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Citation style: Dąbrowska Dominika, Sołtysiak Marek (2015). The impact of anthropogenic factors on the natural values of the water reservoirs in Sosnowiec (Poland). „Environmental & Socio-economic Studies" (2015, Vol. 3, iss. 1, s. 20-25), DOI: 10.1515/environ-2015-0053

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Environmental & Socio-economic Studies

DOI: 10.1515/environ-2015-0053

Environ. Socio.-econ. Stud., **2015, 3, 1: 20-25**

The impact of anthropogenic factors on the natural values of the water reservoirs in Sosnowiec (Poland)

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ABSTRACT

Many plant and animal species are closely related to the aquatic environment. Small reservoirs are a place of the biodiversity concentration. Reservoirs are especially important for amphibian species as a place of feeding, shelter and wintering. Many anthropogenic factors has a significant impact on the natural values of water reservoirs (surroundings of the water reservoirs, the shore`s type, distance from roads and buildings, the role of the object and the chemical status). They can eliminate or change amphibian population. The effect of three such factors was determined for one of the cities in the Upper Silesian Agglomeration – Sosnowiec (91 km^2). The paper presents an assessment of the impact of the type of surroundings, the percentage share of the open space around water reservoirs and the distance from roads and buildings on the number of amphibian species present in the reservoir. In the analysis were taken into account 20 reservoirs, in which amphibian species were found. This analysis indicates the influence urban factors on the number of amphibian species in water reservoirs based on positive correlations in the case of Spearman Rank correlation and the Fisher's exact test. Results of these calculations highlight the negative impact of the anthropopressure (the changes in the environment) on the amphibian breeding places and the biodiversity.

KEY WORDS: correlation, amphibian species, aquatic environment, Upper Silesian Agglomeration

1. Introduction

Water reservoirs and surrounding areas are very important for flora and fauna occurrence. The importance of especially small water reservoirs is often underestimated. Small water reservoirs are often overlooked in the analysis of environmental (Ożgo, 2010). Small reservoirs are aquatic environment, which has the highest number of species of organisms and biomass. Many of animals and plants inhabiting them are very rare and sensitive, any habitat changes may lead to a weakening of the population, reduce its size or to the extinction of entire species in a given area. The high biodiversity of small water reservoirs results mainly from relatively large ranges of their habitats and favorable conditions for flora and fauna (Scheffer & van Nes, 2007). These reservoirs are used to preserve biodiversity.

Water reservoirs are especially important for amphibian species as their breeding place. Three amphibian species (marsh frog, edible frog, grass frog) use them as a wintering place. Amphibians are staying close to water reservoirs during their land lifetime so terrestrial habitat around the reservoir is also important. Amphibians can migrate a distance of 1500 meters from the breeding places (Juszczyk, 1987; Günther, 1996; Berger, 2000; Głowaciński & Rafiński, 2003; Glandt, 2008) and not without significance is the distance from their habitat to roads and buildings. This phylum of animals is an excellent bioindicator of the natural environment. They play a key role in structuring biological assemblages. Amphibians are often treated as a specific indicator of biodiversity because they are vulnerable to changes in the environment, which are mainly associated with the disappearance of aquatic ecosystems.

There is the phenomenon of reducing the surface of wetland habitats and the number of water reservoirs in Europe. In various European countries liquidated 40-90% of small reservoirs

(OERTLI ET AL., 2002). Disappearance of water reservoirs and neighboring local ecosystems is characteristic for an agricultural areas but also for urban areas.

Natural reservoirs in the Upper Silesian Agglomeration are rare. The most popular are artificial reservoirs, which sometimes acquired the features as natural ones. A lot of artificial reservoirs in this region have a complex origin, such as reservoirs created in an artificially water-filled depressions or reservoirs located in the area of mining subsidence (RZĘTAŁA, 2008). Many of them are small reservoirs with an area of less than 1 ha. There are three main types of reservoirs: subsidence reservoirs, excavation reservoirs and industrial reservoirs (SOŁTYSIAK & DĄBROWSKA, 2014). The most common are subsidence reservoirs and excavation reservoirs.

