

## Testing a field methodology for assessing the vegetational impacts of access pathways traversing the reed beds of Lake Balaton at a study site in Balatonfenyves

### *A Balaton nádasait átszelő bejárók növényzetre gyakorolt hatásainak vizsgálatához szükséges terepi módszertan tesztelése balatonfenyvesi mintaterületen*

Tamás Gyurina<sup>1\*</sup>, Zsombor Boromisza<sup>1</sup>

<sup>1</sup>Hungarian University of Agriculture and Life Sciences, Department of Landscape Protection and Restoration, Villányi út 19-43, H-1118 Budapest, Hungary

\*Correspondence: gyurinat1995@gmail.com

**Abstract:** Our study examined the effects of four public access pathways on the surrounding vegetation within the reed beds of Lake Balaton at a study site in Balatonfenyves. The vegetation was analyzed using 1×1 meter quadrats to determine species composition and abundance. The research aimed to assess the extent of the pathways' influence on the vegetation, the spatial scale of this impact, and how the disturbance zone changes with increasing distance from the shore zone. The primary goal of this work was to develop a simple field method to support future, more comprehensive investigations. Our findings suggest that the pathways' impact on the vegetation is most significant in a wider zone near the land-water interface, decreases towards the center of the reed bed, but intensifies again in close proximity to the open water.

**Keywords:** anthropogenic effect, Lake Balaton, reed bed, tourism, shore zone vegetation

**Összefoglalás:** Kutatásunk során Balatonfenyvesen négy, a nádasat átszelő közösségi bejáró mentén vizsgáltuk ezeknek a vonalas létesítményeknek a hatását a környező növényzetre. A vegetáció vizsgálatához 1×1 méteres kvadrátokat használtunk, amelyekben belül meg tudtuk határozni az egyes növényfajok arányát. Azokra a kérdésekre kerestük a választ, hogy a bejárók mekkora mértékben hatnak a körülöttük lévő vegetáció összetételére, ez a hatás milyen távolságban érvényesül a bejáróktól számítva, valamint ez a hatásterület változik-e a nyílt víz felé haladva. Ezeknek a problémáknak a kutatására egy egyszerűen használható terepi módszer kifejlesztésére van szükség. Ezzel az volt a célunk, hogy további részletesebb kutatásokat készítsünk elő. Eredményeink azt mutatják, hogy a szárazföld közvetlen közelében nagyobb szélességben van hatása a növényzetre a bejáróknak, amely a nyílt víz felé haladva csökken, azonban a nyílt víz közelében ismét felerősödik az építmények zavaró tulajdonsága.

**Kulcsszavak:** antropogén hatás, Balaton, nádas, turizmus, partmenti növényzet

## 1 Introduction

Despite its nearly 600 km<sup>2</sup> surface area, Lake Balaton is an exceptionally shallow standing water body, with an average depth of only 3.3 m (http1), and therefore responds rapidly even to minor changes. Owing to its shallowness, an extensive littoral vegetation zone has developed,

which functions as a buffer area. Reed beds filter pollutants arriving from the terrestrial environment and protect the shore zone from wave-induced erosion (Jakucs 1981). This well-functioning ecosystem—often comprising zonation from open water through marsh meadows to woody terminal communities—is subject to anthropogenic mechanical disturbances. Several types of disturbance affect the littoral vegetation, including land reclamation and the construction of boat passages. According to a survey performed in 2012, along the entire shore zone of Lake Balaton an interruption of some type in the vegetation of littoral zone could be observed on average every 59 metres. The study indicates that the reed beds of Balatonmáriafürdő, Balatonfenyves, and Balatonkenese are the most affected by human disturbance (Vidovenyecz 2012).

