THE EFFECTS OF LAND USE CHANGE ON AQUATIC COMMUNITIES

PhD Theses

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1. INTRODUCTION

The effects of land use changes on freshwater organisms have been a growing concern worldwide. As human activities continue to alter landscapes and modify natural habitats, the impacts on freshwater ecosystems and the organisms that inhabit them are becoming increasingly evident. Effective management and conservation of these freshwater ecosystems require a comprehensive understanding of the complex impacts of land use changes on the freshwater environment and ecology.

One of the most destructive land use changes is urbanization representing a complex environmental process including detrimental changes and effects, such as pollution, alteration of the local climate, removal of vegetation, drainage and extraction of freshwater, habitat loss and fragmentation which results in damaged and degraded ecosystems (Grimm et al., 2008). Urbanization will likely have more profound impacts on biodiversity in both rural and urban areas as the exponential growth of linear infrastructures (roads, railways) continues to fragment the landscape (Pullin et al., 2009). Roads are one of the most common and inescapable forms of urbanization, presenting a great service of urban spreading (van der Ree et al., 2015). Human recreation presents a relatively new chapter of human-induced land use changes. Activities, such as fishing, sailing, water sports, bird watching, and bathing present a form of new challenges and pressures for freshwater ecosystems. Although the importance of recreation for human well-being and local economies is well-appreciated and considered a major ecosystem service of freshwaters (Vári et al., 2022), unfortunately, less attention has been paid to the effects of tourism on these ecosystems (Monz et al., 2013; Venohr et al., 2018).

The scope of the dissertation is to study the effects of land use changes and alterations on freshwater ecosystems. Particularly, the thesis was focused on three types of land use changes and three types of waterbodies: the conversion of natural forests into urban areas along low-order streams; the transformation of natural reed-vegetated shorelines into recreational beaches in a large, shallow lake; and the construction of linear infrastructures and fragmentation of ponds on landscape scale.

2. AIMS

1) Investigating the impacts of urbanization on low-order streams in the Balaton Uplands area of the Pannon Biogeographic Region by contrasting the abiotic and biotic parameters of streams originating from natural habitats and flowing through a moderately urbanized landscape.

2) Revealing the effects of recreational beaches on habitat structure and associated chironomid communities of Lake Balaton.
3) Studying the relationships between road and rail infrastructure and the abundance of larval amphibian communities in a highly-fragmented landscape in Central Europe.

3. METHODS

1) Five streams (Aszófői, Burnót, Cserkúti, Koloska, Örvényesi) were selected based on the criteria of having both natural and urban sections along their course. Along streams, six sites were selected in natural sections and six sites in urban sections, respectively. To evaluate abiotic parameters at each site a Stream Visual Habitat Assessment (SVHA) protocol was used. A multi-habitat sampling method and "kick and sweep" technique with a 500 μm mesh size hand-net was used for the collection of macroinvertebrates (AQEM Consortium, 2002). Linear mixed–effect (LME) models and multivariate analyses were conducted to test the effects of urban stream sites on the biotic attributes of macroinvertebrates.
2) 5-5 sampling sites were selected in the southern and northern shoreline of Lake Balaton. Within each site three habitats were sampled: (1) natural reed-vegetated shoreline, (2) open area, which is not used as beach, (3) recreational beach, which is used by beach goers or impacted by beach goers i.e. > 1.5 m depth. Five sampling points (1 m^2 area) were randomly selected within each habitat. Environmental variables were selected based on the experienced and known sensitivity of chironomids (Árva et al., 2015b, 2017) and included measured and visually assessed parameters. Benthic chironomid larvae were sampled with an Ekman grab sampler (sampling area: 0.022 m^2). Three sampling units were taken at each sampling point to increase the representativeness of samples and to support comparability to other studies (Árva et al., 2015a; Specziár et al., 2018). Chironomid specimens were separated from the sediment alive by sugar flotation method (Anderson, 1959). Linear models (LMs) and multivariate analyses were used to test how chironomid richness, abundance and community composition were affected by the different habitat types and the transformation of reed shorelines to recreational beaches.
3) Altogether 30 ponds were selected using Google Earth Pro images (Google Inc., 2020) and the Ecosystem Base Map of Hungary (Ministry of Agriculture, 2019) between Lake Balaton and Budapest, Hungary approximately 50 km South-West of Budapest along

