PRELIMINARY STUDY ON THE ECOLOGICAL STATUS OF RIPARIAN ZONES OF RUNNING WATERS IN A CENTRAL EUROPEAN URBAN AREA (BUDAPEST, HUNGARY)

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Abstract. *The primary objective of this paper was to assess the condition of riparian zones within urban environments, aiming to evaluate the ecological health and functionality of riparian areas through the examination of various indicators, including (but not limited to) vegetation cover, water quality, stream channel morphology and habitat complexity. Such an evaluation is essential to identify areas that require restoration or conservation efforts and develop appropriate management strategies to ensure their effective protection. The present paper is the outcome of investigations that employed a comprehensive research framework, consisting of desk research, field surveys and data analysis. The desk research was utilized to combine the existing knowledge regarding riparian zones and water bodies research methods. The field surveys were conducted to gather empirical data concerning riparian vegetation cover, stream bank erosion and water quality. Data analysis was conducted to identify patterns and trends and determine areas of concern. This work contributes to the overall field of riparian area management by providing an assessment of riparian area conditions in the study area. The findings of the study can be used to inform conservation and restoration efforts and to guide the development of effective management strategies. The paper also highlights the need for ongoing monitoring and evaluation of riparian areas to ensure their continued health and functioning.*

Keywords: *streams, riparian zone, ecological status, urban areas, Budapest, Hungary*

INTRODUCTION

Riparian ecosystems encompass a diverse suite of ecosystem types, including riverbanks, floodplains, and wetlands, that are characterized primarily by being ecotones, or transitional zones, between adjacent terrestrial and aquatic realms (CAPON S.J., 2020**).** Riparian zones have a great value as ecological buffers and filters of pollutant from urban and agricultural areas, in riverbank stabilization, flow of energy through food webs and recharge of aquifers (ODUM E. P.,1979; MAJUMDAR & AVISHEK, 2023), erosion control, water filtration, carbon sequestration, nutrient cycling and regulation of the microclimate (ZAIMES et al., 2010). They serve as a crucial interface between land and water ecosystems, playing a vital role in the interception of terrestrial sediments and nutrients, sustaining water quality, food-web structure, and ecosystem services (PUSEY & ARTHINGTON, 2003).

Riparian zones have high water tables because of their proximity to aquatic ecosystems, certain soil characteristics and some vegetation that requires free (unbound) water or conditions that are more moist than normal. These zones are transitional between aquatic and upland areas containing elements of both (aquatic and terrestrial) ecosystems (BROWN & READE 1985). and, from an ecosystem perspective, they are integral parts of the forest/stream ecosystem complexes (SWANSON et al., 1982).

These areas are essential habitats for aquatic (invertebrates, fish, amphibians, reptiles etc.) species and amphibious organisms are normally found only in these habitats. Many other species, although not completely dependent on riparian or wetland habitats, tend to use them to a greater degree than upland areas (BROWN & READE, 1985). However, due to human activities such as agriculture, urbanization and resource extraction, riparian zones degrade. The ones adjacent to artificial flowing water bodies, including canals and channels, have different characteristics and functions than those adjacent to natural rivers and streams. The condition of these riparian zones can impact the ecological health and sustainability of these systems, as well as their aesthetic and recreational values (DÉCAMPS et al., 2009).