The Upper Silesian Agglomeration, which is located in the Silesian voivodeship, has an area nearly equal to 1500 km^2 and it is one of the most industrialized areas in Poland. The rapid development of industry in the Upper Silesian Agglomeration has started in the early nineteenth century as a result of the discovery of mineral deposits. Development of industry significantly influenced the changes in the environment (regulation of riverbeds, drainage of wetlands, changing water relations). Mining, however, resulted in the creation of excavation and technological reservoirs.

2. The study area

Sosnowiec is a typical city of the Upper Silesian Agglomeration. The area of Sosnowiec is equal to 91.1 km^2. The spatial structure of the city is dominated by built-up areas (42%), which occupy a large region of the central and western part, farmlands accounts for more than 22% and in the third place are forest areas – almost 22% area of the city (Fig. 1).

There are forest areas in the southern and eastern part. Isolated forest area is also located in the northern part of the city. The characteristic of land use in Sosnowiec is shown in the Table 1.

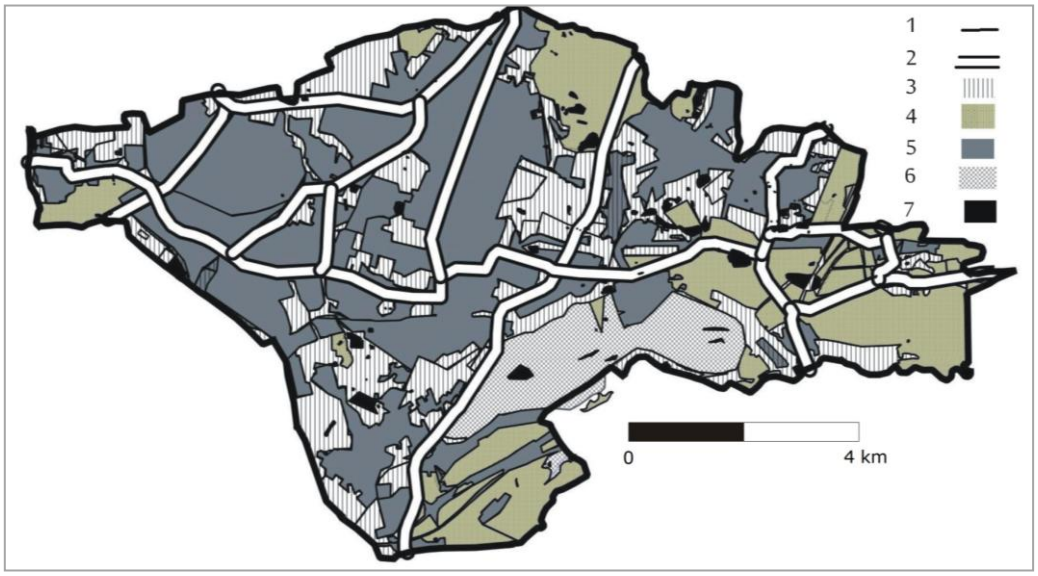

Fig. 1. Spatial structure of Sosnowiec
1 – boundary of the city, 2 – main roads, 3 – agricultural lands, 4 – forest land, 5 – built-up area, 6 – wastelands, 7 – land under water (reservoirs)

Table 1. Land use in Sosnowiec (in km^2) in the mid-nineteenth century (~ 1860) and today (2010) (after Czaja, 1994; Central Statistical Office, 2013)

Type of land use	~ 1860	2010
Built-up areas (industrial areas included)	2,7	38,3
Agricultural lands	36	1,42
Forest lands	51,1	19,28
Urban green area	0,22	21,86
Wastelands	0,1	
Allotment gardens	0	1,56
Heaps	0	0,04
Land under water	0,6	0,72
Sandpit	0	6,56
Another areas (with transport areas)	0,38	1,27

3. Amphibian species and water reservoirs in Sosnowiec

There are 88 water reservoirs in Sosnowiec. All of them are artificial but some was naturalized. There are 68 subsidence and excavation reservoirs, 19 technological reservoirs and 1 in the inaccessible area. Natural valorization of areas was made in 1999 and it was modified in 2007 (CEMPULIK ET AL., 2008). There were indicated 47 valuable natural areas. There are 34 reservoirs within 24 of valuable natural area and the biggest one includes 10 reservoirs.

