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THE IMPACT OF RECREATIONAL BOATING ON WATER QUALITY AND THE ECOSYSTEMS OF THE BATA CANAL

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ABSTRACT

The aim of the study was to evaluate the impacts of recreational boat traffic on the water quality and ecological status of the Bata Canal (Czech Republic), an important tourist waterway in South Moravia. Field measurements of physicochemical water parameters (COD_{Cr}, NO_3^- N, P_{tot}, pH, EC, DO) and an on-site questionnaire survey among canal users were carried out. The results showed that recreational boat traffic does not cause measurable deterioration of water quality, even in the most intensively used sections. The highest values of dichromate chemical oxygen demand (up to 23.4 $mg \cdot l^{-1}$) and total phosphorus (0.2 $mg \cdot l^{-1}$) were recorded in Veselí nad Moravou, while all values remained below Czech surface-water guideline thresholds. The findings highlight the role of natural self-purification processes, hydrological conditions, and responsible visitor behaviour in maintaining water quality. From a landscape-planning perspective, the study emphasises zoning, bank management, and operational regimes as elements of blue-green infrastructure supporting ecological stability. The Bata Canal represents a successful example of coexistence between recreation and aquatic ecosystem protection, showing that under current recreational use, good ecological conditions can be sustained through appropriate management and user awareness.

Keywords: Bata Canal, recreational boating, water quality, eutrophication, environmental management, landscape planning, blue-green infrastructure

INTRODUCTION

The development of recreational navigation on inland waterways in Europe not only brings economic benefits (Calderón-Rivera, Bartusevičienė & Ballini, 2024a) but also poses a significant challenge in terms of sustainable development and for the protection of aquatic ecosystems (Calderón-Rivera, Bartusevičienė & Ballini, 2024b). According to Mako and Galieriková (2021), inland navigation, especially on large European rivers such as the Danube and the Rhine, is of increasing importance for regional economies and tourism. At the same time, however, this trend requires comprehensive management of the environmental impacts associated with the increase in recreational traffic, as well as the development of ports and infrastructure (Schafft, Wegner, Meyer, Wolter & Arlinghaus, 2021).

Current research shows that the interconnection of inland and coastal waterways in the context of climate change may increase environmental risks, such as eutrophication, biodiversity loss, and disruption of the hydrological balance (Némethy, Ternell, Bornmalm, Lagerqvist & Szemethy 2022). Sexton et al.

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(2024) further highlight that the combination of shipping and land-use change negatively affects freshwater biodiversity in Europe, especially for species sensitive to erosion and chemical stresses.

Inland waterways, including those with historical significance, are therefore understood as linear infrastructures that combine transport and ecological functions (Steege et al., 2022). Sustainable management of these systems requires a balance between recreational use and the protection of ecosystem services (Afentou et al., 2022; Arif, Behzad, Tahir & Changxiao, 2022). In the context of landscape planning and architectural design, the visual and spatial quality of the water corridor, the legibility of nodes (piers, footbridges, platforms), and their material and vegetation integration into the surrounding landscape are also gaining importance.

The 53 km long Bata Canal is a unique example of the connection between technical cultural heritage and natural habitat. It was built in the 1930s to transport lignite and irrigate agricultural landscapes, but after the end of its industrial use, it was gradually revitalised into a recreational and tourist waterway. Today, it serves mainly for the purposes of water tourism, recreational boating, and regional tourism, thus becoming a model example of adaptive reuse of technical structures in the landscape (Machar, 2013). From the perspective of landscape ecology, the canal represents an important linear ecosystem, combining natural and artificial sections, slow-flowing and stagnant waters, and extensive littoral zones with wetland vegetation. This mosaic character supports biodiversity and the aesthetic value of the area, but, at the same time, increases its vulnerability to recreational loads and changes in the hydrological regime. In recent years, the Bata Canal has also become a subject of interest from the perspective of landscape and visual planning. The study by Jiang et al. (2025) emphasises that cultural heritage waterways have a high potential for sustainable development and ecotourism if their management is based on the integration of aesthetic, ecological and social functions. The Bata Canal can thus be perceived not only as a transport and tourist route, but also as a cultural landscape corridor that mediates the relationship between humans and the aquatic environment in the conditions of a changing climate and increasing tourist pressure (Fig. 1).