The study area

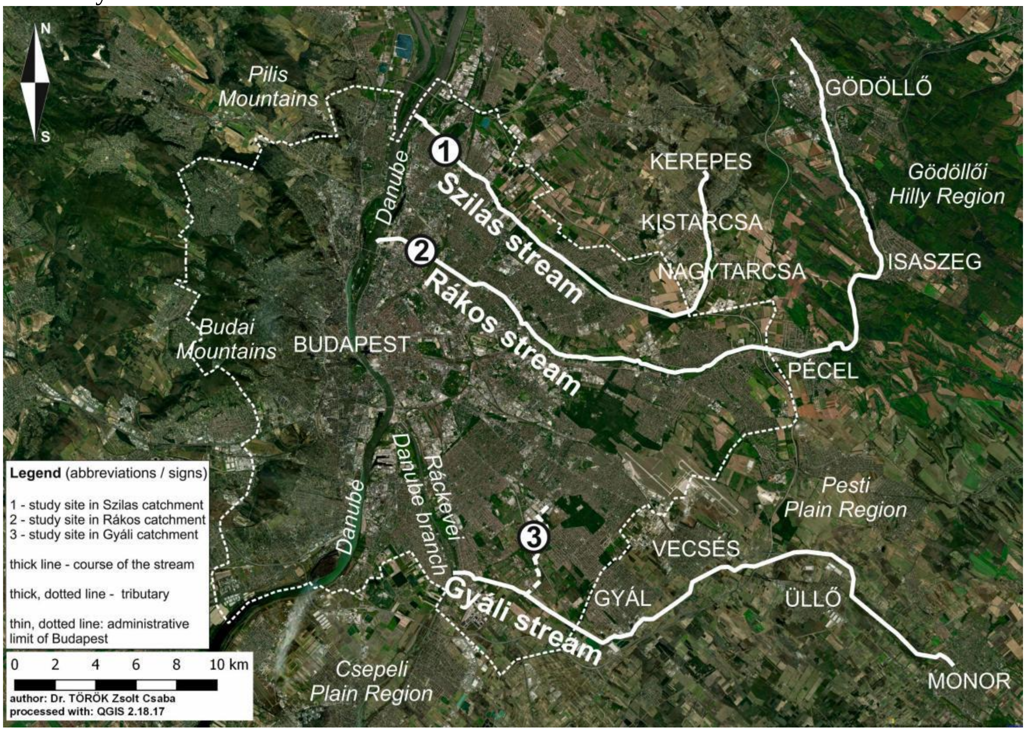

Fig 1. Location of the investigated sites along the target streams

Budapest, the capital city of Hungary, is has an abundance of surface water resources, (including the Danube River, and numerous artificial flowing water bodies) facing a range of environmental challenges, including water pollution, urbanization and climate change (SOOS & IGNITS, 2005). Many of the water bodies that flow inside of the city have been subject to hydro-technical works to regulate them, and the riparian zones surrounding them have been modified and degraded over time. Assessing the condition of these riparian zones is critical for developing effective management strategies and conserving the ecological and cultural values of these unique ecosystems.

Szilas patak (Szilas stream) is one of the collectors of the left bank tributaries of the Danube in the Gödöllő hills (SAEIDI et al., 2019a). It originates in several branches at Kerepes locality and passes through Kistarcsa and Nagytarcsa, than under the M0 expressway and reaches Budapest XVI. district, where it flows into the Naplás Lake, artificially created in 1978 (SCHUMACHER et al., 2022). From there, an artificial drain starts on its way and, not far from the Megyeri bridge, it flows into the Danube. The stream had no connection with the city, it was one among the smaller nearby watercourses. Today it already passes through more districts but indicates the edge of Budapest on a longer distance being in a border situation between the city and nature. At the beginning of the 1950s, it could have been considered a natural watercourse. However, for decades it is merely a runoff in a concrete trough (SOOS & IGNITS, 2005).

Rákos patak (Rákos stream) is a stream located at an elevation of eighty-six meters above sea level (SOOS & IGNITS, 2005). After a catastrophic flood that occurred on the Rákos stream in 1963, large-scale riverbed management was carried out along the Rákos and Szilas streams. As a result of this, the Naplás Lake was created and the Szilas Stream received a solid paved bed in its Rákospalota section. In addition to the residential areas near the coast of Rákosszentmihály, the necessity of the intervention was also justified by the large investment in the Énekes Street real estate being built in the centre of Rákospalota, as well as the Káposztámegyeri real estate. The Rákos stream originates in the Gödöllő hills and flows into the Danube. It is one of the longest left-bank tributaries of the Hungarian section of the river The stream, which is 1-3 meters wide on average, originates in the Gödöllő hills, at the border of Szada. In the city of Gödöllő, it merges with one of its tributaries, the Fiók-Rákos stream. (SAEIDI et al., 2019b).