29 water reservoirs are an inventored breeding place of amphibians. These habitats are located primarily in the eastern part of the city, in forest areas, away from built-up area. Unfortunately data scope indicates that information about batrachofauna in Sosnowiec is incomplete. There`s no information about 74% of water reservoirs (DĄBROWSKA, 2014). 10 amphibian species had been identified in Sosnowiec. *Green frog* is a dominant species and the most rare are *Great crested newt* and *Spadefoot*. Number of amphibians breeding place was shown in Table 2.

Natural valuable areas are very important places where amphibians occur. However, there are amphibian breeding places that are not located within natural valuable areas. Any position of amphibian occurrence is not subject to legal protection. Two water reservoirs among the valuable amphibian breeding sites are appropriately located 350 m south and 800 meters west of the NATURA 2000 area called "The bog Sosnowiec-Bory".

Some urban factors can be dangerous for batrachofauna. They can eliminate amphibian population or at least hinder their survival in the city space. Particular attention should be paid to the reservoirs which can be a breeding site for amphibians. Technological reservoirs are often a trap for amphibians and should not constitute breeding places. An important issue is the water quality. Simultaneously we should also take into account the surrounding terrestrial habitat of reservoirs, which are for amphibians feeding, shelter and – for most species – wintering places.

Table 2. Number of amphibians breeding places in Sosnowiec (according to Cempulik et al. 2008; Cempulik et al. 2002)

Species	Number of breeding places	Number of natural value where amphibians species occur
Ordinary newt Lissotriton vulgaris	10	7
Great crested newt Triturus cristatus	4	3
Fire-bellied toad Bombina bombina	15	11
Spadefoot Pelobates fuscus	2	1
Common toad Bufo bufo	11	8
Green toad B. viridis	5	3
Tree frog Hyla arborea	4	3
Grass frog Rana temporaria	11	9
Moor frog R. arvalis	7	6
Green frog: water and/or pool R. esculenta complex	29	23

4. Material and methods

The aim of this study was to verify if the number of amphibian species is associated with the urban factors influencing the breeding sites. This analysis included 20 water reservoirs with a different number of amphibian species located in Sosnowiec. The location of analyzed water bodies is presented in Fig. 2. The number of amphibians breeding in a given water reservoirs was based on the data from the natural valorization (CEMPULIK ET. AL., 1999, 2002, 2008).

We verified the hypothesis that the number of amphibians species in the water reservoirs subject to the Poisson distribution and we obtained p value = 0.050662 ($\chi 2$ compatibility test), so this is the result on the border of customary use in the critical area. The result of the calculation indicates the possibility of other factors affecting the number of amphibian species in the reservoirs. Visual inspection of the data suggests that there is a combination of the bimodal distribution and Poisson distribution.

Each of the reservoir was characterized on the basis of: type of the surroundings, the percentage share of the open space around water reservoirs in the zone of width equals to 100 m and the minimum distance to the built-up area and roads. Surrounding types for analysis were divided into eight groups: 1. forest, 2. allotments, 3. park or recreation area, 4. farmlands, 5. meadows and wastelands, 6. spoil tip, 7. built-up areas, 8. industrial plant.

