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Changes in a regional batrachofauna in south-central Poland over a 25 year period

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Abstract. Amphibians are a globally endangered group of vertebrates. Incomplete occurrence data preclude both assessments of the scale of the declines and effective amphibian conservation. In this paper we present the results of an inventory of 71 amphibian breeding localities conducted in 2006-2008 in south-central Poland (Nida basin and Vistula river valley). We report presence/absence data for 14 amphibian species representing a typical Central European lowland batrachofauna. We then compare our findings with previous studies conducted in this area in 1979-1984. Overall, the number of species per site declined by 2.2 species. Four (*Triturus cristatus*, *Lissotriton vulgaris*, *Rana temporaria* and *Pelophylax lessonae*) of 15 taxa showed a significant loss in number of populations with a further three species (*Bombina bombina, Bufo bufo*, *P. esculentus*) showing a marginally significant decline. One species, *Pelophylax ridibundus,* showed a recent expansion. The local distributions of some species (particularly *Triturus cristatus*, *Pelobates fuscus*, *Pelophylax lessonae* and *P. ridibundus*) have changed considerably during the 25 year period between inventories. Possible explanations of the decline in amphibian populations in south-central Poland include loss of breeding sites (ponds) due to irrigation, fish introduction, and increased amphibian mortality on account of greater traffic volume.

Key words: amphibian decline, Anura, distribution, Poland, habitat change.

Introduction

Amphibians are declining globally at a higher rate than other groups of vertebrates (Baillie et al. 2004). The most important factors affecting amphibian populations include habitat loss and alteration, disease, environmental pollution, UV radiation and alien species introduction (Alford & Richards 1999, Collins & Storfer 2003). A synergism of these factors may be the most probable reason of amphibian population declines (Collins & Storfer 2003), as in the case of climatic conditions associated with *Batrachochytrium dendrobatidis* virulence (Pounds et al. 2006, Bosch et al. 2007). Some of these factors may work globally (i.e. climate change, diseases) but in general the influence of local human activity is also important, i.e. through habitat loss, fragmentation and urbanization (Hamer & McDonnell 2008). Decreasing amphibian population trends have also occurred in Europe. These have been attributed to habitat loss (Beebee 1997, Rybacki & Berger 2003, Wood et al. 2003, Maletzky et al. 2007), habitat fragmentation and associated inbreeding effects (Andersen et al. 2004), changes in physiology and phenology due to climate warming (Terhivuo 1988, Reading 2007), disappearances due to predator introduction (Brönmark & Edenham 1994, Denoël et al. 2005, Cruz et al. 2006, Orizaola & Brana 2006) and climate change connected with disease (Bosch et al. 2007).

In the context of global threats to biodiversity, knowledge on the occurrence of organisms becomes especially important. Faunistic data based on field inventories are essential for monitoring and distribution modeling in recognition of global environmental change and in consequence, are essential for successful conservation planning (Benayas et al. 2006, Cogălniceanu et al. 2006) and restoration (Rannap et al. 2009). Thus, a lack of sufficient information on the occurrence of species precludes effective assessment of population trends and their conservation.

A total of 18 amphibian species occur in Poland. All have been given legal protection (EU Habitats Directive, Polish law) and figure in the IUCN Red List in the least concern category (LC) and most (with the exception of five species: *Lissotriton vulgaris*, *Bufo bufo*, *Pelophylax ridibundus*, *Rana arvalis*, *Rana temporaria*) show negative population trends across their distribution (Temple & Cox 2009). Two species (*Triturus cristatus* and *Rana dalmatina*) are noted as near threatened (NT) in the Polish Red Data Book of Animals. In the Atlas of Amphibians and Reptiles of Poland (Głowaciński & Rafiński 2003) historical and current presence/absence data from many sources including literature, academic theses and personal observations have been summarized. Data on the occurrence of amphibian species cover only 60% of the area of the country (calculated as the ratio of solid to empty Atlas grids). However, there are a few protected landscape parks that were studied in detail (Rybacki & Berger 1997, Pabijan & Przystalski 2003, Błażuk 2004, Łoban et al. 2004, Dąbrowski & Strużyński 2006, Hermaniuk et al. 2006, Wojdan 2007). Nonetheless, there is still a need for detailed amphibian inventories as species absences' in map grids may not be the effect of their absence in particular areas but may represent places in which amphibian inventories have not been conducted or in which species have not been detected (i.e. false absence). Remarkably, even well studied areas in Poland have recently revealed unknown populations of some species (Szymura & Rafiński 1997, Starzyk & Durak 2007, Pabijan et al. 2009). More importantly, revising historical, baseline data is as essential as providing new species occurrence data and, apart from resource-intensive monitoring, is the only way to assess changes in population trends.

To date, comparative studies on amphibian populations at a regional scale have not been conducted in Poland. However, there were attempts at monitoring local demographic changes in amphibians (summarized in Głowaciński 2003, Głowaciński & Rafiński 2003), mostly in the western part of the country. Recently, the monitoring of species and habitats has been initiated in accordance with the Habitats Directive. This project includes one amphibian species, *T. cristatus*, and is an opportunity for assessing demographic trends as well as habitat change at a country-wide scale (Makomaska-Juchiewicz et al. 2009, Pabijan 2009). In this contribution, we present (i) the results of an amphibian inventory in south-central Poland conducted in 2006-2008, and (ii) a regional scale and multispecies comparative analysis of amphibian population trends over a *ca*. 25 year period at the study sites.

Methods

Study area

The Nida basin is a subregion of Małpolska Upland (south-central Poland, see map Fig. 1). The entire study area is enclosed between (50.936°N; 20.012°E) and (50.069°N; 20.067°E) in the west and (50.9740°N; 21.845°E) and (50.101°N; 21.869°E) in the east. Southwards, the Nida basin adheres to the Vistula river valley, a part of which was also included in this study. Although most of the region is classified as uplands, only 9% of the area lies above 300m a.s.l. (Cabaj & Nowak 1986). Land use is mostly agricultural, with less than 20% forest cover remaining (Oczoś & Strzelec 1986). Local industry includes sulfur mines in the southeast, cement mills in the north and steelworks in the west. The human population density is ca. 88.18 person/km^2 (www.stat.gov.pl). The entire study area encompassed *ca*. 5000 km^2. The amphibians and reptiles of the Nida basin are well known due to herpetofaunal inventories in 1979-1984 during which 188 localities were surveyed (Juszczyk et al. 1988, 1989). Research on amphibian distributions and densities was also conducted at the end of the 20th century along a small transect of the Nida river Valley (Krzyściak-Kosińska 2001). Breeding sites of amphibians in this region consist mainly of artificial ponds such as sand-pits, clay-pits, ditches, small fish ponds, large complexes of fish ponds and ditches as well as natural water bodies including oxbow lakes, karst lakes and small depressions filled with water during spring and summer floods. Most natural water bodies are distributed along the Nida and Vistula rivers. For simplicity, we refer to the Nida basin and the adjacent part of the Vistula river valley as the Nida basin.

Species inventories

Juszczyk and coworkers (1988, 1989) searched for amphibians in 188 localities (this study defined a locality as an area of unspecified extent surrounding villages). Each locality was surveyed at least twice and included various water bodies (all taxa are pond breeding amphibians) as well as terrestrial habitat. Juszczyk et al. (1988, 1989) aimed to maximize the probability of species detection and searched as many breeding sites at each locality as possible. Lists of detected amphibian species were then published as presence/absence data (Juszczyk et al. 1988, 1989). Between 2006-2008 (three seasons) we resurveyed 71 of these localities (Fig. 1, supplementary Tables 1 and 2). The majority of inventories at these localities were conducted between April and June. We focused on breeding sites within localities surveyed in 1979-1984 or in their close environs. Water bodies were localized using satellite maps (Google Earth), aerial photographs available at www.geoportal.gov.pl/ and topographic maps (1:100 000). All surveyed localities are between 140–270m a.s.l. (supplementary Table 1), with the exception of a single site at 395m (Tunel) that has been extensively described elsewhere (Pabijan et al. 2009).