Gyáli patak (Gyáli stream) is a small stream in Hungary that flows through the Soroksar district of Budapest, being a 32 km long watercourse that flows into the Ráckevei (Soroksári)-Danube, with a total catchment area of 450 km^2. The lower section in the southeastern part of Budapest is managed by the Budapest Municipality, meanwhile the upper 24.7 km watercourse section is the exclusive property of the state, managed and operated by the Central Danube Valley Water Administration (****, 2016). The watercourse that used to drain agricultural land is now a large built-up area - Ferihegy Airport, no. 4. main road, M0 and M5 motorways, industrial parks - the recipient of its rainwater and treated wastewater. The lower section of the stream can only provide drainage for the surrounding deep areas to a limited extent during the rainy, inland water season. The upper section does not receive a natural supply during periods without rainfall, the riverbed dries up and only transports purified wastewater (****, 2016).

Given the importance of riparian areas and the need for sustainable management, it is essential to assess their health and identify potential challenges and opportunities for improvement. This evaluation aims to fill this knowledge gap by providing a comprehensive analysis of riparian area health. The results of examining various indicators and metrics related to ecological integrity and biodiversity provide a holistic understanding of the current state of riparian areas.

The present paper, based on the results of scientific studies, field assessments, and data analysis, evaluates the condition and functioning of riparian areas, reviewing current management practices and policies, in order to determine their effectiveness in preserving and enhancing riparian health.

MATERIAL AND METHODS

Study Design:

The assessment is focused on three streams. The primary objective was to evaluate the general health of each stream and compare their riparian areas. Key indicators assessed included biodiversity, bank stability, water quality, and vegetation composition.

The field surveys were conducted during March and April 2023. The surveys involved observations made on the selected riparian areas of the following streams: Szilas patak (Szilas stream), Rákos patak (Rákos stream), Gyáli patak (Gyáli stream). A 20-meter section was selected for observations in each stream's riparian area. Prior to the field trip, a comprehensive review of field assessment methods to ensure accurate data collection. Field observations were conducted at each stream site.

Data Collection

The collected data on the vegetation, land use, water quality and water flow were registered in the data sheet called "Evaluation of Riparian Area Condition". The data sheet contains the following recorded data: site information location (name of the site and GPS position), date and period of investigations, photos on the sampling sites, data on weather conditions (% of cloud cover, rain, wind direction and speed, sun angle, air temperature); data on habitat conditions (1. channel and bank - wetted channel width, vegetated bank width, site length, flow conditions); 2. bank stability (stable no erosion, some erosion, unstable erosion, unstable eroding); 3. streambed geology (more than 50% boulders, cobbles, gravels or logs, 25-49% boulders, cobbles, gravels or logs, 11-24% boulders, cobbles, gravels or logs, less than 10% boulders, cobbles, gravels, or logs); 4. substrate (sand, gravel and rock, hard clay, sand and slit, slit and sand, slit and clay); 5. detritus (present or absent); 6. depth of the stream, water transparency and colour; data on aquatic plant diversity (free-floating species, emergent, submersed or rooted floating plants, algae), coverage (%) and density of the aquatic plants; data on the riparian area with its adjacent land use destination (conservation, recreation, agriculture, industrial, forest, urban and other), data on stack damage of the area (high, moderate, minor , none); data on riparian vegetation (1. structural diversity (optimal: more than 3 hight classes grass/ shrub/tree; suboptimal: 2 hight classes/mostly tree; fair: 1 hight class grass/forbs ; poor: 1 hight class sparse vegetation); 2. buffer width (optimal: more than 18 m on least buffered side; suboptimal: 12-18m; fair: 6-12 m; poor: less than 6 m); 3. vegetation diversity: trees, shrubs, grasses, sedges, rushes and forbs (optimal: more than 20 plants species; suboptimal:15-19 plant species; fair: 5-14 plant species; poor 0-5 plant species); 4. vegetation shading the water (optimal: mixed sun and shade; suboptimal: sparse canopy filtered light; fair: nearly compete sun or shade; poor: no shade complete sun).

Data Analysis:

Quantitative data collected during the assessments were analysed using appropriate statistical methods for calculating species richness indices, bank stability scores and conducting water quality parameter comparisons. Comparisons between the three streams were made to identify differences and similarities in biodiversity, bank stability, water quality, and vegetation composition.