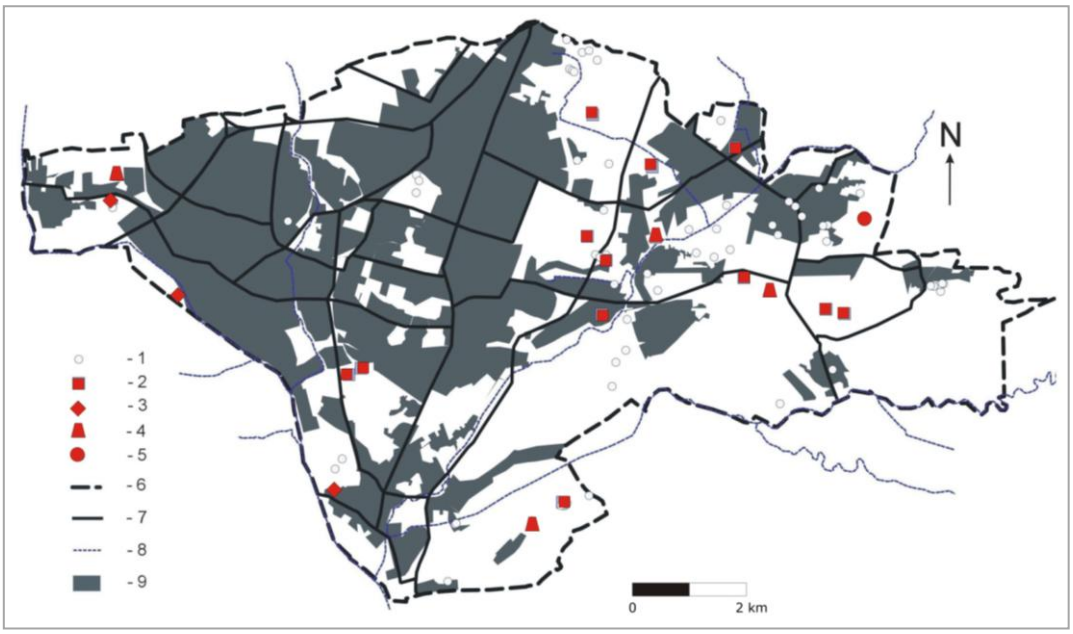

Fig. 2. The location of analyzed water reservoirs

Table 3. The data set

Number of amphibian species	Classification of surroundings	Min distance between reservoir and built-up area or road	The percentage share of the open space around the reservoir
6	3	1	5
5	3	2	5
6	3	1	5
2	2	1	1
4	1	1	3
7	3	4	5
1	1	1	1
2	2	3	2
8	2	1	4
1	1	3	1
1	1	1	1
2	3	3	5
6	2	1	4
2	2	3	2
1	2	1	2
1	2	1	2
3	2	2	2
5	2	2	4
2	2	3	2
1	1	2	1

These groups were then generalized to three classes: 1. anthropogenic surroundings, 2. mixed surroundings, 3. natural surroundings. The second class included some of those reservoirs that were initially in a diverse surroundings, for example, it was surrounded by forest and buildings, etc. (Tab. 3).

Second urban factor used to analyze – the minimum distance between water reservoirs and roads or built-up area, was divided into four classes: 1. small distance, 2. 100 metres, 3. 200 metres, 4. 300 metres. The data set is shown in Table 3.

Our observation suggest that the analyzed reservoirs should be classified into five groups in respect of third factor - the percentage share of the open space (without human impact) around them. We had identified the following groups: 1. 0-10%, 2. 10-40%, 3. 40-60%, 4. 60-90%, 5. more than 90% of the open space around water reservoirs.

The number of reservoirs in each class was presented in Table 3.

All statistical analyses were performed using programming language and software environment for statistical computing and graphics R (R CORE TEAM, 2012). For determining the effect of the type of surroundings and the differentiation of the open space on the number of species in reservoirs we used non-parametric analysis – Spearman Rank correlations. P value < 0.01 was statistically significant. For assessing the relationship between the distance from roads or buildings and the number of amphibian species in each water reservoir we used Fisher's exact test. P value < 0.05 was statistically significant.

5. Results

Mixed surroundings of reservoirs, the percentage share of the open space around the water reservoirs at the level of 10-40% and the proximity to buildings and roads dominate in Sosnowiec. There was a positive relationship between the number of amphibian species and the type of reservoirs surroundings. More amphibians were certainly in reservoirs located among the natural areas (forest, meadow).

In this case, the Spearman's rank correlation coefficient (r_s) is equal to 0.64 with the significance level equal to 0.01. Critical value for Spearman's Rank Correlation Coefficient for this analysis equals 0.57. 0 64 > 0.57 so selected factor has a statistically significant effect on the number of amphibian species in water reservoirs in Sosnowiec.

The results obtained in the case of the percentage share of the open space around the reservoirs indicate the positive correlation between this urban factor and the number of amphibian species. The Spearman's rank correlations coefficient in this case is equal to 0.82. This is a statistically significant strong correlation (Fig. 3).