Many amphibian breeding sites have disappeared since 1984 (W. Zamachowski, pers. comm.) but some new water bodies have been created (M. Bonk, unpubl.). Unfortunately, neither detailed maps nor GPS coordinates of particular sites are available from the historic study. Thus, some of the breeding ponds surveyed in 2006-2007 may not coincide precisely with historical water bodies, but nonetheless are mostly located in their vicinities (less than 1km).

Surveys conducted in 2006-2007 consisted of at least two visits (supplementary Tables 1 and 3) at each locality with the intent of conducting the first survey in early spring and the second in late spring/early summer in order to maximize the detection of early and explosive breeding species as well as amphibians with extended breeding seasons. Eggs, larvae, juvenile and adult specimens were recorded by visual inspections as well as by dip-netting. Captured amphibians were identified and immediately released. We also recorded calling anuran species. Additionally, terrestrial habitat near ponds was investigated and the occurrence of individuals dead on roads was noted. The eggs and larvae of *Triturus cristatus*, *Lissotriton vulgaris*, *Bombina bombina*, *Pelobates fuscus* and *Hyla arborea* were identified in the field. Species detectability was assessed by counting the number of visits required to detect each species and by calculating a species accumulation curve based on number of localities and number of species in EstimateS v8.2 (Colwell 2009).

To avoid problems with *Pelophylax sp.* misidentification, the *P. esculentus* complex (including *P. lessonae*, *P. ridibundus* and *P. esculentus*) was added as an additional taxonomic category. This category was used if specimens difficult to identify were encountered in the field, as well as if any of these three species were detected.

Statistical analysis

We calculated the mean number of species per site for the historical data (Juszczyk et al. 1988, 1989) and for the present-day data. The differences between mean number of species per site between Juszczyk and coworkers (1988, 1989) and the results of the 2006-2008 inventory were tested using a Students pairwise test performed in MS Excel. Jaccard coefficients and simple matching coefficients were calculated to compare the historical and present species distributions (Heyer et al. 1993).

A colonization event was invoked if a species was absent at a site in the historical inventory of 1979-1984 (Juszczyk et al. 1988, 1989), but was present in the 2006-2008 survey. Extinction was defined as the presence of a species at a particular site in the historical study and its absence in 2006-2008. The number of populations of a species was considered stable if the numbers of colonization and extinction events were similar (i.e. a null hypothesis of an equal number of colonization and extinctions was assumed). If the number of extinctions was higher than the number of colonizations, a species was considered to be in decline. In contrast, a higher number of colonizations reflected a positive trend. Note that this approach is similar to the metapopulation (*sensu* Hanski & Gilpin 1997) approach of e.g. Crochet et al. (2004). However, we do not specifically assume metapopulation structure for each surveyed amphibian species because our study area is probably much larger than metapopulations of most pond breeding, temperate amphibians. Therefore, we examine long term trends in numbers of populations over a relatively large regional scale by recording presence/absence data for an amphibian assemblage from a large number of localities.

Differences in number of colonizations and extinctions were tested using chi square tests performed in MS Excel. Due to the high number of species and sites, and the possible non-independence of extinctions or colonizations between species, we also applied a sequential

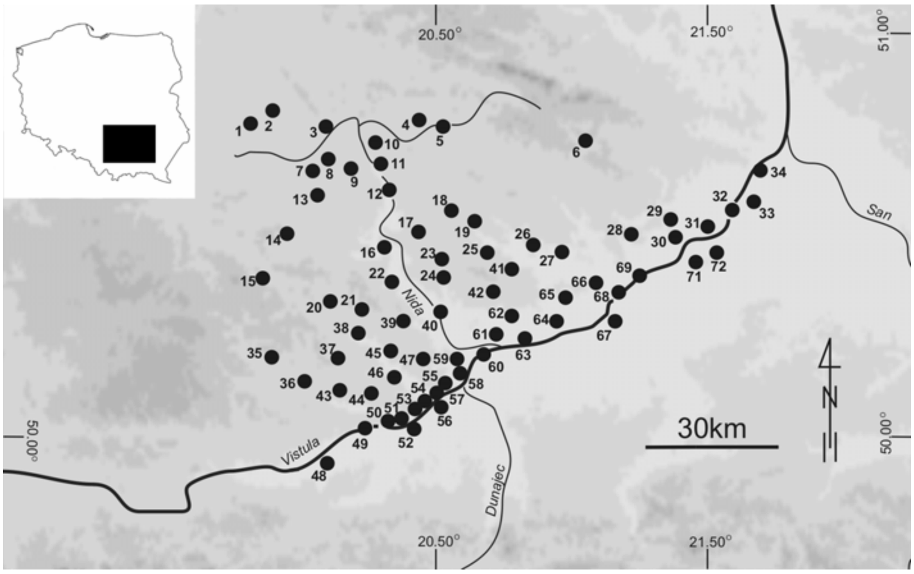

Figure 1. Distribution of the localities in the Nida basin and adjacent part of the Vistula River Valley surveyed in 2006-2008: 1) Sułków, 2) Krasocin, 3) Wola Teserowa, 4) Piaseczna Górka, 5) Marzysz, 6) Wola Malkowska, 7) Cierno-Żabieniec, 8) Chorzewa, 9) Raków, 10) Sobków, 11) Korytnica, 12) Motkowice, 13) Łysaków, 14) Łany, 15) Tunel, 16) Skrzypiów, 17) Podłęże, 18) Holendry, 19) Ciecierze, 20) Działoszyce, 21) Drożejowice, 22) Chroberz, 23) Łatanice, 24) Chotel Czerwony, 25) Widuchowa, 26) Jarząbki, 27) Niziny, 28) Strzegom, 29) Osiek, 30) Mikołajów, 31) Długołęka, 32) Chodków, 33) Zakrzów, 34) Sielec, 35) Brończyce, 36) Gniazdowice, 37) Ostrów, 38) Skalbmierz, 39) Soboszów, 40) Wiślica, 41) Kołaczkowice, 42) Smogorzów, 43) Dalechowice, 44) Wojsławice, 45) Kazimierza Wielka, 46) Podolany, 47) Piotrkowice, 48) Ispina, 49) Jaksice, 50) Morsko, 51) Witów, 52) Dąbrówka Morska, 53) Sokołowice, 54) Przemyków, 55) Urzuty, 56) Wola Przemykowska, 57) Rogów, 58) Opatowiec, 59) Senisławice, 60) Podraje, 61) Nowy Korczyn, 62) Zagórzany, 63) Błotnowola, 64) Oblekoń, 65) Beszowa, 66) Ruszcza, 68) Rybitwy, 69) Zawada, 70) Krzemienica, 71) Zaduszniki.

Bonferroni correction for multiple tests in the final analysis.

For *Pelophylax* taxa, we acknowledged the possibility of misidentification by treating the complex as a separate taxonomic group in two ways: (i) inclusion of the group (*Pelophylax esculentus* complex) as an additional taxon (ii) inclusion of *Pelophylax esculentus* complex in analyses with the simultaneous exclusion of the three *Pelophylax* taxa.