The indicators were scored from 4 (optimal) to 0 (bad).

The overall ecosystem health scores have been ranged between very good to bad (Tab. 1) and is the sum of optimal and suboptimal overall indicators.

Table 1

The overall ecosystem health scores

GRADE	**GOOD**	**RELATIVE GOOD**	**PROPER**	**BAD**
SCORE	75-100	50-75	25-50	0-25

RESULTS AND DISCUSSIONS

Based on the field observations conducted on the three streams, several key characteristics regarding the channel and bank properties have been revealed such as, the channels were relatively narrow (being only 1-2 meters wide) and the average depth of the water in the sites was 35 cm, reduced water levels and slow and low flow which can have detrimental impacts on the quality of in-stream habitats. Water transparency was high, with only some inconsistent greenish colour due to the presence of algae.

Inadequate water depth leads to a rise in water temperature, posing a threat to the survival of aquatic organisms that require cooler waters. Furthermore, it results in a reduction in dissolved oxygen levels, which can have deleterious consequences for aquatic organisms. Low flow also has unfavourable effects leading to an increased sedimentation rate, which causes a decline in water clarity and suffocates aquatic habitats. Additionally, slow flow can cause structural changes in streams, such as channel widening or narrowing, leading to modifications in the available habitat for various species (MACURA et al., 2016).

More than that, the stream habitat (Fig.2) has been strongly modified by the human intervention through hydrotechnical works and the banks were found to be stabilized artificially. The streambed geology in all the sites consisted of less than 10% boulders, cobbles, gravels or logs.

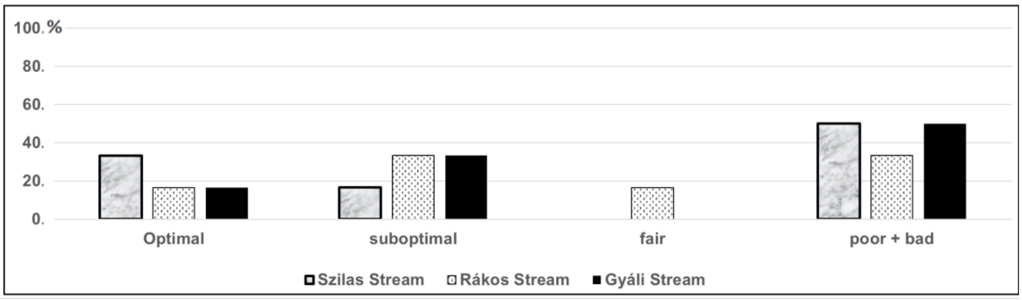

Fig 2. The stream habitat

The substrate of Szilas and Rákos streams consisted mainly of sand, with some gravel mixed in, while the substrate of Gyáli stream was composed entirely of sand. Detritus was absent in all the sites.

Regarding aquatic diversity (Fig.3), only algae were found to be present in all three streams, while emergent plants were only present in Rákos and Gyáli streams. Free-floating, submerged, and rooted floating plants were not observed in any of the sites. The scarcity of aquatic plants is a reliable indicator of the water body's health, which can destabilize the ecological processes, as aquatic plants have numerous functions.