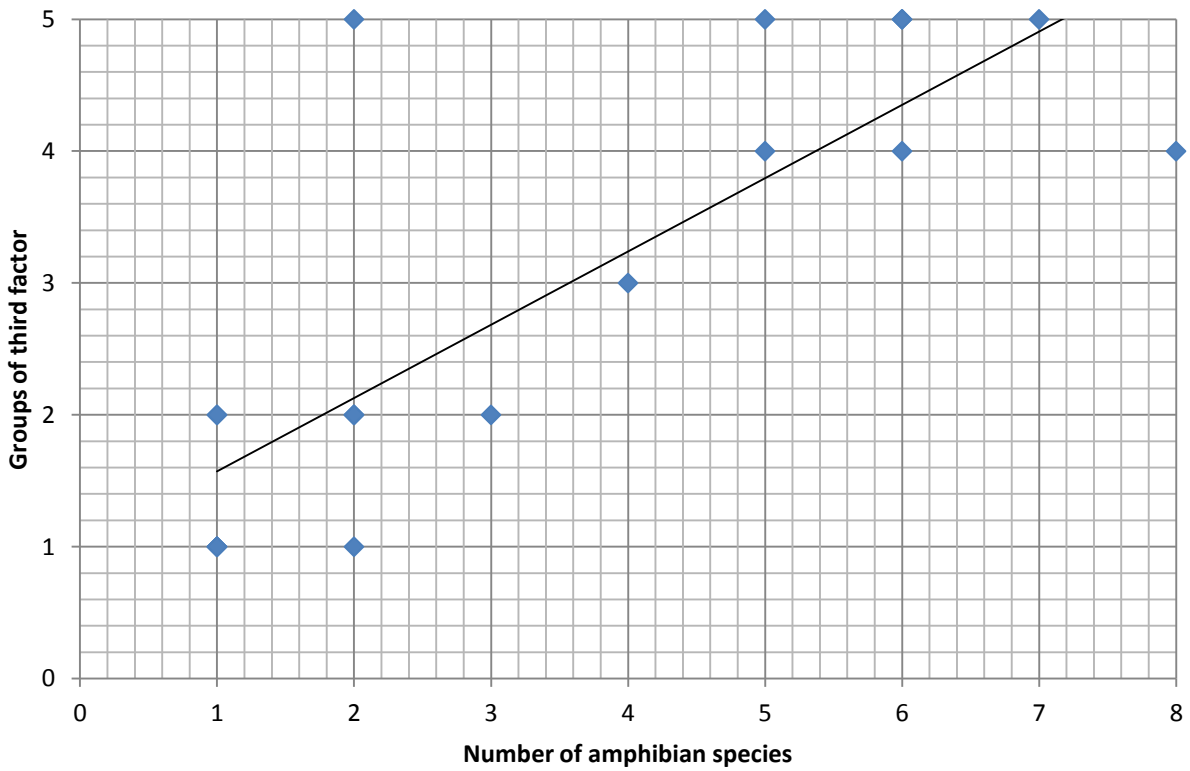

Fig. 3. Correlogram of the number of amphibian species and groups of the percentage share of the open space around water reservoirs

Using the Fisher's exact test, we revealed that the number of amphibian species and the minimum distance between water reservoir and built-up area or roads are not independent. Localization of water reservoirs in the spatial structure of the city is an important urban determinant of the occurrence of amphibians.

The number of amphibians in the water reservoirs in Sosnowiec was positively dependent on the analyzed distance (p=0.006786). The negative impact of buildings or roads in the neighborhood on biodiversity is marked. Amphibians are the most globally threatened group of vertebrates (NIWELIŃSKI, 2008; KIESECKER, 2011).

6. Conclusions

The results obtained from our study showed that urban factors have an impact on amphibian occurrence in water reservoirs in Sosnowiec. The analysis revealed that the number of amphibian species depends on the urban factors and amphibians are negatively affected by industrial changes. The next part of research should be a natural inventory. It would be allow to get the new set of the data.

Amphibians are the most threatened group of vertebrates in the world. This phylum of animals is also an excellent bioindicator. Amphibian species are closely associated with water reservoirs. They have got the specific habitat requirements so the abundance of amphibians in water reservoirs in the city space is varied. One of the most important factors determining the biodiversity in water reservoirs is the type of surroundings (Spearman's rank correlation coefficient is equal to 0.64). Favorable conditions for amphibians are characteristic for reservoirs which are only extensively used by humans (i.e. forest or meadow) and are located far from roads and built-up areas. The natural importance of reservoirs increases with the bigger distance from developed areas and with the larger percentage share of the open space around the water reservoir (Spearman's rank correlation coefficient is equal to 0.82). Unfortunately, the number of isolated reservoirs in Sosnowiec is decreasing. When reservoirs are buried, fragments of precious local ecosystems are destroyed irrevocably.

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