several highways (M7 motorway, no. 7, no. 8, no 801 roads, all ≥ 4-lanes) and the main railway line from Budapest to Veszprém. A 1000-m radius was selected as the landscape buffer to cover the dispersal distances of most amphibian species expected to occur in the study area (Vos & Stumpel, 1995; Smith & Green, 2005). Among landscape-scale environmental variables the amount of total habitat and accessible habitat, road coverage within the 1000-m radius, and the distance from a pond margin to the nearest highway or the railway was determined. Local-scale variables included pond area, hydroperiod and the presence of predatory fish. Three aquatic surveys were conducted over one breeding season in spring and summer. Repeated surveys were undertaken to reduce uncertainties that may arise from high variability in larval abundance within a single season. Ponds with sufficient water levels (water depth >5 cm) were dip-netted during the day using a net designed for safe capture of amphibians (300-mm wide frame, 350 mm deep, 1 mm mesh size). The number of net sweeps was calculated beforehand regarding the pond area - one net sweep for every 25 m^2 of pond surface area (Shulse et al., 2010). Multi-species abundance models (MSAMs) were developed to assess relationships between larval amphibian abundance and landscape- and local scale variables.

4. RESULTS IN THESIS POINTS

4.1. Urbanization and stream macroinvertebrates

Taxa richness and Shannon diversity were significantly lower in urban stream sections, but they showed considerable variability between different streams, stream identity as a random factor explained a notable amount of variance. Macroinvertebrate abundance showed no decrease in the urban sections, the mean abundance was higher in urban sites, but not significantly. EPT (Ephemeroptera-Plecoptera-Trichoptera) taxa were negatively affected by urbanization for all biotic attributes (richness, Shannon diversity and abundance), but the relative richness of EPT (EPT%) did not change in urban sections and remained high (around 40% of all species). Macroinvertebrate assemblage composition showed significant differences between natural and urban sections. Streams showed strong unique characteristics and distinct macrofauna. EPT compositions also differed between natural and urban sites, however, they were not well separated according to stream identity. Concrete coverage and current velocity were negatively associated with macroinvertebrate richness and Shannon diversity, while wetted width and canopy coverage had a positive effect. Macroinvertebrate abundance showed only a few

negligible correlations with our predictors (except for EPT). The total variance of macroinvertebrate assemblage explained mostly by microhabitat-level environmental variables and site-level variables had minor importance in the natural sections. The total explained variance was relatively low. In the urban sections, both microhabitat and site-level variables explained a notable amount of the total variation and the total explained variance was substantially higher than in the natural sections. For the EPT assemblage, site-level variables were more important than microhabitat-level variables in the urban sections.

4.2. Recreational beaches and chironomid assemblages in Lake Balaton

The transformation from a natural reed shoreline to a recreational beach had an overall negative impact on the richness and abundance of chironomids causing an 18% reduction in the taxon richness and a 5.6% reduction in abundance. The richness of chironomids depended on the shoreline position with the northern shoreline having higher species richness. The effect of habitat transformation on taxon richness was also shoreline-specific and while it significantly decreased on the northern shoreline, it did not change on the southern shoreline. The abundance was also shoreline dependent, on the southern shoreline less individuals were found overall, and the beach habitat was more abundant in chironomids than reed. Chironomid taxon richness was positively associated with organic matter, and negative effects was found for water depth and pH. The community composition of chironomids was highly sensitive both to shoreline position and habitat differences. The composition of chironomids was different between the reed and beach habitats, between the reed and open habitats, and between the northern and southern shorelines. Ten indicator taxa were observed for natural reed habitat, six for open and a single taxon for beach habitat in the northern shoreline, while four indicator taxa for open habitat in the southern shoreline. Environmental variables had a significant impact on the community structure of chironomids and indicator taxa were influenced by the most decisive parameters for each habitat, such as high amount of reed and organic matter in reed habitat, high water depth in open habitat and high proportion of sand in beach habitat.

4.3. Linear infrastructures and pond ecology

Among road models, distance to the nearest highway and the percentage cover of road surface within a 1000-m radius had the strongest and clearest effect on the mean community abundance of amphibian larvae. Distance to the nearest highway model had the best fit with the mean community abundance data and showed clear effects on individual species abundance for all seven species observed and therefore considered to be the best-supported model. Accessible habitat and total habitat models showed considerably weaker effects on mean community