However, the most common disturbances are access paths, predominantly originating from private properties in recreational areas (Gyurina 2025), which cut through reed beds and open the formerly closed vegetation both toward open water and toward land. Under these conditions, species indicative of human disturbance and invasive alien plants, such as *Echinocytis lobata* are able to penetrate the reed beds from the terrestrial side (Pomogyi 2011). In the areas of Balatonfenyves and Balatonmáriafürdő, these pathways also indirectly promote shrub spread within reed beds (Gyurina & Boromisza 2025). In addition, wave action can enter the reed beds from the open water side along these access paths, initiating internal erosion of the vegetation (Pomogyi 2011).

Numerous studies have addressed disturbances affecting littoral vegetation in lakes; however, relatively few have focused specifically on the issue of access paths, which cause substantial fragmentation of shore zone vegetation along Lake Balaton (Vidovenyecz 2012). In 2011, natural and developed shore zones of three lakes in northern Germany were compared. In the three studied lakes, shore zone development affected 9%, 24%, and 65% of the total shore zone length, respectively, resulting in reductions of macroinvertebrate biomass of 5%, 20%, and 36%.

An investigation of beaches established within the littoral vegetation of tourist-frequented lakes in a nature conservation area in Germany revealed that plant cover in disturbed reed belts was considerably lower than in control sites. Furthermore, the proportion of ruderal species was slightly higher in areas close to the beaches, although the difference was modest. The study ultimately concluded that, among the examined habitat types, reed beds exhibited the greatest contrast between control and disturbed sites, although even in this case the differences were not pronounced (Meyer et al. 2023).

Along lake shores with well-developed infrastructure, it is common for owners of waterfront properties to consider littoral vegetation as aesthetically undesirable and therefore to cut or remove it. This practice reduces habitat diversity and reduces the capacity of vegetation to fulfill its water-quality protection functions. A study of lake shore zones in The USA, Maine found that, along access paths leading to docks, macrophyte species in the littoral zone presented significantly lower shoot densities (Ness 2006). Similar phenomena can also be observed along certain shoreline sections of Lake Balaton.

In 2009, potential damage caused by anglers was examined along the shores of Canadian lakes and rivers. On shoreline sections that were rarely used by anglers, the area devoid of vegetation was almost four times greater than on frequently used sections; however, this effect was moderated to the immediate shoreline and reduced toward open water (O'Toole et al. 2009). Comparable effects can be expected in relation to access paths occurring within the reed beds of Lake Balaton.

The protection of the reed beds of Lake Balaton is regulated by two legal instruments: the provisions of Act CXXXIX of 2018 concerning the Lake Balaton Priority Resort Area, and

Government Decree No. 22/1998 (II.13.). The first regulation stipulates that, with limited exceptions, all mechanical interventions are prohibited in class I–III reed beds and within a buffer zone of at least 2 meters around them, as well as in reed beds located in protected natural areas and their buffer zones. Prohibited activities include dredging, infilling, construction, and the establishment of piers or access structures, where such actions may damage reed stands, degrade their quality, or lead to their destruction. Exceptions are limited to environmental damage prevention, interventions required for life and accident safety, specific maintenance of the lakebed, the removal of unauthorized structures or infill, and management measures defined in nature conservation or Natura 2000 management plans.

The latter regulation further stipulates that the conservation of class IV and V reed beds must be ensured and, where possible, their restoration should be undertaken. In addition, Government Decree No. 283/2002 (XII. 21.) also addresses the protection of reed beds by requiring that, during the preparation of shoreline regulation plan documentation, the areas of classified reed beds be taken into account. This provision therefore offers a form of protection against the designation of inappropriate land-use categories. Although these legal instruments could provide suitable protection for the reed beds of Lake Balaton, the vegetation of the lake's littoral region remains highly fragmented (Vidovenyecz 2012).

This review of the relevant literature also reveals that the effects of access paths crossing the reed beds of Lake Balaton on the composition of riparian vegetation have not been investigated in sufficient depth. The aim of the present study is to develop a simple, easily applicable, and spatially replicable field methodology suitable for assessing the impact of access paths on vegetation.