Results

Species occurrence and distribution in 2006-2008

During three survey seasons (2006-2008; nearly 240 hours spent at 71 localities; two to six hours/person at each locality) in the Nida basin, a total of 14 amphibian species (15 taxa with *P. esculentus* complex) were detected among the 18 occurring in Poland. Species occurrence data for each locality is given in supplementary Table 2. Excluding the *P. esculentus* complex as a separate taxonomic category, the number of species per locality ranged from 0 (four localities) to 9 (six localities, Fig. 2). Detailed information on the distribution and numbers of populations of each species can be found in supplementary Table 2 and supplementary Figures 1-15. Common species include *Bufo bufo* found in 76% of the surveyed localities, *R. temporaria* (67.6%), *H. arborea*

(49.3%), *B. bombina* (43.7%), *P. esculentus* (43.7%), *L. vulgaris* (40.8%), *R. arvalis* (42.2%), *Pseudepidalea viridis* (33.8%) and *Pelobates fuscus* (29.6%). Two relatively uncommon species, *P. lessonae* and *P. ridibundus,* were found only in 18 (25.3%) and 17 (23.9%) localities, respectively. *P. lessonae* was detected mostly in the central and eastern parts of the region, whereas the distribution of *P. ridibundus* was limited to river valleys (supplementary Figures 12 and 14). *T. cristatus* was relatively uncommon (21.1% of surveyed localities) and was absent from the western part of the Nida basin. The rarest species were *Epidalea calamita*, found only in two localities 4km distant from each other in the eastern part of the study area, and *Mesotriton alpestris* with only one locality (Tunel) in the most western part (supplementary Fig. 3).

<u>Changes in community structure</u>

We compared presence/absence data for each species noted in 1979-1984 (Juszczyk et al. 1988, 1989; supplementary Table 2.) with the survey results from 2006-2008. We detected all of the 14 species (15 taxa with *P. esculentus* complex) found in 1979-1984. However, most species decreased in number of occupied localities (Table 1). The mean number of species per locality decreased significantly when compared to historical data. These means were significant with the inclusion of *P. esculentus* complex as a taxonomic category (8.0 [1SD: 2.8] and 5.8 [1SD: 3.0], means and their standard deviations for historical and present data, respectively; t-test, P<0.0001), and also when only one category (*P. esculentus* complex) was used for *P. lessonae*, *P. ridibundus* and *P. esculentus* (6.6 [1SD: 2.3] and 4.9 [1SD: 2.6]; t- test, P<0.0001). The net change in species number is shown in Figures 3. On average, the number of species per locality declined by 2.2 (calculated with the inclusion of the *P. esculentus* complex as a separate category), or 1.7 (Fig. 3) when a single category (*P. esculentus* complex) was used for water frogs.

Failure to detect a species that does reside in a given locality (i.e. false absence) will underestimate the species richness of a site. Thus, we conducted an additional analysis comparing the mean number of species per site with the exclusion of declining species that may be in our opinion difficult to detect. We excluded *T. cristatus*, *L. vulgaris* and *P. lessonae*. For both scenarios involving the differential treatment of the *P. esculentus* complex, the mean number of species per site was still significantly higher in 1979-1984 than in 2006-2008 (5.9 [1SD: 2.1] and 4.9 [1SD: 2.5]; P=0.011), including *P. esculentus* complex as a separate taxonomic category; (5.3 [1SD: 1.8] and 4.3 [1SD: 2.2]; P=0.003) with only *P. esculentus* complex used for water frogs (all probabilities based on t-tests).

A total of 11 of 15 taxa (including *P. esculentus* complex*)* showed negative population trends (Table 1). However, four species, *T. cristatus, L. vulgaris, R. temporaria* and *P. lessonae* revealed significant declines in numbers of populations after sequential Bonferroni correction (Table 1). Declines in three other species, *B. bombina*, *B. bufo* and *P. esculentus,* were significant before Bonferroni correction (i.e. at the level of 0.05) but not after correction. One species, *P. ridibundus,* significantly increased in number of populations. *M. alpestris* occurred only in two historical and one present locality, whereas *E. calamita* was present in two historical and two present localities. Thus, assessing the significance of differences between colonizations and extinctions in these two species was not meaningful.

<u>Shifts in local distributions</u>

The similarity between historical and present local distributions of amphibian species in the study area was assessed by calculating Jaccard's coefficients. Identical species distributions yield a Jaccard coefficient of 1, whereas distributions that show no overlap between years have a 0 value. As an alternative measure, we also calculated the simple matching

Table 1. Summary of amphibian population data from the Nida basin. Number of occupied sites for two survey periods (1979-1984 and 2006-2008) and extinction/colonization events for each taxon calculated from a total of 71 localities. Probability of rejecting the hypothesis of equal numbers of colonizations and extinctions for each taxon using the chi-square statistic. Arrows denote declines (↓) or increases (↑) of numbers of populations. The last two columns list Jaccard and Simple Matching coefficients (SMC) used to compare the historical and present distributions of each taxon.

Species or taxonomic category	Occurrence (1979-84)	Occurrence (2006-08)	Colonization	Extinction	*P*	Jaccard	SMC
Triturus cristatus	37	15	9	31	**0.001**↓	0.13	0.44
Lissotriton vulgaris	57	29	9	37	**0.001**↓	0.30	0.35
Mesotriton alpestris	2	1	1	2	1.000	0.00	0.96
*Bombina bombina**	45	31	7	21	0.008↓	0.46	0.61
Pelobates fuscus	18	21	15	12	0.564↑	0.18	0.62
*Bufo bufo**	63	54	5	14	0.039↓	0.72	0.73
Pseudepidelea viridis	30	24	12	18	0.273↓	0.29	0.58
Epidelea calamita	2	2	2	2	1.000	0.00	0.94
*Hyla arborea**	44	35	12	21	0.117↓	0.41	0.54
*Rana temporaria**	69	48	1	21	**0.000**↓	0.72	0.68
*Rana arvalis**	39	30	11	20	0.106↓	0.38	0.56
Pelophylax lessonae	59	18	3	44	**0.000**↓	0.24	0.34
Pelophylax esculentus	42	31	10	21	0.048↓	0.40	0.56
*Pelophylax ridibundus**	2	17	17	2	**0.001**↑	0.00	0.73
Pelophylax esculentus complex	61	59	7	9	0.617 ↓	0.76	0.73

Probabilities significant after sequential Bonferroni correction are in bold (adjusted to P<0.0045).
*Species with subjectively higher detection probabilities.

coefficient which takes into account, and strongly emphasizes, double absences and double presences.

Jaccard's coefficients for amphibian species in the Nida basin varied from 0.00 to 0.72. The most common taxa, *B. bufo*, *R. temporaria* as well as *P. esculentus* complex, had the most stable distributions (Table 1, supplementary Figures 6, 10 and 13), as shown by relatively high values of both similarity coefficients. Very low Jaccard coefficients were found for *T. cristatus*, *Pelobates fuscus* and *Pelophylax lessonae.* Three species, *M. alpestris, E. calamita* and *P. ridibundus* occur at present in completely different localities than in 1979-1984. The shortest distances between the new and historical localities are *ca.* 55 and 40 km, for *M. alpestris* and *E. calamita,* respectively, whereas for *P. ridibundus* the shortest distance is *ca.* 2 km (supplementary Figures 3, 8 and 14). Simple matching coefficients were generally high for species that showed little overlap in occupied localities between the two study periods (i.e. low Jaccard coefficients), but this is the result of double absences at a large number of sites (Table 1) unduly inflating this coefficient.