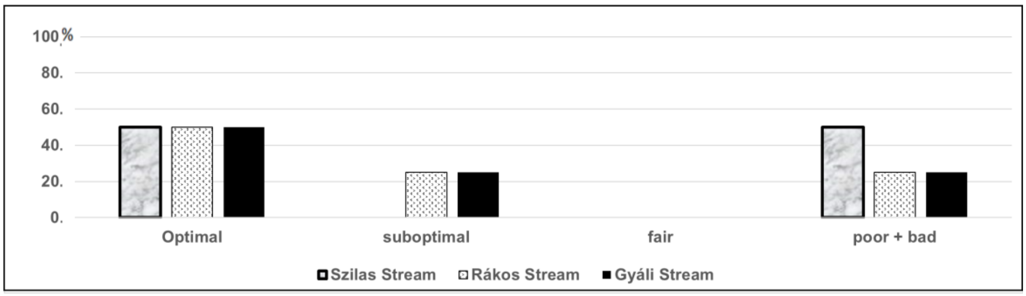

Fig 3. Aquatic diversity

Aquatic plants are important for providing oxygen, absorbing excess nutrients, providing shelter and habitat for aquatic animals, and stabilizing sediment. Without aquatic plants, water quality can degrade, leading to an increase in algae blooms and a decrease in dissolved oxygen levels especially during night and early morning if the flow of water is low or absent. The absence of habitat and shelter can also lead to a decline in aquatic animal populations, particularly those that rely on aquatic plants for food or shelter. The lack of plant roots to stabilize sediment can lead to erosion and sedimentation, further impacting water quality and aquatic habitats (****, 2002).

The riparian area of the sites was surrounded by urban areas and mainly used for recreational activities.

Vegetation structural diversity (Fig. 4) was found to be different in all the sites, with sparse one-class vegetation, dense one-class vegetation, and all classes of vegetation, including grass, shrubs and trees.

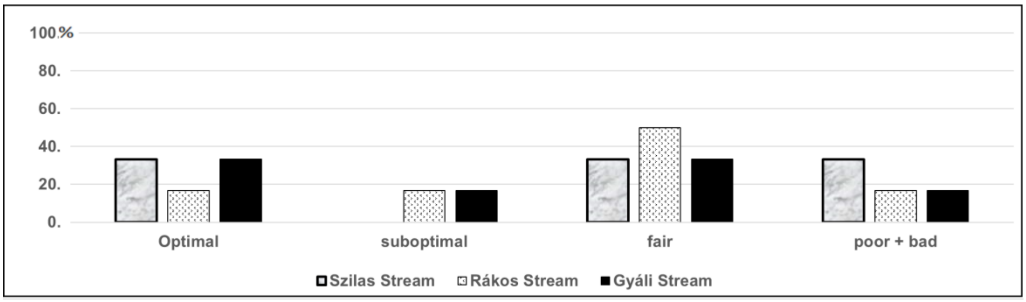

Fig 4. The riparian area structure.

The width of the riparian vegetation area also varied across the three investigated streams, with Szilas stream having a width of more than 18 meters, the Rákos stream ranging between 12 to 18 meters, and the Gyáli stream having between 6 to 12 meters width. The last one, while providing some level of buffer, it is narrower compared to the other two sites (as a wider buffer is generally desirable for improved riparian health and ecosystem functioning).

The number of recorded species ranged between 5 to 14 which can be associated with lower ecosystem resilience, habitat availability and support for a wider range of organisms.

The vegetation structure over the stream water revealed that at all three sites, there was no shade provided by vegetation, with the water being fully exposed to sunlight. The absence of shading can have a detrimental effect on river water quality. Vegetation shading plays a crucial role in regulating water temperature and providing habitat for shade-adapted species which, in turn, can improve water quality by reducing the growth of algae and other aquatic plants. Without shading and low flow of water the growth of algae will increase multiple times. This can have negative effects on water quality, including decreased dissolved oxygen levels and changes in the food web. Additionally, the absence of shading increases the rate of evaporation from water bodies, which is particularly harmful (GHERMANDI et al., 2009), especially in summertime when water in the stream bank is scarce.

The assessment identified variations in adjacent land use among the three sites. The differences in land use patterns significantly influence the condition and composition of riparian vegetation along the three investigated streams. The variations in adjacent land use among the assessed sites have direct implications for riparian area health. Recreation and urban land use can introduce disturbances, such as increased human activities, pollution, and habitat fragmentation, which can negatively impact the riparian ecosystem. On the other hand, a mix of forest, recreation, and urban land use can provide more diverse habitats and potentially support a wider range of riparian species. By combining the given values of the 16 recorded parameters (Fig. 5), the authors depict the value of the ecosystem health (Table 2) as being relative good in the case of Rákos and Gyáli stream and proper in the case of Szilas stream.

