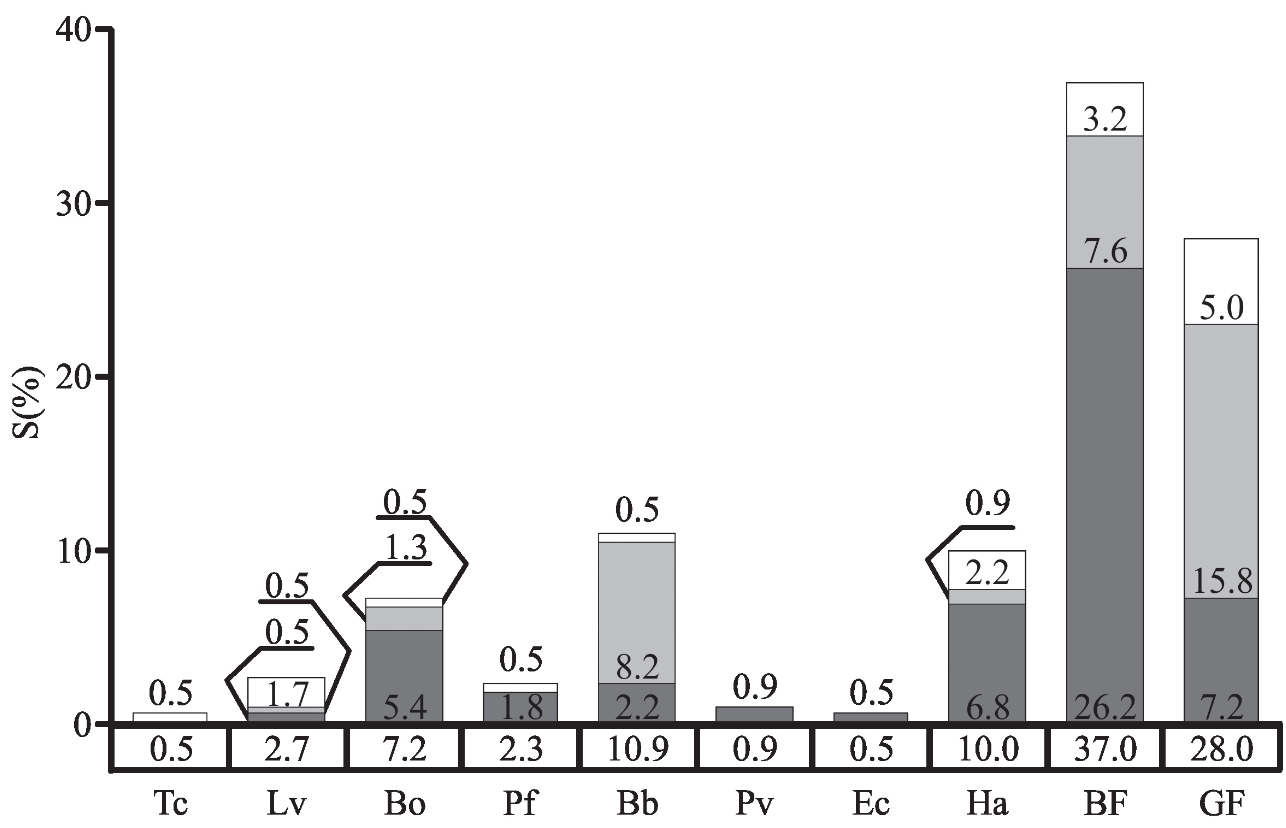


Figure 4. The percentage of all breeding sites (S) (total number = 221) occupied by particular amphibian species in the study area in 2011. Species names according to Table 1. Colours represent breeding habitats: dark grey – ephemeral ponds; light grey – riverbeds and oxbows; white – anthropogenic water bodies. Species representing the genera *Rana* (BF) and *Pelophylax* (GF) were pooled to genus.

study, Sidoruk (2005) found *B. bombina* only at four sites in two plots. Our study confirmed its presence at 16 sites in four plots, a fourfold increase in site occupancy. Other species, such as *R. temporaria* or *R. arvalis*, also displayed an improved breeding status in the study area (Table 1).