Discussion

Evaluation of methods

The amphibian inventory conducted in 2006-2008 focused on detecting the highest number of species at each locality. While the confirmation of species presence is relatively straightforward, it is generally impossible to

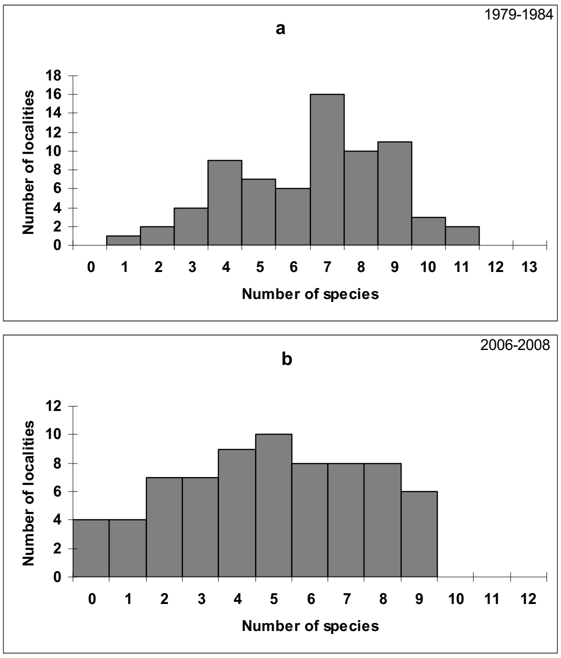

Figure 2. Number of species detected per locality (*N*= 71) in 1979-1984 (Juszczyk et al. 1988, 1989) and 2006-2008. A single category (*P. esculentus* complex) was used for *P. lessonae*, *P. ridibundus* and *P. esculentus* (see Methods)..

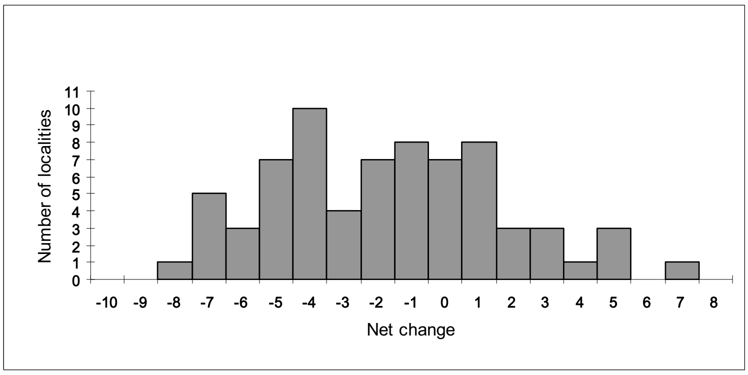

Figure 3. Net change in number of species per locality. A single category (*P. esculentus* complex) was used for *P. lessonae*, *P. ridibundus* and *P. esculentus* (see Methods).

verify that a species is absent (MacKenzie 2005). The detection of all species at a locality depends upon many factors (Heyer et al.1993, MacKenzie et al. 2002, MacKenzie 2005) including the survey methodology, the amount of time and effort put into the survey, the experience of the surveyor, habitat complexity, climatic conditions and the biology of the target organism (e.g. a conspicuous species is more likely to be detected than a species with cryptic coloration). In this respect, we scheduled our surveys to be coincident with the breeding seasons and/or the emergence of juveniles, at which times central European amphibian species are relatively easily observed. For most species two or three visits to each locality was enough to find the majority of species typical for the region (supplementary Table 3 and Fig. 16). However, it is important to note that our comparison of essentially two periods in time, without further background data, may not fully represent trends in numbers of populations for all species (cf. Sparks & Tryjanowski 2005).

Our methods paralleled those of Juszczyk et al. (1988, 1989) to which we compared our results, i.e. the number of surveys per site and the extent of habitat penetration (both aquatic and terrestrial) were similar (W. Zamachowski, pers. comm.). This survey scheme allowed for a quantitative assessment of the population dynamics of several amphibian species. However, given the small number of visits per site and the imprecise locality data of the historical survey, we consider the results as being robust for only the following species: *B. bombina*, *B. bufo*, *H. arborea*, *R. temporaria*, *R. arvalis*, *P. ridibundus* and *P. esculentus* complex. These taxa are relatively easily detected due to either prolonged activity during the breading season, easily recognizable male calls or explosive breeding and consequent high number of individuals at breeding sites. Moreover, similar percentages of occupied localities were found for these species for localities visited two or more times (supplementary Table 3), indicating adequate sampling effort. Therefore the results of our study are best viewed as an attempt to track the regional distributions of these species over a *ca.* 25 year period of time.

<u>Amphibian species occurrence</u>

The amphibians of the Nida basin portray a typical amphibian fauna of the central European lowlands and include three salamandrids (*T. cristatus*, *L. vulgaris*, *M. alpestris*), five ranid taxa (*R. temporaria*, *R. arvalis*, *P. lessonae*, *P. ridibundus, P. esculentus*), three bufonids (*B. bufo*, *Ps. viridis*, *E. calamita*) and representatives of Bombinatoridae (*B. bombina*), Hylidae (*H. arborea*) and Pelobatidae (*P. fuscus*). The majority of species detected in the Nida basin are widespread and at least locally common in central Poland and neighboring countries (e.g. Rybacki & Berger 1994, Gasc et al. 1997, Głowaciński & Rafiński 2003, Pabijan & Przystalski 2003, Dąbrowski & Strużyński 2006, Wojdan 2007, Covaciu-Marcov et al. 2008, 2009a, Strugariu et al. 2008). The most common species in the Nida basin, *R. temporaria* and *B. bufo,* are also widespread throughout lowland Poland, present in 90% and 89% of atlas grid quadrates (each quadrate represents 1250 km^2, Głowaciński & Rafiński 2003), respectively. The occurrence of the rarest species in the Nida basin requires comment. The newt species *M. alpestris,* found in a single locality, is associated with mountainous areas and reaches its northeastern distribution limit at the western margin of the Nida basin. The origin and occurrence of *M. alpestris* in this area was discussed by Pabijan et al. (2009). The northern fringe of the Nida basin is close to (approximately 20km) the Holy Cross Mts National Park. The most common amphibians in this hilly and forest-covered area are *M. alpestris* and *R. temporaria* (Wojdan 2007). The high frequency of *M. alpestris* in the Holy Cross Mts. may explain its presence at the northeastern edge of the Nida basin in 1979-1984 (Juszczyk et al. 1988). *E. calamita* was found in two localities. However, Krzyściak-Kosińska (2001) also found this species within the Nida river valley in localities that we have not surveyed, so it may be more widespread than our data suggest. Although *E. calamita* is widely distributed in Poland (Głowaciński & Rafiński 2003), it is generally rare (Dąbrowski & Strużyński 2006, Wojdan 2007) or even absent in some areas (Pabijan & Przystalski 2003, Hermaniuk et al. 2006). A fifth ranid, *Rana dalmatina*, is present approximately 7 km to the southeast of the study area (M. Bonk & M. Pabijan, unpublished), but was not detected in either the historical surveys or our inventory. This species occupies an isolated and disjunct distribution north of the Carpathians (Szymura 2003) and is associated with dry pine and mixed forest habitat (Szymura 2003, Bartoń & Rafiński 2006). Detailed surveys in south-central Poland suggest that this species is not found north of the Vistula river (M. Bonk & M. Pabijan, unpublished), which approximated the southern boundary of our study.

Distributional changes and population turnover

We noted significant declines in four species and nearly significant losses in a further three species. Moreover, we detected an overall decline (an average loss of 2.2 species) in species richness per site even after accounting for taxonomic uncertainty in *Pelophylax* and limited detection of some species.

