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EFFECTS OF URBANIZATION ON THE OCCURENCE OF ANURA ASSEMBLAGES IN THE CITY OF SZEGED (HUNGARY)

D. Herczeg, R. Gallé and N. Molnár

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Abstract. Nowadays, rapidly expanding urbanization influences the existence of many plant and animal species. The amphibian decline is largely related to habitat loss, in which expansion of urban areas and the degradation of aquatic habitats within the city play a significant role. There were 18 study sites involved in our study, all within the administrative area of Szeged. Their state was different regarding the adverse impacts of urbanization. In our study we seek to answer which amphibian species occur in Szeged and what are the environmental parameters that affect the community of amphibians living in urban areas. Our results clearly show that *Pelophylax esculentus* complex is fully dominating the heavily polluted, affected and also the most seminatural aquatic habitats. Moreover, regarding the environmental parameters, we detected negative correlation between the length of the main roads, the total area of the study sites and its vegetation cover and water transparency. However, according to our results, there is positive correlation between the locally occurring amphibian community and the coastal water depth and the linear extent of the surrounding concrete and dirt roads.

Keywords: urbanization, environmental parameters, amphibian community, species richness, aquatic habitats

D. Herczeg, R. Gallé, N. Molnár, Department of Ecology, University of Szeged, H-6726 Szeged, Közép fasor 52, Hungary

Introduction

Worldwide, the number of amphibian species shows a persistent decline (Houlahan *et al.* 2000). That progression has different reasons such as degradation (Blaustein *et al.* 1994; Corn, 2000) and fragmentation (Hartel *et al.* 2007) of habitats, environmental pollution and excessive use of chemicals (Berill *et al.* 1997; Harte and Hoffman 1989), respectively climate change (Pounds *et al.* 1999) and inter alia some disease like chytridiomycosis (Berger *et al.* 1998; Daszak *et al.* 1999; Pessier *et al.* 1999). The amphibian decline is largely related to the general decline in biodiversity, whose current rate is faster than that of any time in the last 10,000 years (Eldridge 1998). Urbanization exerts an influence on a number of animal species thus amphibians are also affected by it. The aquatic habitats, which are indispensable for the reproduction of amphibians, are often drained in the cities or they are highly degraded that they become unsuitable for the amphibians to maintain viable populations. Due to their extremely sensitive skins, amphibians play an important role as indicator species in the detection of environmental and ecological changes (Piotr 2006; Price *et al.* 2008). The amphibians have to adapt to the altered habitat conditions occurring in urban environments. Some species can keep up with the changes in their habitat easier while some species hardly can, thus such changes can lead to local extinction (Drinnan 2005). In urban areas breeding places are often separated from hibernating places by different infrastructure elements like roads. Thus the latter form physical barriers which are usually hostile for anurans to cross, during springtime (Puky 2006; Puky and Vogel 2003). For some species like the Green frogs, which are hibernating in mud, roads are less dangerous than they are for toads (*Bufo* spp.) that die in great quantities while reaching the breeding sites. However, earlier studies show the migrating behavior of Green frogs in Lake Fertő (Frank and

Pellinger 1988). Finally many aquatic habitats are transformed into fishponds where predator fish species negatively affect the composition of the amphibian community (Smith *et al.* 1999). Amphibians sensitively indicate the perturbations listed above as well as to the loss and fragmentation of habitats.

Habitat degradation can be traced by the presence or absence of the amphibian species living there, but the main goal of our study is the monitoring of aquatic habitats. The herpetofauna of Szeged and its surroundings has already been the topic of several previous studies (Marián 1963; Ilosvay 1974). According to those studies 11 of the 18 Hungarian amphibian species occur in the region. Among the anurans Fire-bellied Toad (*Bombina bombina*, Linnaeus, 1761), Common Spadefoot (*Pelobates fuscus*, Laurenti, 1768), Common Toad (*Bufo bufo*, Linnaeus, 1758), Green Toad (*Bufo viridis*, Laurenti, 1768), European Tree Frog (*Hyla arborea*, Linnaeus, 1758), Moor Frog (*Rana arvalis*, Nilsson, 1842), Agile Frog (*Rana dalmatina*, Bonaparte, 1840), Marsh Frog (*Pelophylax ridibundus*, Pallas, 1771) and the Edible Frog (*Pelophylax* kl. *esculenta*, Linnaeus, 1758) were described.