## 2 Materials and Methods

The access paths selected as sampling sites for this study are located in Balatonfenyves, at the boundary between the Nagyberek and Lake Balaton microregions (Csorba 2021). The entire study area can be classified as the General Habitat Classification System (ÁNÉR) habitat type B1a, Eu- and mesotrophic reed and *Typha* beds (Bölöni et al. 2011). In the vicinity of the investigated access paths, in addition to the dominant *Phragmites australis*, *Carex riparia*, *Salix cinerea*, and *Typha angustifolia* are also present as frequent species.

As shown in Figure 1, four access paths were selected for investigation. Vegetation was surveyed at four sampling points along each access path, with the exception of the access path located at the end of Daru Street, where the structure did not extend across the entire reed bed. In this case, but the access path was included in the study because conducting the survey within a single, ecologically coherent vegetation patch was considered essential in order to minimise variability associated with differing shore zone characteristics along Lake Balaton. This criterion was met during the selection of the access paths; however, the access path located on Fogoly Street is situated farther from the other investigated structures. At the time of the field surveys, this was the nearest access path that was not closed and could be accessed from the terrestrial side.



**Figure 1** The location of the examined pathways and the sampling points

The primary criterion for selecting the study area was the presence of a reed bed along the shoreline that is heavily fragmented by access paths. This allowed the research to be performed in an area where the problem addressed by the study is particularly relevant.

The development of the field methodology was informed by a study published in 2023 that examined the effects of beaches established within riparian vegetation on lakeshores in Germany (Meyer et al. 2023). In that study,  $2 \times 8$  m quadrats were designated in each vegetation zone. Adapting this approach, sampling points were established within the vegetation from the terrestrial side towards open water, such that botanical surveys were conducted at the terrestrial end of the access paths (land 1), at one third of their length (land 2), at two thirds of their length (water 1), and at the border at the open water (water 2).

Field surveys were carried out in early June 2025. At each sampling point, vegetation was recorded using the Braun–Blanquet method; however, the cover of each species was expressed as a percentage (Braun-Blanquet 1964). In contrast to the German study (Meyer et al. 2023),  $1 \times 1$  m quadrats were used, as these are easier to establish in the field than those applied in the referenced study, in line with the objective of developing a simple and easily applicable methodology. Furthermore, the use of larger field quadrats would not have provided a sufficiently detailed representation of the vegetation at varying distances from the access pathways.

Unlike the German research, which also considered bathing areas arranged in continuous strips, the linear extent of the access paths themselves was not included in the survey. This decision was motivated by the aim of determining the distance from the structures at which their effects on vegetation remain detectable. Quadrats were placed progressively farther away from the access paths; at each sampling point, a minimum distance of two quadrats (i.e. 2 m)

from the structures was applied. Where the proportion of disturbance-tolerant species exceeded 20%, the distance was increased to 4 m from the structures.

This approach subsequently allowed the distance over which disturbance-indicator plant species can spread from the structures to be identified during data analysis. Based on these results, an acceptable proportion of degradation-indicator species within reed bed habitats could also be determined.

For the categorisation of the recorded plant species, Borhidi's system of social behaviour types was applied (Borhidi 1995). The species identified in the survey were assigned to seven types, which were subsequently grouped into two main categories. The first category comprised habitat stability indicator species, including specialists (S), generalists (G), and natural competitors (C). The second category consisted of disturbance-indicator species, including weeds (W), disturbance-tolerants (DT), adventive aliens (A), and alien competitors (AC). Open water and bare mud surfaces observed during the field survey were also assigned to the latter category, as these features generally indicate some form of disturbance within reed bed habitats.

For each quadrat, the proportional representation of the two species groups was calculated, and the results were compared across distances from the access paths as well as among sampling points. Field data were compiled in tabular form. Within the scope of the present study, priority was given to testing the applicability of the methodology; therefore, the analysis focused primarily on descriptive statistics, including mean species proportions and trends related to band width.