The local distributions of most species have changed during the 25 year period between inventories. The most common species, *B. bufo* and *R. temporaria,* had relatively stable ranges in the studied area. Species presumed to be philopatric (*R. temporaria* and *B. bufo*) or confined to aquatic habitats (*B. bombina*) showed relatively low turnover but all have fewer populations at present. This result suggests that species characterized by low dispersal or particular habitat requirements have declined, perhaps due to a decrease in hospitable water bodies (see below). Two other putatively declining species in the Nida basin (*T. cristatus* and *L. vulgaris*) which are also believed to have low migration/dispersal abilities (Puky 2006, Smith & Green 2005 and papers cited therein, Kovar et al. 2009) showed a relatively high population turnover in our study. However, this should be interpreted with caution because the high turnover may be an overestimate due to difficulties in detecting these species in the field. Another species, *P. lessonae*, showed a pronounced change in distribution and a sharp decline. Although it is highly mobile (Tunner 1992), it is generally confined to shallow water bodies (Berger 2008) that are highly vulnerable to desiccation. Thus the regional dynamics of this species, and of others that share similar habitat preferences (e.g. newts, some ranids, *B. bombina*), may in fact reflect the rise and demise of the shallow water bodies themselves, which in ecological terms, are transient elements of the landscape.

Although we noted an overall decline in species richness, not all taxa were affected equally. Indeed, *P. ridibundus* has seemingly thrived in the area over the last 25 years, increasing in abundance from 2 to 17 localities. Most colonization events occurred in the Vistula river valley, an important ecological corridor in central Europe (Romanowski 2007). Habitat continuity for some amphibians may be provided for by the banks of this river, as they harbor many temporary and permanent water bodies that can be used by fish-tolerant and mobile species such as *P. ridibundus* (Holenweg Peter 2001). Moreover, irrigation canals that have been built in recent years probably benefit this species. All species that have maintained relatively stable and numerous populations in the Nida basin are those capable of dispersing over large distances such as *H. arborea* and *P. esculentus* (Holenweg Peter 2001, Smith & Green 2005 and therein cited papers) and/or are known to frequent open, agricultural habitat (*Ps. viridis* and *P. fuscus*). Interestingly, the latter two species also revealed considerable shifts in local distribution.

Although there are no globally threatened amphibian species in Poland (Brandon et al. 2008), decreased amphibian abundance has been signalized by some authors. Szyndlar (1995) reported negative population trends in Ojców National Park; Rybacki and Berger (2003) found a strong decline in west-central Poland; whereas Głowaciński and coworkers (1980) noted that 15 species were in decline and one (*R. dalmatina*) was highly endangered in Poland. However, all these considerations are based on mostly small scale or a small number of localities without statistical assessment. Nevertheless, in spite of numerous reports on amphibian declines in Europe (see Introduction), not all amphibians have declined at a regional scale (Crochet et al. 2004). Our results refine this observation by showing that in an agricultural landscape declines are species specific, possibly contingent on life history traits of particular species (e.g. philopatry, dispersal distances, habitat preferences) and habitat connectivity.

Possible factors contributing to amphibian declines in the Nida basin

Terrestrial and breeding habitat for amphibians has deteriorated in the Nida basin during the 25 year period between surveys. Agriculture in the Nida basin is generally small scale and may therefore be relatively benign for most amphibian species, or even advantageous for some, e.g. *Ps. viridis* and *P. fuscus*. However, agriculture endows irrigation, which in turn decreases the ground water level, affecting the permanence of small water bodies, eliminating breeding sites and increasing inter-pond distances (but creating a network of canals that may be used by some species). The negative influence of irrigation on some habitats was reported for at least one area in the Nida basin (Jońca 1975) but is probably more widespread. Fish introduction has contributed to declines in many amphibian populations (Brönmark & Edenham 1994, Drost & Fellers 1996, Oldham et al. 2000, Denoël et al. 2005, Orizaola & Brana 2006). In Poland there is a strong tendency for local communities to introduce fish into even very small ponds; in this respect the rural communities inhabiting the Nida basin are no exception (M. Bonk, personal observation). A similar inclination was recently noted in Romania (Hartel & Öllerer 2009, Covaciu-Marcov et al. 2009b).

It is well known that traffic volume harms amphibian populations by road kill during migration and dispersal (Orłowski et al. 2008, Elżanowski et al. 2009, Hartel et al. 2009). An important population effect of road kill is the increase of landscape resistance evidenced by higher genetic distance between populations (Vos et al. 2001). Two species in decline in the Nida basin (*B. bufo*, *R. temporaria*) are also the most common amphibian road kills recorded for Europe (Elżanowski et al. 2009, Hartel et al. 2009). Traffic volume in Poland has escalated in recent years, as shown by an increase in both the total length of paved roads and the number of cars (Oleński & Dmochowska 2009). In the surveyed area, many previously unpaved roads have recently been paved (M. Bonk, personal observation).

Thus, circumstantial evidence exists for a drop in ground water level through irrigation, fish introduction and an increase in traffic volume in the general area of the Nida basin. All of these factors limit habitat connectivity between breeding sites, acting as potential barriers to dispersal (e.g. Denoel et al. 2005, Nyström et al. 2007, Piha et al. 2007) and contributing to the deterioration of amphibian breeding and terrestrial habitat.

Conclusions

Amphibian surveys in south-central Poland have revealed significant regional declines for at least four amphibian species over a *ca*. 25 year period. Several species have maintained relatively stable numbers of populations, while one has expanded its range. Because not all species were negatively affected, differing life histories and population biology incur a species-specific response to general habitat loss and local factors (e.g. fish introduction, modernization of infrastructure). From a conservation perspective, the restitution of breeding sites and adjacent terrestrial habitat is of upmost importance for amphibians in the Nida basin. The maintenance of a network of breeding sites could possibly be facilitated by utilizing the river valleys that transverse the study area and the natural amphibian breeding sites that they provide.

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Supplementary material

Table 1. Geographical coordinates, altitude and number of visits at each resurveyed locality in 2006-2008.

Localities	Coordinates (NE)		Altitude (m.a.s.l.)	Number of visits	Localities	Coordinates (NE)		Altitude (m.a.s.l.)	Number of visits
Beszowa	50.414571	21.097298	189	3	Ostrów	50.23367	20.363058	254	3
Błotnowola	50.310333	20.900947	165	2	Piaseczna Górka	50.766309	20.63954	231	3
Brończyce	50.230862	20.119583	228	2	Piotrkowice	50.237327	20.644902	221	4
Chodków	50.534934	21.589063	146	2	Podłęże	50.551472	20.543827	197	3
Chorzewa	50.696901	20.232473	236	4	Podolany	50.240362	20.556987	183	4
Chrobosz	50.425147	20.558026	176	3	Podraje	50.295756	20.842085	167	3
Ciecierze	50.594896	20.764121	251	3	Przemyków	50.190021	20.653652	181	3
Cierno-Żabieniec	50.681228	20.212241	258	2	Raków	50.641647	20.395606	214	2
Czerwony Chotel	50.379719	20.689176	193	4	Rogów	50.22664	20.700742	178	3
Dalechowice	50.203036	20.454296	218	2	Ruszcza	50.412122	21.231398	169	3
Dąbrówka Morska	50.137235	20.590397	177	2	Rybitwy	50.413681	21.281181	155	2
Długołęka	50.512697	21.503338	147	4	Senisławice	50.279141	20.731622	179	2
Drożejowice	50.345594	20.401299	239	2	Sielec	50.630915	21.724342	140	3
Działoszyce	50.367227	20.345692	218	5	Skalbmierz	50.320242	20.392851	197	2
Gniazdowice	50.210639	20.261962	208	6	Skrzypiów	50.508879	20.517377	181	2
Holendry	50.605627	20.686603	259	3	Smogorzów	50.435285	20.840218	270	5
Ispina	50.11481	20.395944	183	5	Sobków	50.708187	20.44126	203	3
Jaksice	50.141439	20.509266	179	2	Soboszów	50.331116	20.556827	213	4
Jarząbki	50.575402	20.915889	207	2	Sokołowice	50.157207	20.603482	175	4
Kazimierza Wielka	50.269989	20.497519	186	3	Strzegom	50.521152	21.344360	201	2
Kołaczkowice	50.499341	20.855099	210	2	Sułków	50.885559	20.083454	241	3
Korytnica	50.663558	20.526467	209	3	Surowa	50.384127	21.254904	155	2
Krasocin	50.887798	20.119376	252	2	Tunel	50.434179	20.001726	395	2
Krzemienica	50.428738	21.433299	151	2	Urzuty	50.218397	20.659148	196	2
Łany	50.524165	20.168563	244	2	Widuchowa	50.495399	20.794621	216	2
Łatanice	50.417367	20.701184	194	2	Wiślica	50.344873	20.670787	173	4
Łysaków	50.59463	20.309318	261	2	Witów	50.155969	20.576803	181	2
Marzysz	50.7775	20.708855	238	2	Wojsławice	50.199642	20.497019	221	2
Mikołajów	50.499788	21.418826	163	3	Wola Malkowska	50.660029	21.197087	261	2
Morsko	50.149159	20.544839	217	2	Wola Przemykowska	50.176857	20.677192	173	2
Motkowice	50.611096	20.495676	193	2	Wola Tesserowa	50.76764	20.287872	231	4
Niziny	50.504169	21.07101	184	2	Zaduszniki	50.464125	21.469240	150	2
Nowy Korczyn	50.293469	20.802846	168	3	Zagórzany	50.350387	20.860917	189	2
Oblekoń	50.333279	21.028743	162	3	Zakrzów	50.611914	21.687804	142	3
Opatowiec	50.236838	20.718718	169	2	Zawada	50.431788	21.320589	153	5
Osiek	50.526836	21.44291	178	2					