The aims of the present study were (1) to assess the amphibian fauna of Szeged and compare the present data with the results of former faunistical surveys (Marián 1963, Ilosvay 1974) and (2) identify the environmental parameters that influence the composition of the amphibians living in urbanized habitats.

Materials and methods

Study sites

Our surveys have been done in 17 permanent and 1 temporary aquatic habitats between April and September 2011. All habitats are located within the administrative area of Szeged and they show a considerable variation in perturbation and pollution. The exact location of sampling sites is given in Fig. 1. The only temporary aquatic habitat is located in a fenced off area in the centre of the city — hereinafter Centrum — which lies 2-3 meters below the street

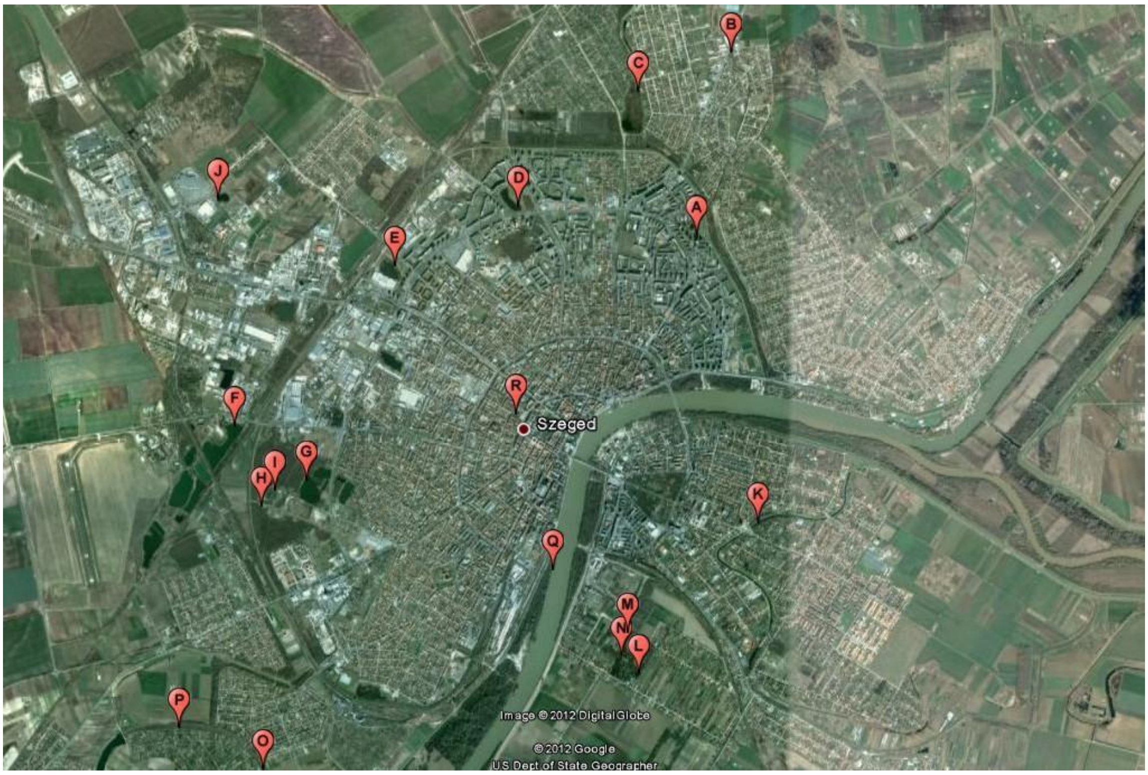

Fig. 1. Study sites. A: Zápor Garden (1); B: Szillér Baktó main channel (2); C: Lake Bika (3); D: Vértó (4); E: Lake Búvár (5); F: Lake Keramit (6); G: Sancer ponds (7); H: Marsh near "Pantanal" (8); I: "Pantanal" (9); J: Zápor-tározó (10); K: Dead Maros (11); L: Botanic Garden outer pond (12); M: Botanic Garden inner pond (13); N: Canals within Botanic Garden (14); O: Gyála Oxbow black water (15); P: Gyála oxbow middle section (16); Q: Boszorkánysziget (17); R: Centrum (18).