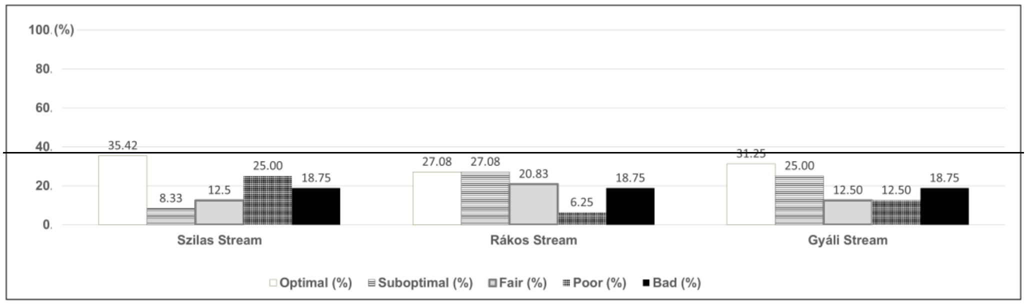

Fig 5. The overall of the "Field Surveys" score.

Table 2

The value of the ecosystem health

ECOSYSTEM HEALTH VALUE	GOOD	RELATIVE GOOD	PROPER	BAD
Szilas stream			43.75	
Rákos stream		54.17		
Gyáli stream		56.25		

CONCLUSIONS

By assessing the condition of riparian zones and water quality of running waters from the Eastern part of Budapest, there have been detected several issues having a detrimental impact on the overall health and biodiversity of these ecosystems. The low water depth, slow flow, scarcity of aquatic plants, water pollution, deficient vegetation and absence of shading have been identified as primary issues that could affect the health of these water bodies.

These factors have contributed to a range of problems, including increased water temperature and sedimentation and a small number of aquatic species.

Land use among the three sites were predominantly for recreation and urban purposes (Szilas and Rákos streams) and a mix of forest, recreation, and urban land uses in the case of Gyáli stream.

The riparian vegetation buffer width, along Szilas stream, exhibited an optimal buffer width (more than 18 meters). This substantial buffer zone indicates effective measures in place to protect the riparian area, offering benefits such as improved water quality and habitat preservation.

In case of Rákos stream the riparian vegetation buffer width was determined to be sub-optimal. While still relatively substantial, this narrower buffer suggests a need for increased protection and management efforts to enhance the buffer zone and its associated ecological functions.

For the Gyáli stream, the riparian vegetation buffer width was fair. Consideration should be given to potential land use activities and management practices that could contribute to the increase of the buffer width.

Along the riparian areas none of the investigated zones had big trees that allow a water bodies shading.

Riparian vegetation structure in all three sites exhibited the fair diversity. The absence of vegetation shade suggests a potential lack of riparian vegetation cover or specific management practices such that of cutting the vegetation along the riverbank that have resulted in reduced shading.

An optimal buffer width, as observed in the case of Szilas stream, provides multiple benefits such as enhanced water quality through sediment filtration, bank stabilization, and habitat provision. A sub-optimal or narrow buffer width, as found in case of Rákos and Gyáli streams, can result in increased sedimentation, reduced water quality, and limited habitat availability for riparian organisms.

As these issues are having a significant impact on the health and biodiversity of these water bodies, it is important to address these problems through appropriate management strategies and restoration efforts to improve the resilience and sustainability of these critical ecosystems.

There are several recommendations for management strategies that can be implemented to address the issues identified in the water bodies of Budapest.

1. Enhance the riparian buffer zones through land management practices, land acquisition, or restoration efforts can improve riparian area health by reducing pollution inputs, preventing erosion, and promoting diverse vegetation communities. These zones should be composed of native vegetation and implementing proper management practices should promote a more diverse and robust riparian plant community.
2. Promote natural channel design. Natural channel design techniques can help restore and stabilize streams and rivers, improving their ecological health and protecting riparian zones.
3. Provide education and outreach. Educating the public about the importance of riparian zones and their role in maintaining healthy aquatic ecosystems can help increase support for conservation efforts and encourage individuals to adopt environmentally friendly practices.
4. Monitor and evaluate restoration efforts. Regular monitoring and evaluation of restoration efforts can help identify potential problems and ensure that management strategies are effective in protecting riparian zones.

By implementing these recommendations, management efforts can help protect and preserve riparian zones in the urban settings of Budapest, ensuring the long-term health and sustainability of its aquatic ecosystems.

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