Table 2. Present and historical (Juszczyk et al. 1988, 1989) presence/absence data for amphibian taxa at 71 localities in the Nida basin.

Species or taxonomic category	*Triturus cristatus*		*Lissotriton vulgaris*		*Mesotriton alpestris*		*Bombina bombina*		*Pelobates fuscus*		*Bufo bufo*		*Pseudepidela viridis*		*Epidelea calamita*		*Hyla arborea*		*Rana temporaria*		*Rana arvalis*		*Pelophylax lessonae*		*Pelophylax esculentus*		*Pelophylax ridibundus*		*Pelophylax esculentus* complex	
Locality/Season	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008
Beszowa	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	1	1	1	0	0	1	0	0	0	0	0	1	1
Błotnowola	1	0	1	1	0	0	1	1	0	1	1	1	0	1	0	0	1	1	1	1	1	1	0	0	0	0	0	1	0	1
Brończyce	0	0	1	1	0	0	1	1	1	1	1	1	1	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0
Chodków	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	1	0	0	1	0	0	1	1
Chorzewa	1	1	1	0	0	0	1	1	1	0	1	0	1	1	0	0	1	1	1	0	1	0	1	1	1	1	0	0	1	1
Chrobosz	1	0	1	0	0	0	1	1	1	0	1	0	1	1	0	0	0	0	1	1	1	1	1	1	1	1	0	0	1	1
Ciecierze	1	1	1	1	0	0	1	1	1	1	0	1	1	0	0	0	0	1	1	1	1	1	0	1	1	1	0	0	1	1
Cierno-Żabieniec	1	0	1	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	1	1
Czerwony Chotel	0	1	0	1	0	0	1	1	0	0	1	0	1	1	0	0	1	1	1	1	1	1	1	1	1	1	0	0	1	1
Dalechowice	0	0	0	1	0	0	0	0	0	0	1	1	1	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
Dąbrówka Morska	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Długołęka	1	0	1	0	0	0	1	1	0	0	1	1	0	0	0	0	1	1	1	1	0	1	1	1	1	1	0	1	1	1
Drożejowice	0	0	1	0	0	0	0	0	0	0	1	1	1	1	0	0	1	0	1	1	1	0	1	0	0	0	0	0	1	0
Działoszyce	0	0	1	0	0	0	0	0	0	0	1	1	1	1	0	0	1	0	1	1	1	0	1	0	0	1	0	1	1	1
Gniazdowice	0	0	0	1	0	0	0	0	0	0	1	1	0	1	0	0	0	0	1	1	0	0	0	0	0	1	0	1	0	1
Holendry	1	1	1	1	0	0	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	1	1
Ispina	1	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	0	0	1	0
Jaksice	0	0	1	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	0	0	1	0	0	0	0	1	1	1
Jarząbki	0	1	1	1	0	0	0	1	0	1	1	1	0	0	0	0	0	1	1	1	0	1	1	1	0	0	1	0	1	1
Kazimierza Wielka	1	0	1	1	0	0	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	0	1	0	1	1	0	1	1	1
Kołaczkowice	0	1	0	1	0	0	0	0	0	1	0	1	0	0	1	0	0	1	0	1	0	1	0	1	0	0	0	0	0	1
Korytnica	1	0	1	0	0	0	1	1	0	1	1	1	1	1	0	0	0	1	1	1	1	1	1	0	1	1	0	0	1	1
Krasocin	1	1	1	0	0	0	1	0	1	0	1	1	0	0	0	0	1	1	1	0	1	1	1	0	1	1	0	0	1	1

Table 2. (Continued)