abundance than the first two models. Railway models showed highly ambiguous effects on mean community abundance suggesting only a little impact of the railway on amphibians. There was only a small increase in abundance at sites located 0 – 1000 m from a highway suggesting that the road-effect zone extended for up to 1 km and further. Distance to the nearest highway was the most decisive for the mean amphibian species abundance showing a clear positive relationship with all seven species, with the strongest effect for *Bufo bufo* and the weakest for the *Pelophylax* spp. complex. Similarly, the percentage cover of road surface within a 1000-m radius clearly negatively influenced amphibian abundance with *Bufo bufo* as the most, while the *Pelophylax* spp. complex as the least sensitive species. The percentage of accessible habitat and total habitat within a 1000-m radius had notably smaller effects on amphibian abundance and showed mixed relationships with different species, but similar to the others, *Bufo bufo* showed the strongest relationship and was positively influenced by the amount of both accessible and total habitat. The pond area had a strong, clear positive effect on mean community abundance and on mean species abundance. The strongest relationship was found for *Bufo bufo*, whereas the weakest relationship was for *Rana dalmatina*. A positive, but ambiguous, relationship was observed between mean community abundance and fish presence with high variability in species responses. *Bombina bombina* and *Pelobates fuscus* larvae were negatively influenced by fish, whereas there was a strong positive effect of fish presence on the *Pelophylax* spp. complex.

5. REFERENCES

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6. LIST OF ACADEMIC ACTIVITIES

6.1. Publications related to the dissertation

Bohus, A., B. Gál, B. Barta, I. Szivák, K. Karádi-Kovács, P. Boda, J. Padisák, & D. Schmera, 2023. Effects of urbanization-induced local alterations on the diversity and assemblage structure of macroinvertebrates in low-order streams. Hydrobiologia 850: 881–899, https://doi.org/10.1007/s10750-022-05130-1, **IF: 2.822, SJR: Q1**

Árva, D., A. Mozsár, B. Barta, A. Specziár, M. Tóth, **A. Bohus**, B. Gál, & D. Schmera, 2021. Effects of recreational beaches on chironomid assemblages in a large, shallow lake. Ecological Indicators 125: 107469, http://doi.org/10.1016/j.ecolind.2021.107469, **IF: 4.958, SJR: D1**

Hamer, A. J., B. Barta, **A. Bohus**, B. Gál, & D. Schmera, 2021. Roads reduce amphibian abundance in ponds across a fragmented landscape. Global Ecology and Conservation 28:e01663, https://doi.org/10.1016/j.gecco.2021.e01663, **IF: 3.38, SJR: Q1**

6.2. Congress attendances related to the dissertation

Bohus, A.; Gál, B.; Schmera, D. (2021). Az urbanizáció hatása a makrogerinctelenek diverzitására kisvízfolyásokban. LXII. Hidrobiológus Napok, 6-8 October 2021, Tihany, Hungary, ***oral presentation***

Bohus, A.; Gál, B.; Barta, B.; Szivák, I.; Karádi-Kovács, K.; Boda, P.; Padisák, J.; Schmera, D. (2022). Effects of urbanization-induced local alterations on the diversity and assemblage

structure of macroinvertebrates in low-order streams. XXV. Tavaszi Szél Konferencia, 6-8 May 2022, Pécs, Hungary, ***oral presentation***

Bohus, A.; Gál, B.; Barta, B; Szivák, I; Karádi-Kovács, K.; Boda, P.; Padisák, J.; Schmera, D. (2022). Effects of urbanization-induced local alterations on the diversity and assemblage structure of macroinvertebrates in low-order streams. 36th Congress of the International Society of Limnology (SIL 100), 7-10 August 2022, Berlin, Germany, ***oral video presentation***

6.3. Other publications

Mészáros, B., J. Bürgés, M. Tamás, B. Gál, **A. Bohus**, & D. Schmera, 2023. Effects of the urban environment on the developmental stability, size and body condition of dice snakes (*Natrix tessellata*) living in artificial lakeside habitats. Ecological Indicators 156: 111117, https://doi.org/10.1016/j.ecolind.2023.111117, **IF: 6.9, SJR: D1**

6.4. Other congress attendances

Barta, B.; Vad, Cs. F.; Márton, Zs.; Kratina, P.; Petermann, J. S.; Dobosy, P., **Bohus, A.**; Zezula, D.; Nash, L.; Duanyai, P.; Horváth, Zs. (2022). The effect of forest management and connectivity loss on water-filled tree hole communities. 36th Congress of the International Society of Limnology (SIL 100), 7-10 August 2022, Berlin, Germany, ***oral presentation***

Mészáros, B.; Bürgés, J. G.; Tamás, M.; Gál, B.; **Bohus, A.**; Schmera, D. (2023). A városi tájhasználat mértékének hatása a balatoni kockás siklók (*Natrix tessellata*) fluktuáló aszimmetriájára. 8. Szünzoológiai Szimpózium (SZÜSZI), 31 March – 01 April 2023, Tihany, Hungary, ***oral presentation***

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