The available data clearly indicate that restoration works have improved the water flow and therefore increased the water level in the valley: water flow measured in the summer of 2011 in two oxbows was significantly higher than in the years before the restoration project (1992–1993) (Table 2). We suggest that the increased water level has prolonged the hydroperiod, which is extremely important for species such as *R. temporaria*, *R. arvalis*, and *B. bombina*, because they breed in ephemeral ponds that are highly susceptible to drying up (especially in summer). It must be emphasised that precipitation – that directly influences the water flow – did not differ substantially between the years used for comparison (Table 2).

Data from other studies confirm that the hydroperiod is one of the primary characteristics linked with the amphibian species occupancy of wetlands. A prolonged hydroperiod has a positive impact on species richness in general, determining both the breeding success and the occurrence of rare species (Beja & Alcazar 2003, Baldwin et al. 2006) as well as influencing the distribution of amphibian larvae (Babbitt et al. 2003). Some species can adjust to a shortened hydroperiod by accelerating their metamorphosis (Loman 2002), while others cannot (Amburgey et al. 2012). Accelerated metamorphosis can cause a reduction in body size through a trade-off between time spent in development and body size (Loman & Claesson 2003), which can lead to decreased chances of individual survival. It has been demonstrated that an increased water level on meadows affects the occurrence of amphibians (Roche et al. 2012), and wetland desiccation causes a severe decline in amphibian species richness (McMenamin et al. 2008).

We cannot entirely exclude the explanation that increased breeding activity as compared to the previous study was the result of other factors (e.g., differences in spring flooding, changes in precipitation over the years, or methodological issues such as skill level of the field personnel). It is doubtful, though, that these factors may have significantly influenced the comparison of qualitative data. With regard to personnel issues, the species observed in this region are fairly easy to detect even for a person with only basic field experience in amphibian surveying. Instead, it is likely that our data underestimate the positive effects of the restoration project, as the data used for comparison come from a period of time after the restoration project had already begun. Unfortunately, there is no information about the structure of amphibian populations from this region at any time prior to the restoration works.

Our study showed an unequal distribution of amphibian species across the NNP buffer zone. Less-frequently observed species like *L. vulgaris*, *H. arborea*, or *P. fuscus* were found only or mainly in the southern part of the study area (Table 1). This may be an effect of the more heterogeneous habitat distribution in those locations, which makes plots IV, V, and VI suitable for sustaining a more diverse amphibian community. In contrast, the northern plots were more homogenous, with the presence of a large forest and greater agricultural land area. The unequal distribution of amphibian species could be also an effect of isolation of the amphibian populations that live in the northern parts of the study area in plots I, II, and III. This region contains busy roads, and rivers can be barriers that restrict free migration to and from breeding sites (Zhao et al. 2009, Fouquet et al. 2012, Canessa & Parris 2013). This prevents gene flow and can affect the structure of an amphibian population, even leading to its extinction. Existing research shows that roads crossing through wetlands have the highest kill rates for amphibians (Forman & Alexander 1998), even though individuals may try to avoid them (Fahrig et al. 1995). Garcia–Gonzalez et al. (2012) showed that even small roads with low-intensity traffic act as barriers to amphibian migration. Also, anthropogenic noise from roadway traffic interferes with animal behaviour by masking male calls and weakening the females' perception of them, which can affect amphibian breeding success (Bee & Swanson 2007, Nityananda & Bee 2012).

Ephemeral ponds play an important role in the breeding success of amphibian communities, as they serve as the most common breeding sites for a large number of the species observed here (Fig. 4). These ponds were frequently used for breeding by common species, such as *R. temporaria* and *R. arvalis*, as well as rarer species such as *B. bombina*. Likewise, anthropogenic ponds played a significant role in the maintenance of local amphibian populations. Although they accounted for only 10.6% of all breeding sites, anthropogenic ponds were used by 10 of the 12 species that we observed, including *T. cristatus*, *B. bombina*, and *L. vulgaris*. Similar results were reported in a study by Le Viol et al. (2013), in which artificial highway ponds exhibited a similar richness in species as surrounding natural ponds, but with a lesser abundance of individuals. This could be because small anthropogenic ponds are often free of predators. Also, the water in those ponds heats up more quickly, which provides optimal conditions for breeding earlier in the season (Chester & Robson 2013). Together, these data emphasise the role of anthropogenic ponds in amphibian communities and the extent to which they contribute to biodiversity preservation at a local scale.

In conclusion, our study demonstrates that the restoration of a damaged river valley ecosystem has improved the condition of the local amphibian community, increasing the number of species and their breeding activity through the improvement of habitat quality.

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