level. Many Green Toads reproduce and lay eggs during spring time in that quick warming habitat. Around the end of June the entire water dries out, consequently the tadpoles that could not metamorphose die and the juvenile specimens hive off seeking shelter in the surrounding downtown areas. The oxbow of Gyála is the only aquatic habitat located outside the city, where two sampling sites were selected. One at the more polluted part, which is called "Black water" and the other is in the middle section of the water body. The water quality is less polluted in the latter section of the aquatic habitat, which is surrounded by houses and gardens. Among the study sites Lake Bika is in the most advanced in the eutrophication process and has the largest surface, although 90% of the water body is covered by the reeds belt. The ponds of the Botanical Garden, where we set up 3 sample places, belong to those which are less exposed to disturbance. The Sancer ponds in the Szeged Zoo are less disturbed too and the same applies to the other two sampling sites we set in the area of the Zoo. Regarding the nature of the study sites, Boszorkánysziget is the only one which is connected to a River. It is situated a floodplain of the River Tisza. Zápor Garden, Vértó and Lake Búvár are located in densely populated areas. Finally Lake Keramit, the Maros oxbow and the Zápor-tározó (rain reservoir) are used for fishing activities. Sample sites are shown on the map (Fig. 1) edited with the software Google Earth Plus v6.0.3.2197.

Sampling methods

Samplings were performed 4 times at each study site (from April to September). We performed our survey in daytime and used two methods; visual identification combined with fishing out with scoop net and acoustic monitoring (Anthony and Puky 2001). The latter was just an additional method to identify those species which are difficult to locate visually (e.g.: *H. arborea*). Above the adult linked methods, a spawn and tadpoles study was also carried out, although we only found spawn in two study sites (Centrum and Maros oxbow). The collected adult specimens were released nearby the capturing places right after the morphological identification and registration.

Environmental Parameters

The following 10 environmental parameters were chosen to characterize the aquatic habitats and the impact of urbanization: the total area of the study site (m^2), the surface of water (m^2), the surface of the reed belt (m^2), the vegetation cover (%), water transparency (cm), average water depth alongside the shore (cm), the length of the main roads (m), the length of the concrete roads (m), the length of the dirt roads (m), the proportion of residential areas (%). The length of the main roads, concrete roads, dirt roads and the proportion of residential areas were determined within a radius of 300m. Google Earth Plus and ArcView (ArcGIS 9.1, ESRI) softwares were used to determine the size of the habitats, the water surface, the size and coverage of the reed belt and the vegetation, the main roads, concrete roads, dirt roads and the proportion of residential areas. All asphalt roads, which had more than two lanes was categorized as a main road. The transparency of aquatic habitats was measured with Secchi disk. The Secchi transparency is the quantity of the water where the disk vanishes and reappears. The average water depth was measured ten times at each study site at one meter from the shore.

Statistical analysis

We used Generalized Linear Models with Poisson error distribution term to determine the correlation between the number of species and individuals and the measured environmental parameters. Stepwise selection was applied for model selection. The non-metric multidimensional scaling (NMDS) was used to visualize the similarity of the amphibian assemblages of the study sites. Similarity matrices based on Bray-Curtis distance measure were used. The data was log-transformed ($\log(x+1)$) prior to the analyses to avoid distortion due to the high number of individuals of *Pelophylax esculentus* complex. We took into consideration only permanent aquatic habitats, thus Centrum was not included in the NMDS (Figure 2). Data analysis was performed with R software package (R Development Core Team 2009) and vegan package (Oksanen *et al.* 2006).

Results

During the present study we found the following 6 species (Table 1); Fire-bellied Toad, Common Toad, Green Toad, European Tree Frog, Moor Frog, Agile Frog and the Green frog group (*Pelophylax* spp., Ranidae) all of the identified species were recorded formerly from Szeged (Marián 1963, Ilosvay 1974). We did not separate the individuals of the Green frog group, which consist of three species in Hungary: *P. ridibundus, P. lessonae* and *P.* kl. *esculenta*; due to a high hybridization rate. Thus they are mentioned as *Pelophylax esculentus* complex. We could not find any Common Spadefoot, since that species is more active at night, although they probably occur in Szeged and its surroundings (Solomampianina and Molnár 2011). The highest