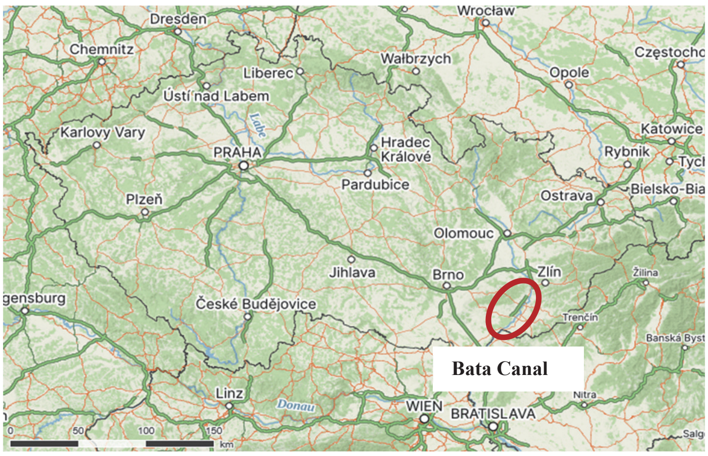

Fig. 1. Area of interest in Czech Republic

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The aim of this study was to verify whether the current intensity of recreational boat traffic affects the water quality and ecological processes of the Bata Canal. The hypothesis assumed that at the current level of tourism, there is no significant deterioration of the physicochemical parameters of the water, with the key factors being the tributaries from the Morava basin and agricultural activity in the vicinity. The secondary aim is to interpret the environmental results in terms of landscape-architectural planning and to propose principles for spatial and operational management of the riverbank sections and docks.

MATERIAL AND METHODS

Site characteristics,

The Bata Canal is a significant waterway in South Moravia (Czech Republic), connecting the Morava River between Otrokovice and Rohatec, with a total length of 53 km. It was built in the 1930s to supply water to the Bata industrial enterprises and to irrigate agricultural land. Today, it is used mainly for recreational boating and water tourism.

The channel has the character of a shallow, slow-flowing stream with a width of 10–12 m and a depth of 1.5–2.5 m. The water body is formed by alternating natural sections of the Morava River and artificially constructed branches. The banks are partially fortified, in places with natural growth of reed (*Phragmites australis*) and cattail (*Typha latifolia*), which contribute to the self-cleaning capabilities of the system. The surrounding landscape is used for agriculture, and there are several smaller villages, recreational docks, and campsites nearby (Fig. 2).

Fig. 2. Boating season on the Bata Canal

Source: authors.

Selection of sites and sampling

Field sampling was carried out during the main boating season (April–October 2022) at five representative sections of the Bata Canal: Veselí nad Moravou, Vnorovy, Strážnice, Výklopník and Rohatec. These sites represent different levels of recreational load and hydrological conditions along the canal. At each site, surface water samples were collected approximately 0.5 m below the water surface from the central part of the channel profile to minimise bank effects. Sampling was conducted monthly. Water samples (1 L) were collected into clean polyethylene bottles, stored in a portable cooler, and transported to the laboratory for analysis on the day of sampling (Fig. 3).

Fig. 3. Simple profiles on the Bata Canal

Source: © Seznam.cz, edited by authors.