### 3 Results/ Results and Discussion

A total of 26 species were recorded across 34 quadrats established along the surveyed transects. Among the disturbance-tolerant species, *Calystegia sepium* exhibited the highest frequency of occurrence, being recorded in 14 quadrats. Notably, *Solanum dulcamara* and *Urtica dioica* were each present in 12 quadrats. Table 1 presents the mean proportions of habitat stability indicator species and disturbance-indicator species at varying distances from the surveyed transects.

**Table 1** Average proportions of two groups of species present at measured distances from the examined pathways

	Land 1				Land 2		Water 1			Water 2	
	1. me- ter	2. me- ter	3. me- ter	4. me- ter	1. me- ter	2. me- ter	1. me- ter	2. me- ter	3. me- ter	1. me- ter	2. me- ter
Habitat stability indicator species	67.5%	73.75%	85%	100%	87.5%	95%	65%	75.5%	65%	43.3%	86.7%
Disturbance-indicator species	32.5%	26.25%	15%	0%	12.5%	5%	35%	24.5%	35%	56.7%	13.3%

It is clearly evident that, at sampling points closest to the terrestrial zone, the access structures exert an influence on the surrounding vegetation across a wider spatial band. This effect reduces at sampling points located one meter farther from the terrestrial zone along the access routes; however, in those sections of the riparian vegetation where permanent water cover is present, the influence of the access structures intensifies again. Table 1 presents only mean values; therefore, these patterns are not equally pronounced at all access routes.

For example, at the Seregély Street access route, at the first sampling point the proportion of disturbance-indicator species in the quadrat located within the first meter laterally from the structure was slightly lower (20%) than in the second meter (25%). In contrast, at the Fogoly Street access path, a more pronounced difference was detected: the proportion of disturbance-

indicator species was 15% within the first meter from the structure, increased to 50% at the second meter, and subsequently decreased again to 15% at the third meter.

At the remaining sampling points of the access routes, the proportion of disturbance-indicator species in the quadrats generally decreased or remained stable with increasing distance from the structures.