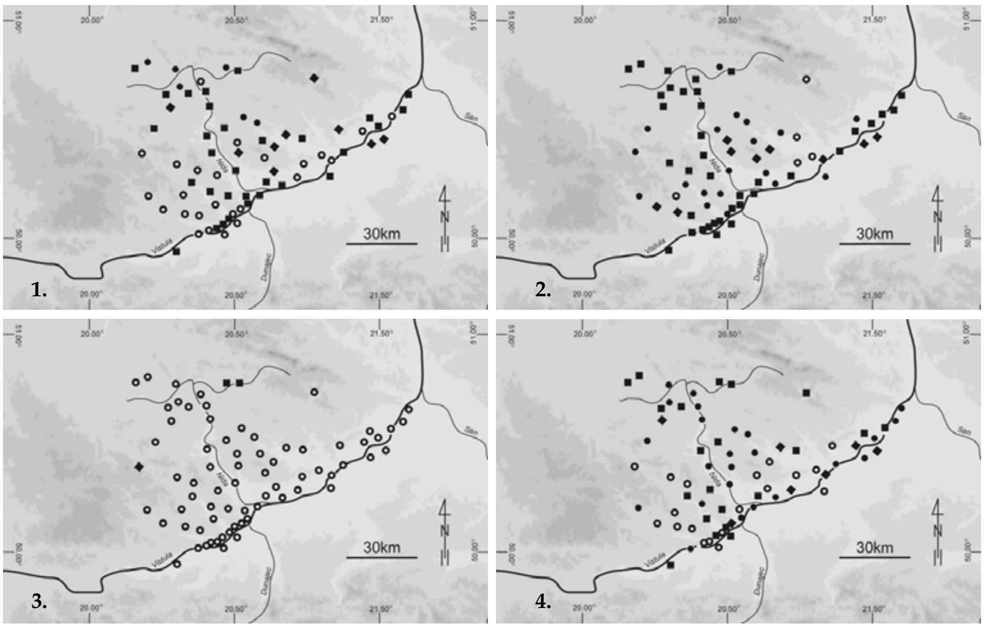
Species or taxonomic category	*Triturus cristatus*		*Lissotriton vulgaris*		*Mesotriton alpestris*		*Bombina bombina*		*Pelobates fuscus*		*Bufo bufo*		*Pseudepidela viridis*		*Epidelea calamita*		*Hyla arborea*		*Rana temporaria*		*Rana arvalis*		*Pelophylax lessonae*		*Pelophylax esculentus*		*Pelophylax ridibundus*		*Pelophylax esculentus* complex	
Locality/Season	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008
Krzemienica	0	1	0	1	0	0	1	1	0	0	0	1	0	0	0	0	0	1	1	1	0	1	1	1	1	1	0	0	1	1
Łany	1	0	1	1	0	0	1	1	0	1	1	1	0	1	0	0	1	0	1	1	1	1	1	0	0	1	0	0	1	1
Łatanice	0	0	0	1	0	0	1	1	0	0	1	1	1	1	0	0	1	1	1	1	1	1	1	0	1	1	0	0	1	1
Łysaków	0	1	1	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	1	0	1	0	1	0	1	0	0	0	1	0
Marzysz	1	0	1	0	1	0	1	0	1	0	1	1	0	0	0	0	1	0	1	1	1	0	1	0	1	1	0	0	1	1
Mikołajów	0	0	1	0	0	0	0	1	0	1	1	1	0	1	0	1	0	1	1	1	0	1	1	0	0	0	0	0	1	1
Morsko	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	1	0
Motkowice	1	0	1	0	0	0	1	1	0	1	1	1	0	0	0	0	1	1	1	1	1	1	1	0	1	1	0	0	1	1
Niziny	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	1	0
Nowy Korczyn	1	0	1	0	0	0	1	0	1	0	1	1	1	0	0	0	1	0	1	0	0	1	1	0	1	0	0	0	1	0
Oblekoń	0	0	1	0	0	0	0	1	0	1	1	1	0	1	0	0	0	0	1	0	1	0	0	0	0	1	0	0	0	1
Opatowiec	1	0	1	0	0	0	1	1	1	1	1	1	1	0	0	0	1	0	1	1	0	1	1	0	1	0	0	1	1	1
Osiek	1	0	1	1	0	0	1	0	0	0	0	1	0	1	0	1	1	1	1	0	1	1	1	1	1	0	0	0	1	1
Ostrów	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Piaseczna Górka	1	1	1	1	1	0	1	0	1	0	1	1	1	0	0	0	1	0	1	0	1	0	1	0	1	1	0	0	1	1
Piotrkowice	1	0	1	1	0	0	1	0	0	1	1	1	0	0	0	0	0	1	1	1	1	0	1	0	1	1	0	0	1	1
Podłęże	1	0	1	1	0	0	1	0	0	0	1	1	1	0	0	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0
Podolany	0	0	1	1	0	0	1	0	0	1	1	1	1	1	0	0	1	1	1	1	1	0	1	0	1	0	0	1	1	1
Podraje	1	0	1	0	0	0	1	1	1	0	1	1	0	0	0	0	1	0	1	0	0	0	1	0	1	0	0	1	1	1
Przemyków	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	1	1
Raków	1	0	1	0	0	0	1	0	1	0	1	1	1	0	0	0	0	0	1	1	1	0	1	0	1	1	0	0	1	1
Rogów	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	1	1	0	1	1	0	0	1	0	0	1	1
Ruszcza	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	1	1	1	1	1	1	1	0	0	0	0	0	1	1
Rybitwy	0	0	0	1	0	0	0	1	0	1	1	1	0	1	0	0	1	1	1	1	1	1	1	1	0	1	0	1	1	1

Table 2. (Continued)

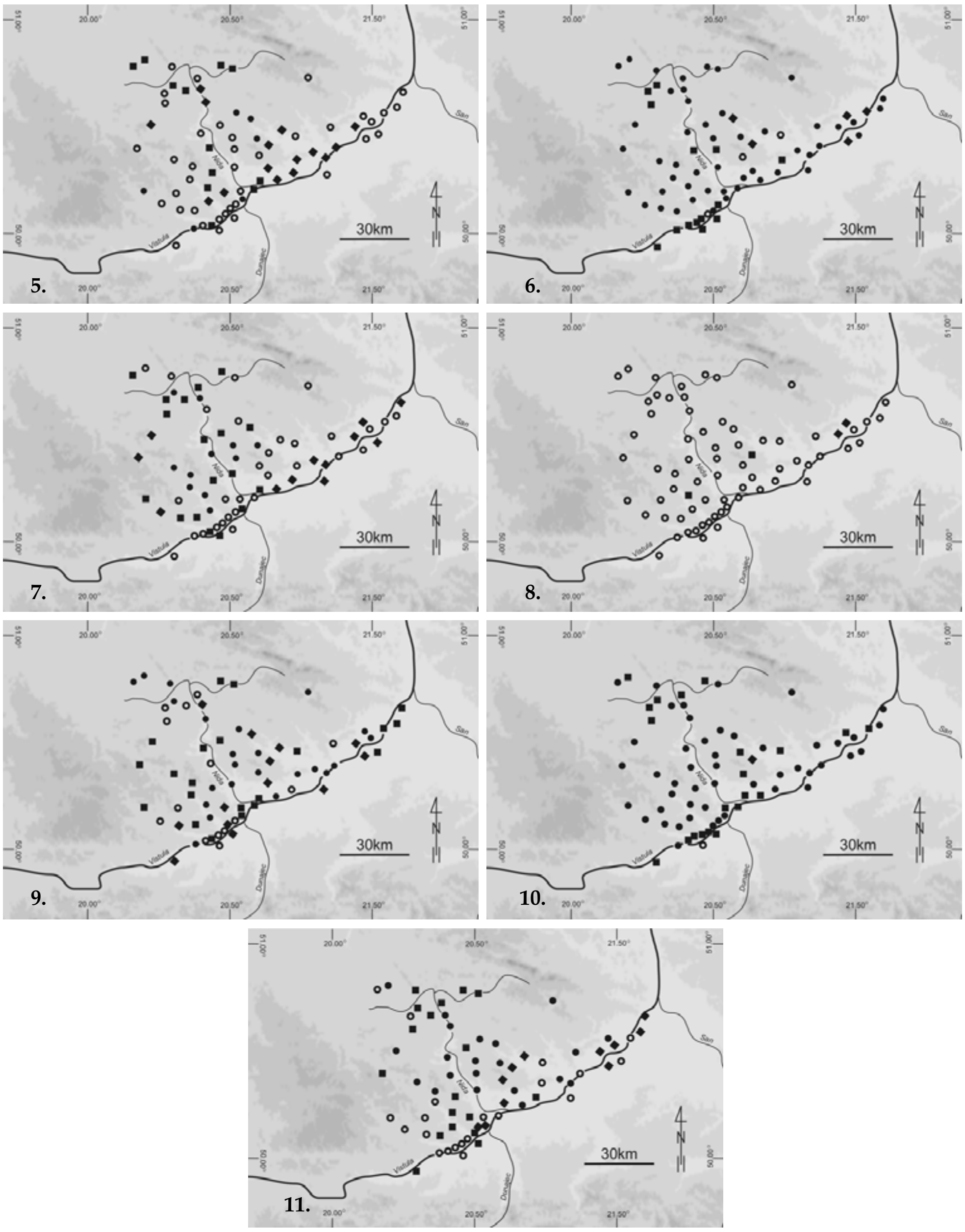
Species or taxonomic category	*Triturus cristatus*		*Lissotriton vulgaris*		*Mesotriton alpestris*		*Bombina bombina*		*Pelobates fuscus*		*Bufo bufo*		*Pseudepidela viridis*		*Epidelea calamita*		*Hyla arborea*		*Rana temporaria*		*Rana arvalis*		*Pelophylax lessonae*		*Pelophylax esculentus*		*Pelophylax ridibundus*		*Pelophylax esculentus* complex	
Locality/Season	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008	1979-1984	2006-2008
Senisławice	1	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	1	0	0	0	1	0	1	1	0	1	1	1
Sielec	1	0	1	0	0	0	1	1	0	0	1	1	0	1	0	0	1	0	1	1	0	1	1	0	1	0	1	0	1	1
Skalbmierz	1	0	1	1	0	0	1	0	0	0	1	1	1	1	0	0	1	0	1	1	0	0	1	0	1	0	0	1	1	0
Skrzypiów	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	0	1	0	1	1	1	1	1	0	1	1	0	1	1	1
Smogorzów	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1	1	1	0	0	0	1	1
Sobków	0	0	1	0	0	0	1	1	0	0	1	1	1	0	0	0	0	0	1	0	1	0	1	0	1	0	0	0	1	1
Soboszów	0	0	1	0	0	0	1	0	1	0	1	1	1	0	0	0	1	1	1	1	1	0	0	0	1	1	0	0	1	0
Sokołowice	1	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	1
Strzegom	0	1	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	1	1	0	1	0	1	0	0	0	1
Sułków	1	0	1	0	0	0	1	0	1	0	1	1	1	0	0	0	1	1	1	1	0	0	1	0	1	1	0	0	1	1
Surowa	1	0	1	1	0	0	0	0	0	0	1	1	0	1	0	0	0	1	1	1	0	0	1	1	0	1	0	0	1	1
Tunel	0	0	1	1	0	1	0	0	0	0	1	1	0	1	0	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0
Urzuty	0	0	1	1	0	0	1	0	0	0	1	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	1	0	1
Widuchowa	1	0	1	1	0	0	1	1	1	1	1	1	1	1	0	0	1	1	1	0	1	1	1	1	1	0	0	0	1	1
Wiślica	1	0	1	1	0	0	1	1	0	0	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	1	1
Witów	1	0	1	0	0	0	0	0	1	0	1	0	1	0	0	0	1	0	1	0	0	0	1	0	1	0	0	0	1	0
Wojsławice	0	0	1	0	0	0	0	0	0	0	1	1	1	0	0	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0
Wola Malkowska	0	1	0	0	0	0	1	0	0	0	1	1	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	1	1
Wola Przemykowska	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	1	0	1	0	1	0	0	0	0	0	1	1
Wola Tesserowa	1	1	1	0	0	0	1	1	0	0	1	1	0	0	0	0	1	1	1	1	1	0	1	0	1	1	0	0	1	1
Zaduszniki	0	1	0	1	0	0	0	1	0	0	1	1	0	1	0	0	1	0	1	1	0	0	1	0	0	1	0	0	1	1
Zagórzany	0	1	1	1	0	0	0	0	0	1	1	1	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	1	1
Zakrzów	1	0	1	0	0	0	1	1	0	0	1	1	0	0	0	0	1	0	1	1	0	1	1	0	1	1	0	1	1	1
Zawada	1	0	1	0	0	0	1	1	0	1	1	1	1	1	0	0	1	1	1	1	0	0	1	0	1	0	0	0	1	1