Laboratory analyses

The following physicochemical parameters were analysed:

- pH [-], according to CSN EN ISO 10523 (Czech Standardisation Agency [ČAS], 2012a), and water temperature [°C] with a portable Hach HQ40d,
- dissolved oxygen (DO) [mg·l⁻¹], electrochemical probe method according to standards ČSN EN 25814 and ČSN EN ISO 5814 (ČAS, 1993a, ČAS, 2012b),
- electrical conductivity (EC) [mS·m⁻¹], conductometric method according to ČSN EN 27888 (ČAS, 1993b),
- dichromate chemical oxygen demand (COD_{Cr}) [mg·l⁻¹], dichromate method according to ČSN ISO 6060 (ČAS, 1996),
- nitrate nitrogen (NO_3^-N) [mg·l⁻¹], spectrophotometry according to ČSN EN ISO 13395 (ČAS, 1997),
- total phosphorus (P_{tot}) [mg·l⁻¹], spectrophotometry after mineralisation according to ČSN EN ISO 6878 (ČAS, 2004).

All analyses followed Czech quality standards for surface water.

Data processing

Measured data were evaluated using descriptive statistics (mean values). Results were interpreted in relation to Czech surface water quality classifications (Table 1).

Table 1. Water quality indicators and their classification according to ČSN 75 7221 (ČAS, 2017)

Indicator	Unit	Class I	Class II	Class III	Class IV	Class V
Conductivity (EC)	$mS \cdot m^{-1}$	< 40	< 70	< 110	< 160	≥ 160
Dissolved oxygen (DO)	$mg \cdot l^{-1}$	> 8.5	> 7.5	> 6	> 4	≤ 4
Nitrate nitrogen (NO_3^- N)	$mg \cdot l^{-1}$	< 2.5	< 5	< 8	< 12	≥ 12
Dichromate chemical oxygen demand (COD_{Cr})	$mg \cdot l^{-1}$	< 15	< 25	< 45	< 60	≥ 60
Total phosphorus (P_{tot})	$mg \cdot l^{-1}$	< 0.05	< 0.15	< 0.3	< 0.6	≥ 0.6

Class I – unpolluted water, Class II – slightly polluted water, Class III – polluted water, Class IV – heavily polluted water, Class V – extremely polluted water.

Source: own work.

Questionnaire survey

The research also included a short on-site questionnaire survey focused on visitors' attitudes toward the protection of the aquatic environment and basic boating behaviour (Fig. 4). The survey was conducted in August 2022 at the Petrov lock during the main boating season. A total of 15 respondents participated. The questionnaire consisted of six simple questions concerning visit frequency, group size, route choice, onboard waste handling and general environmental awareness. The purpose of the survey was to obtain indicative information on visitor responsibility and awareness in relation to the protection of water quality in the Bata Canal.

Fig. 4. Questionnaire survey process

Source: photo by authors.

Field observations

In parallel with the questionnaire survey, systematic field observations were conducted focusing on: (i) the cleanliness of the banks and docks, (ii) the presence of litter on the water surface, (iii) the intensity of navigation traffic (in number of boats per hour), and (iv) visible signs of pollution (oil stains, turbidity, foam). Observations were carried out three times a week for six weeks (July–August). Field notes included a visual assessment of boating frequency and bank cleanliness.

RESULTS

Water quality and spatial differences

The measured results (Table 2) confirmed that the water in the canal has a stable quality for most indicators corresponding to water quality Classes I–II. Only the TP indicator values show water quality Class III. The slight increase in COD_{Cr} and P_{tot} in the middle part of the canal (Veselí nad Moravou) can be attributed to a combination of lower flow, more intensive tourist traffic and local inflows from urbanised areas. Spatial patterns were interpreted descriptively based on measured average values. The results show that recreational boat traffic currently has a negligible influence on basic water quality indicators.

Table 2. Seasonal average values of physicochemical water parameters on the Bata Canal (April–October 2022)

Location	Nitrate nitrogen (NO_3^- N) [mg·l⁻¹]	Total phosphorus (P_{total}) [mg·l⁻¹]	Dichromate chemical oxygen demand (COD_{cr}) [mg·l⁻¹]	Dissolved oxygen (DO) [mg·l⁻¹]	pH [-]	Conductivity (EC) [mS·m⁻¹]
Veselí nad Moravou	3.07	0.2	20.1	9.5	8.2	46
Vnorovy	2.01	0.17	22.3	11.09	8.1	45
Strážnice	2.1	0.13	21.5	7.05	8.3	48
Výklopník	2.12	0.19	23.4	10.26	8.0	60
Rohatec	2.11	0.18	20.0	8.98	8.4	48

Source: own work.