Table 1. The occurrence of amphibians in each study sites. Investigated ponds: 1: Zápor Garden; 2: Szillér Baktó main canal; 3: Lake Bika; 4: Vértó; 5: Lake Búvár; 6: Lake Keramit; 7: Sancer ponds; 8: Marsh near „Pantanal"; 9: „Pantanal"; 10: Zápor-tározó; 11: Dead Maros; 12: Botanic Garden outer pond; 13: Botanic Garden inner pond; 14: Canals within Botanic Garden; 15: Gyála oxbow black water; 16: Gyála oxbow middle section; 17: Boszorkánysziget; 18: Centrum Species: BOBO=*Bombina bombina*; BUBU=*Bufo bufo*; BUVI=*Bufo viridis*; HYAR=*Hyla arborea*; PESC=*Pelophylax esculentus* complex; RDAL=*Rana dalmatina*; RARV=*Rana arvalis*

	Study sites																	
Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
BOBO	×											×	×		×	×		
BUBU											×	×						
BUVI	×																	×
HYAR		×									×	×	×			×	×	
PESC	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	
RDAL													×				×	
RARV												×						

species richness was found in the Botanical Garden, where in the outer pond four species and a species group occurred (Fire-bellied Toad, Common Toad, European Tree Frog, Moor Frog, Green frog group) and in the inner pond we found three species (Fire-bellied Toad, European Tree Frog, Agile Frog) and the Green frog group. As mentioned above, Boszorkánysziget was the only one study site which is directly connected to the Tisza River. We found a few individuals of Agile Frogs there, not surprisingly, where the breeding sites are surrounded by wooded areas (Boszorkánysziget, inner pond of the Botanical Garden) (Table 1).

The *Pelophylax esculentus* complex had an undisputable dominancy in the aquatic habitats of urbanized areas. Within more than half of the study sites, the members of the *Pelophylax esculentus* complex were the only one dominant species. We found them in heavily polluted habitats or ponds with significantly simplified structure as well as in near-natural water bodies. Marsh Frog was the least typical species, which occurred only in the outer pond of the Botanical Garden (Table 1).

Table 2. Explanatory variables influencing number of species

	beta-value (β)	z-value	p-value
Length of main roads	-0.001169	-2.095	0.0362

We used Generalized Linear Models to determine the correlation between number of species and individuals and the environmental parameters. Only the main roads had a significant impact on the number of species. Negative correlation occurred between the number of species and the length of the main roads in the vicinity of the aquatic habitats (Table 2). Regarding the number of species, the total area of the study sites, the vegetation cover and the water transparency were proved to have a significantly negative effect, while the water depth, the length of concrete roads and dirt roads show positive correlation (Table 3). Interestingly the main roads, which have exclusive effect on the number of species, showed no significant effect on the number of individuals.

Table 3. Explanatory variables influencing number of individuals

	beta-value (β)	z-value	p-value
Total area	-1.882e-05	-9.179	< 0.001
Vegetation cover	-1.649e-02	-9.474	< 0.001
Transparency	-7.641e-02	-13.365	< 0.001
Water depth	2.652e-02	5.613	< 0.001
Length of main roads	1.847e-04	1.518	0.129
Length of concrete roads	3.025e-04	6.443	< 0.001
Length of dirt roads	7.528e-04	12.035	< 0.001

NMDS was used to plot the similarity between the aquatic habitats (Figure 2). The biplot shows that the aquatic habitats in Szeged are characterized by the members of Green frog complex. At the habitat 3, 4, 5, 6, 7, 8, 9, 10 and 14 the only recorded species was the *Pelophylax esculentus* complex. The habitat 12 and 13 in the Botanical Garden is moderately disturbed so this may be the reason why we found there the individuals of *B. bufo, R. arvalis* and *H. arborea*.

Discussion

The habitat properties of urban environments, fragmentation (Hartel *et al.* 2007) and habitat degradation (Blaustein *et al.* 1994; Corn, 2000) also cause problems in the aquatic habitats of Szeged. Our faunistical results match all results of previous studies (Marián 1963; Ilosvay 1974). Among previously described anurans, Common Spadefoot was the only one species that we could not find, although former studies recorded their occurrence in Szeged and its surroundings (Solomampianina and Molnár 2011). It is possibly due to the nocturnal activity of the species. We detected six species and the *Pelophylax esculentus* complex.