Table 3. Number of visits required to detect amphibian species in the Nida basin. Localities are grouped according to the number of conducted amphibian surveys (top row). *N* – total number of localities surveyed twice, three times and four times. Percentage of occupied localities for each species, e.g. *Triturus cristatus* was found in 24% of all localities that were surveyed twice, 15% of localities that were surveyed 3 times, etc. Only five localities were surveyed more than 4 times and were therefore excluded from this analysis.

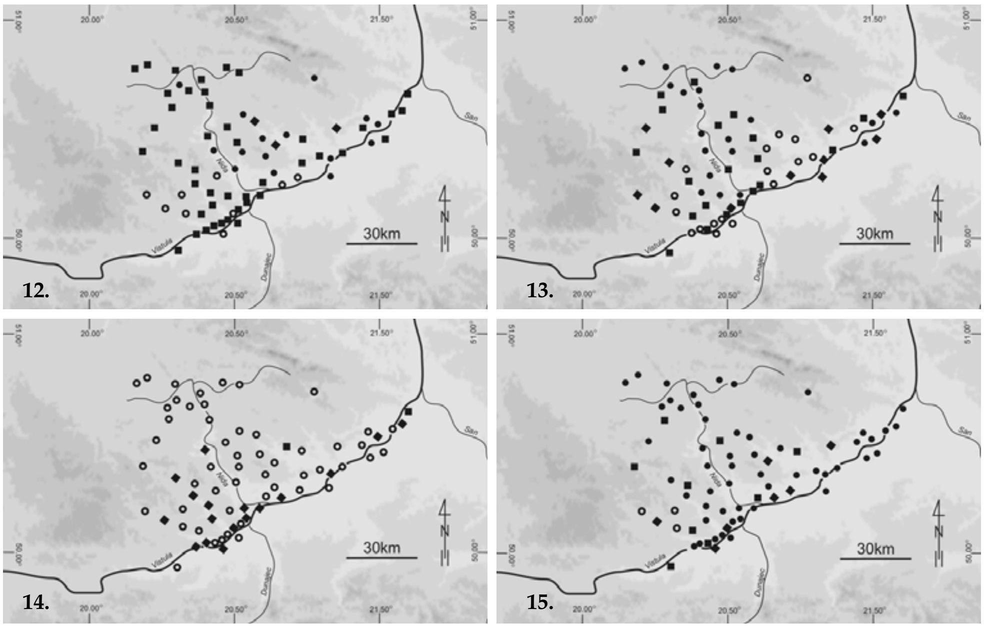
Species	2 surveys (*N*=37)	3 surveys (*N*=20)	4 surveys (*N*=9)
Triturus cristatus	24%	15%	33%
Lissotriton vulgaris	49%	25%	44%
Bombina bombina	48%	60%	55%
Pelobates fuscus	30%	35%	22%
Bufo bufo	78%	80%	66%
Bufo viridis	30%	35%	33%
Hyla arborea	43%	45%	89%
Rana temporaria	67%	70%	78%
Rana arvalis	43%	50%	33%
Pelophyylax lessonae	27%	15%	44%
Pelophylax esculentus	38%	45%	67%
Pelophylax ridibundus	27%	15%	22%
P. esculentus complex	73%	85%	89%



Figures 1.-4. Changes in distribution of *Triturus cristatus* (**1.**), *Lissotriton vulgaris* (**2.**), *Mesotriton alpestris* (**3.**), *Bombina bombina* (**4.**) between 1979-1984 (Juszczyk et al. 1988, 1989) and 2006-2008; empty circles indicate absence of the species in both 1979-1984 and 2006-2008, solid circles denote the presence of the species in both 1979-1984 and 2006-2008, squares are extinctions and diamonds are colonizations.



Figures 5-11. Changes in distribution of *Pelobates fuscus* (**5.**), *Bufo bufo* (**6.**), *Pseudepidelea viridis* (**7.**), *Epidelea calamita* (**8.**), *Hyla arborea* (**9.**), *Rana temporaria* (**10.**), *Rana arvalis* (**11.**), between 1979-1984 (Juszczyk et al. 1988, 1989) and 2006-2008; empty circles indicate absence of the species in both 1979-1984 and 2006-2008, solid circles denote the presence of the species in both 1979-1984 and 2006-2008, squares are extinctions and diamonds are colonizations.



Figures 12-15. Changes in distribution of *Pelophylax lessonae* (**12.**), *Pelophylax esculentus* (**13.**), *Pelophylax ridibindus* (**14.**), *Pelophylax esculentus* complex (**15.**) between 1979-1984 (Juszczyk et al. 1988, 1989) and 2006-2008; empty circles indicate absence of the species in both 1979-1984 and 2006-2008, solid circles denote the presence of the species in both 1979-1984 and 2006-2008, squares are extinctions and diamonds are colonizations.

Figure 16. Species acumulation curve calculated in EstimateS (Colwell 2009) *Sobs* – observed species richness. Note that most species in the Nida basin can be detected by visiting two (*Sobs*=9.76) or three (*Sobs*=11.52) localities.