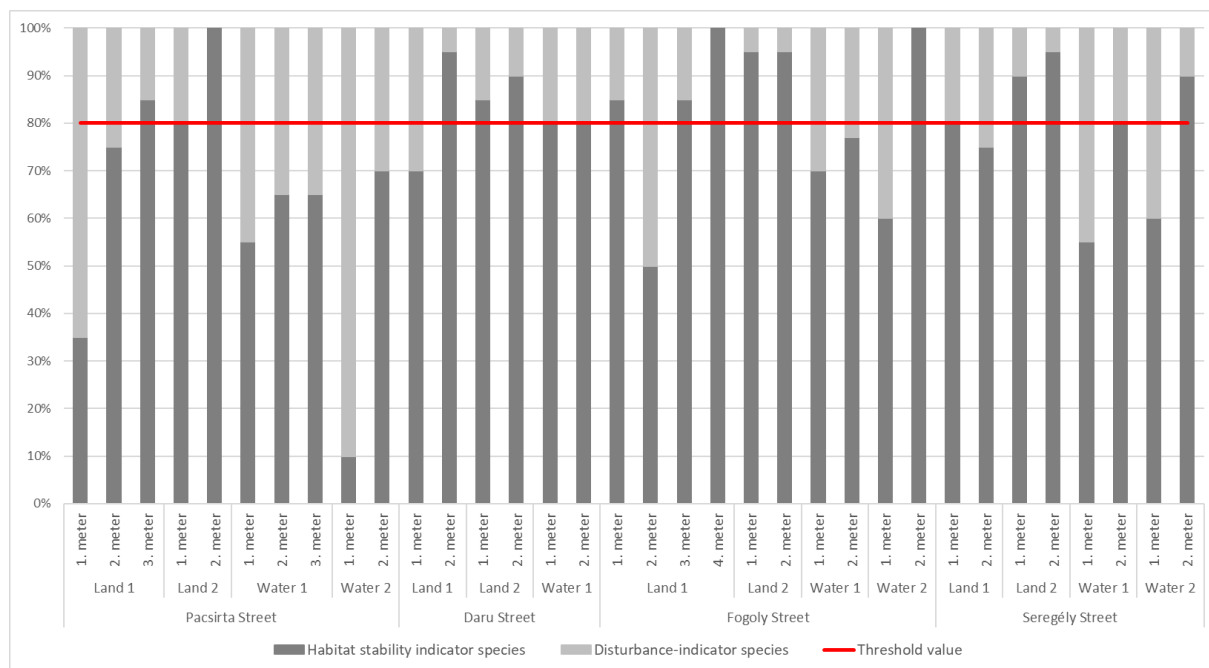
#### **4 Discussion**

The access paths fragmenting the reed beds of Lake Balaton, together with the associated vegetation degradation, have posed a threat to the maintenance of the lake's favourable ecological status for decades. In order to determine the extent to which these structures negatively affect vegetation, a simple and easily applicable field methodology is required for vegetation assessment.

At the sampling points which are closest to the terrestrial zone of the access paths, within the first meter from the structures, disturbance-indicator species may occur in higher proportions as a result of anthropogenic impacts originating from the shoreline. At the open-water end of the access paths, directly adjacent to the structures, the proportion of habitat stability indicator species is low despite the lower intensity of other forms of human disturbance. This can be attributed to the penetration of wave action along the access paths into the vegetation of the littoral zone, where it is able to cause erosion. At the boundary of open water, wave action is less capable to degrade the reed bed at a lateral distance of two meters from the access path.

Based on field observations and the description of the ÁNÉR B1a habitat type, which states that in reed beds classified within naturalness category 3 the proportion of alien species does not exceed 20% (Böölöni et al. 2011), we propose defining the acceptable proportion of disturbance-indicator species at the same threshold, although the concepts of alien and disturbance-indicator species do not fully overlap. Accordingly, we consider it optimal to apply this proportion as a definition of vegetation of littoral zone in favourable condition in future studies.

Based on our experience to date, in order to reliably achieve this threshold during vegetation surveys along access paths, it is necessary to move at least four meters away from the structures. Only in a single case was it necessary to conduct sampling at this distance, as the proportion of disturbance-indicator species exceeded 20% in quadrats located at distances of 1–3 meters from the structures. Consequently, within individual quadrats the proportion of habitat stability indicator species reaches 80%. Figure 2 illustrates, together with this threshold value, the proportions of plant species belonging to the two examined groups within the quadrats.



**Figure 2** The ratios of the two target species groups per quadrat and the associated threshold for a desired ecological state

In addition, further indicators may be required for the field assessment of the impacts of access structures on reed beds in order to obtain more accurate results in future studies. Such indicators may include, for example, measurements of reed shoot height or estimates of the proportion of dead reed stems, which are also applied within the National Biodiversity Monitoring System (NBmR) to assess the condition of reed beds (Bata et al. 2010).

Long-term research may subsequently determine the density of access paths that can cause reed dieback along a 100 m shoreline section. The removal of these structures would promote more natural vegetation dynamics. This could also benefit species inhabiting the margins of reed beds, as anthropogenic disturbance is more pronounced along artificially created edges associated with built structures. Furthermore, the results of this research may support the rehabilitation of vegetation the littoral zone at sites where access paths have been removed.