Self-cleaning processes and ecological stability

Due to the slow flow and the presence of macrovegetation (*Ph. australis*, *T. latifolia*), the channel exhibits the ability of biological filtration and nutrient accumulation. Plants in the littoral zone act as biofilters, contributing to the reduction of nitrate and phosphorus content. The presence of periphyton and small aquatic animals indicates a stable ecological balance. No signs of massive cyanobacterial development or hypoxia were observed, confirming the good trophic stability of the system.

Tourist burden and user behaviour

Questionnaire results show a high level of environmental responsibility. Only a small proportion of users reported water pollution (12%). Subjective perception of the state of the environment correlates with objective data – areas with higher visitor numbers did not show higher nutrient concentrations. Local pollution in the marinas (especially from the operation of refreshments) remains a problem, which requires regular waste collection and supervision.

Climate change connection

Due to climate change and longer periods of drought, reduced flows can be expected, which may increase the risk of eutrophication in the future. Therefore, it is necessary to continue long-term monitoring and optimisation of channel management with respect to the hydrological regime.

DISCUSSION

Main implications of the findings

A set of physicochemical indicators (COD_{Cr}, NO_3^- N, P_{total}, pH, EC, DO) demonstrated stable water quality corresponding to Class II, with no clear spatial deterioration along the canal. Slightly higher values of COD_{Cr} and P_{total} in Veselí nad Moravou can be attributed with high probability to local tributaries and hydrological conditions (lower dilution effect, longer residence times), not to recreational navigation itself. These results support the working hypothesis that the current intensity of recreational traffic on the Bata Canal does not have a detectable negative impact on basic water quality parameters. From the perspective of corridor planning, this means that the key to sustainability does not lie in area-wide restrictions on navigation, but in targeted management of point and line "inflows" and in fine-tuning of operational rules in time and space.

Comparison with the literature: what impacts can be expected and when

The findings are consistent with framework reviews that low- to moderate-intensity aquatic recreation has limited impact on chemical parameters if self-cleaning processes are functioning and basic management is applied (Venohr et al., 2018; Steege et al., 2022). At the same time, however, syntheses and meta-analyses point out that the ecological impacts of recreation tend to be underestimated, spatially and temporally variable, and can cumulate with other pressures (land-use change, drought) – resulting in measurable changes in biodiversity, bank erosion, sediment resuspension, or faunal disturbance (Schafft, Engelbart, Hädicke, Schäfer & Wey, 2021; Sexton et al., 2024). The practice of smaller streams and canals also shows that land-based recreational activities in the immediate vicinity of the water (docks, water inlets, riparian areas) can contribute to an increase in turbidity, coliform indicators, and nutrients, especially during high visitor numbers (Cooke & Xia, 2020). In managed systems with monitoring, these impacts can be prevented and kept below significance thresholds (Butler, Pearson & Birtles, 2021). For the canal as a linear infrastructure, this supports the "hotspot-oriented management" approach, in which measures and monitoring are preventively concentrated in a few of the most loaded nodes instead of area-wide interventions.