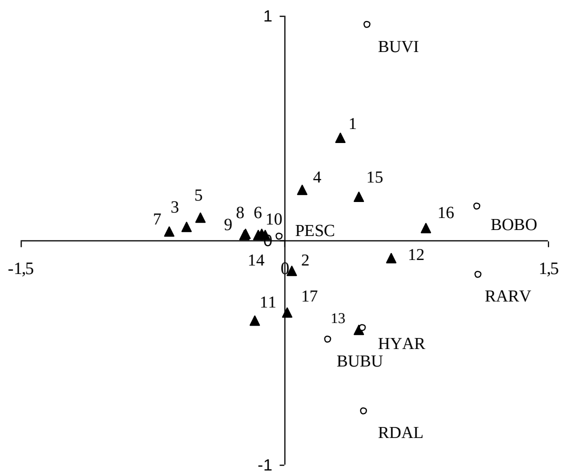

Fig. 2. The result of NMDS ordination in terms of study sites and the occurring species drawn as biplot (stress: 9.43759). The study sites and the name of species are shown in Table 1. ○ - Species; ▲ - Study sites

In terms of species diversity, we reached the similar conclusion as earlier studies in similar urban environments (Mollov 2011; Rácz *et al.* 2009). Together with the Green frogs, European Tree Frog is also a species, which – although in our study not in large numbers – does occur in urban environments (Pellet *et al.* 2004). Numerous individuals of Green frogs occurred in heavily polluted water bodies as well as in less perturbed, seminatural aquatic habitats. The dominance of Green frogs in these ponds is caused by the wide tolerance against the human perturbation and water pollution (Mollov 2011). Among the study sites, in six cases we found European Tree Frogs and in five cases Fire-bellied Toads, these species were comparatively occurred in more aquatic habitats or their surroundings. The Common Toad is usually frequent in urban areas (Mazgajska 2009) but we only found these species in two sampling sites, and also a small number of individuals. Compared to other amphibians the Common Toads often make apart far from the breeding sites (Reading *et al.* 1991) so the traffic is threatening them in the centre of the city. That could be the reason why we found Common Toads in those aquatic habitats, which were surrounded by less traffic roads. As for the species richness, the Botanical Garden raises above the study sites, where we found four species and the *Pelophylax esculentus* complex. The above mentioned species richness can be explained by the fact that the aquatic habitats of the Botanical Garden are less perturbed by human activity. Moreover, among the environmental parameters, the coastal water depth, the concrete and dirt roads have positive effect on the amphibian community. The deeper coastal water secures the eggs against the dehydration when the weather turns dry and the ponds have no water supply. The deeper water provides safer environment for growing eggs so it could be the adequate explanation why we found correlation between the number of individuals and the water depth. Negative correlation can be demonstrated between the length of the main roads and the following parameters: total area, the vegetation cover and the water transparency of aquatic habitats. The linear extension of the main roads within 300 meters radius, the fewer the species that occurred in the given aquatic habitat. The roads, especially the busy ones, like the main roads, form strong physical barriers for amphibians, while migrating from hibernation sites to breeding and feeding sites during the springtime and back to the hibernation sites in the autumn (Frank and Pellinger 1988, Puky 2006, Puky and Vogel 2003). For those aquatic habitats, which are surrounded by main roads, the vast majority is dominated by one species group less frequently two species can occur. Adequate explanation for that phenomenon is the fact that the life of Green frogs is closely linked to water throughout the year. In the case of Secchi transparency when the value is low, the ponds organic matter content is high or pollution level is massive. Except the Green frog complex the inland species can moderately tolerate the polluted water bodies what our survey clearly showed. The other negatively correlated environmental parameters were the extension of the total area and the cover of the coastal vegetation. In the case of Green frogs the excessively rich coastal vegetation prevents the animals to go back quickly the water when something suddenly disrupts their resting period at the shore. The bigger the habitat the more negative human impact it can be exposed to and these impacts negatively correlate with the number of individuals. Based on the results of NMDS, it can be concluded that no grouping between the above mentioned species can be detected regarding the similarity of the amphibian assemblages on the studied habitats. It can be established that several amphibian species are able to form and maintain a relatively stable population in urban areas, however, only the species of the *Pelophylax esculentus* complex can tolerate human disturbance and changed habitat conditions.

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