## References

- http1: Közép-Dunántúli Vízügyi Igazgatóság: <https://www.vizugy.hu/print.php?webdokumentumid=44>
2018. évi CXXXIX. törvény Magyarország és egyes kiemelt térségeinek területrendezési teréről
- 22/1998. (II. 13.) Korm. rendelet a Balaton és a parti zóna nádasainak védelméről, valamint az ezeken folytatott nádgazdálkodás szabályairól
- 283/2002. (XII. 21.) Korm. rendelet a balatoni vízpart-rehabilitációs szabályozás követelményeiről
- Bata, K., Varga, I. and Takács, G. 2010. Természetvédelmi Információs Rendszer – Központi protokoll – Hírnártársulások, nádasok monitorozása. 5 p.
- Borhidi, A. 1995. Social behaviour types, the naturalness and relative ecological indicator values of the higher plants in the Hungarian Flora. *Acta Botanica Hungarica*. **39** 97–181.
- Böloni, J., Molnár, Zs. and Kun, A. 2011. Magyarország élőhelyei; Vegetációtípusok leírása és határozója – ÁNÉR 2011. MTA ÖBKI, Vácrátót

- Braun-Blanquet, J. 1964. Pflanzensozologie 3. Aufl. Springer-Verlag, Wien. <https://doi.org/10.1007/978-3-7091-8110-2>
- Brauns, M., Gücker, B., Wagner, C., Garcia, X., Walz, N. and Pusch, M. T. 2011. Human lakeshore development alters the structure and trophic basis of littoral food webs. *Journal of Applied Ecology*. **48** 916–925. <https://doi.org/10.1111/j.1365-2664.2011.02007.x>
- Csorba, P. 2021. Dunántúli-dombvidék. In: Csorba, P. 2021. Magyarország kistájai. Meridián Táj- és Környezetföldrajzi Alapítvány, Debrecen, pp. 214–269.
- Gyurina, T. (2025): Településtervezés fenntarthatósági problémái Balaton-parti települések példáján In: Hajdú, Péter (eds) Doktoranduszok Fenntarthatósági Szimpóziuma – Absztraktkötet (2025) pp. 21–21.
- Gyurina, T. and Boromisza, Zs. 2025. A Balaton nádasait felszabdoló bejárók és a fás szárú vegetáció terjedésének kapcsolata a parti zónában. In: Somlyódy, B., Váradi, J. (eds): A Magyar Hidrológiai Társaság által rendezett XLII. Országos Vándorgyűlés dolgozatai Budapest, Magyarország: Magyar Hidrológiai Társaság (MHT) (2025)
- Jakucs, P. 1981. Magyarország legfontosabb növénytársulásai. In: Hortobágyi, T., Simon T. (eds): Növényföldrajz, társulástan és ökológia. Tankönyvkiadó, Budapest, pp. 225–263.
- Meyer, N., Swatloch, A., Dittrich, S. and von Oheimb, G. 2023. Lakeshore vegetation: More resilient towards human recreation than we think?. *Ecology and Evolution*. **13** e10268. <https://doi.org/10.1002/ece3.10268>
- Ness, K. L. 2006. The effects of shoreline development on lake littoral and riparian habitats: are shoreline protection regulations enough?. The University of Maine, 182 p.
- O’Toole, A. C., Hanson, K. C. and Cooke, S. J. 2009. The Effect of Shoreline Recreational Angling Activities on Aquatic and Riparian Habitat Within an Urban Environment: Implications for Conservation and Management. *Environmental Management*. **44** 324–334. <https://doi.org/10.1007/s00267-009-9299-3>
- Pomogyi, P. 2011. A Balaton parti sávban a nádasok és az egyéb növényzet összetételének felmérése, minősítése és bemutatása. Záróértékelés. Felmérő és Szerkesztő: KÖDU-KÖVIZIG, Székesfehérvár
- Vidovenyecz, V. 2012. Direkt emberi beavatkozások hatása a Balaton parti sávjában. KDTVIZIG, Székesfehérvár. p. 22

*This work is licensed under a  
Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License.*

*A műre a Creative Commons 4.0 standard licenc alábbi típusa vonatkozik:  
CC-BY-NC-ND-4.0.*