Mechanisms of ecological resilience: the role of the littoral, hydrology and user behaviour

The observed absence of hypoxia and massive cyanobacterial development in the summer season suggests that the trophic regime is currently stable. Littoral reed (*Ph. australis*) and cattail (*T. latifolia*) belts support biofiltration, sedimentation of fine particles and nutrient retention, thereby reducing the likelihood of short-term eutrophic episodes. In slow-flowing sections, microbial oxidation-reduction processes are applied, which stabilise the organic load (reflected in COD_{Cr}). Pro-environmental behaviour of users also plays an important role: our questionnaires confirmed a high level of responsible behaviour and acceptance of regulatory measures, which the literature identifies as a key "soft" tool with a rapid effect on water quality (Butler et al., 2021). From the perspective of landscape and architectural design, "semi-permeable" shore edges, floating vegetation elements, and mosaic littorals appear to be functional, which simultaneously increase the aesthetic quality of the embankment and reduce hydraulic wave peaks; such solutions also increase social acceptance of regulations (Machar, 2013; Jiang et al., 2025).

Where problems can arise: threshold phenomena and "hotspots"

Reviews show that even with moderate navigation, local hotspots can arise in certain contexts: bank erosion and resuspension of sediment from waves and propellers (wake and prop wash), increased turbidity and phosphorus in shallow bays, disturbance of fish and waterfowl, and transfer of non-native species (Venohr et al., 2018; Schafft et al., 2021). These phenomena did not manifest themselves to a measurable extent in the Bata Canal, but they can accumulate during the confluence of low flows, high temperatures, and weekend peaks. For these situations, the literature recommends operational measures: temporary speed limits, restrictions on sharp manoeuvres in narrow sections, controlled avoidance of zones with loose sediments, and clear tracking of ship movements in berths (Cooke & Xia, 2020; Butler et al., 2021). Additionally, it is advisable to set "trigger points" for management (e.g. a combination of low flow, water temperature above 24–26°C, and visitor peaks), after which local speed restrictions or traffic redirection are automatically activated.

Evidence-based management: what to add to canal practice

Based on the studies mentioned, the implication framework for the management of the Bata Canal can be expanded to include a comprehensive approach based on adaptive management principles. A key tool is integrated monitoring of water quality and recreational use, which should combine regular sampling campaigns throughout the season (spring–summer–late summer) with continuous logging of temperature and dissolved oxygen concentration. During peak tourist periods, it is appropriate to conduct rapid screenings of turbidity and indicators of faecal pollution in the most visited sections, while in the docks, short-term increases in COD_{Cr} and P_{tot} values should be monitored after large public events (Cooke & Xia, 2020; Butler et al., 2021). Management should also include zoning and capacity regulation, i.e. the definition of quiet zones and sections with speed restrictions in ecologically sensitive parts of the canal, such as littorals with bird nesting or shallow, muddy banks prone to erosion. Soft capacity limits can be applied in selected berths during the busiest periods of the season to avoid excessive load and environmental degradation (Schafft et al., 2021). Prevention of erosion and sediment resuspension is also an important element. These measures include technical and organisational interventions, such as guiding navigation routes through the middle of the profile in shallow sections, reducing waves at sensitive banks, stabilising water entrances and platforms, or restoring littoral vegetation that naturally dampens the hydrodynamic effects of ship traffic (Venohr et al., 2018). No less important is the issue of biosecurity and berth management. It includes the introduction of standards for rinsing vessels and equipment to limit the spread of invasive species, ensuring adequate waste and sanitation infrastructure, and the creation of a user code with an emphasis on zero wastewater discharge and the use of biodegradable cleaning agents. Such a system of supporting measures can significantly contribute to the sustainability of the aquatic environment of the Bata Canal while encouraging environmentally friendly behaviour among its users (Cooke & Xia, 2020; Butler et al., 2021).

Placing the results in the European context

The Bata Canal can be seen as a model of managed linear water infrastructure: at the current intensity of recreation and the application of targeted management, it achieves a balance between recreational and ecological functions. At the same time, the warning from meta-analyses applies that long-term and spatially cumulative effects of recreation may be underestimated if monitoring and management in "hotspots" are missing (Venohr et al., 2018; Schafft et al., 2021). Therefore, we recommend adhering to the principle of adaptive management with clear triggers for temporary restrictions (drought, hot episodes, extreme visitor numbers). On a European scale, the Bata Canal can be understood as a "living lab" for blue-green cultural heritage corridors, where combinations of spatial design, operating rules and community education are tested and their impact on water quality and user comfort.

CONCLUSIONS

Monitored indicators (COD_{Cr}, NO_3^- N, P_{tot}, pH, EC, DO) confirmed the stable water quality of the Bata Canal corresponding to Class II. A slight increase in COD_{Cr} and P_{tot} in Veselí nad Moravou is likely associated with local hydrology and tributary inflows rather than the intensity of recreational boating. Ecological stability is supported by self-purification processes and littoral vegetation, while responsible user behaviour reduces the likelihood of local pollution "hotspots" in marinas. Potential threshold risks may occur during periods of low flows, heat, and peak visitor numbers; therefore, adaptive management supported by regular monitoring and targeted measures (zoning, speed regulation, control of nutrient inputs, and strengthening of waste and sanitation infrastructure) is recommended. The main limitations of this study include the seasonal sampling period and the focus on physico-chemical indicators; multi-year monitoring incorporating biological parameters and sediment analyses should be considered in future research. Overall, the Bata Canal currently represents a successful example of the coexistence of recreational navigation and aquatic ecosystem protection, with water quality remaining stable under current use intensity due to natural self-purification capacity, littoral vegetation, and user responsibility, while long-term sustainability will rely on proactive, evidence-based management.

Authors' contributions

Conceptualisation: V.H; methodology: V.H.; validation: V.H. and M.F.; formal analysis: V.H.; investigation: V.H. and M.F.; resources: M.F.; data curation: M.F.; writing – original draft preparation: V.H.; writing – review and editing: V.H.; visualisation: V.H.; supervision: V.H.

All authors have read and agreed to the published version of the manuscript.

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WPŁYW ŻEGLUGI REKREACYJNEJ NA JAKOŚĆ WODY I EKOSYSTEMY KANAŁU BATA

STRESZCZENIE

Celem badania była ocena wpływu ruchu łodzi rekreacyjnych na jakość wody i stan ekologiczny kanału Bata (Czechy), ważnego szlaku turystycznego na Morawach Południowych. Przeprowadzono pomiary terenowe parametrów fizykochemicznych wody ($ChZT_{Cr,}$ NO_3^- N, P_{tot}, pH, przewodność, tlen rozpuszczony) oraz ankietę na miejscu wśród użytkowników kanału. Wyniki wykazały, że ruch łodzi rekreacyjnych nie powoduje mierzalnego pogorszenia jakości wody, nawet na najbardziej intensywnie użytkowanych odcinkach. Największe wartości $ChZT_{Cr}$ (do 23,4 $mg \cdot l^{-1}$) i P_{tot} (0,2 $mg \cdot l^{-1}$) odnotowano w miejscowości Veselí nad Moravou, podczas gdy wszystkie wartości pozostawały poniżej progów wytycznych czeskich dla wód powierzchniowych. Wyniki podkreślają znaczenie naturalnych procesów samooczyszczania, warunków hydrologicznych oraz odpowiedzialnego zachowania odwiedzających dla utrzymania wysokiej jakości wód. Z perspektywy planowania krajobrazu badanie wskazuje na kluczową rolę zróżnicowania stref funkcjonalnych, właściwego zarządzania linią brzegową i dostosowanych reżimów operacyjnych jako elementów błękitno-zielonej infrastruktury wzmacniającej stabilność ekologiczną. Kanał Bata stanowi udany przykład harmonijnego współistnienia rekreacji i ochrony ekosystemów wodnych. Pokazuje, że przy obecnym poziomie użytkowania rekreacyjnego dobre warunki ekologiczne można utrzymać dzięki odpowiedniemu zarządzaniu oraz wysokiej świadomości użytkowników.

Słowa kluczowe: kanał Bata, żeglarstwo rekreacyjne, jakość wody, eutrofizacja, zarządzanie środowiskiem, planowanie krajobrazu, błękitno-zielona infrastruktura