A Methodology for River Connectivity Assessment: a case study in the Alviela River, Portugal

Une méthodologie pour l'évaluation de la connectivité fluviale: étude de cas sur la rivière Alviela, Portugal

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RÉSUMÉ

L'importance de la restauration des rivières et des cours d'eau libres est de plus en plus reconnue par la politique environnementale européenne, notamment dans la Stratégie de l'UE pour la biodiversité. Une grande partie des pressions anthropiques sur les écosystèmes fluviaux provient des obstacles à la connectivité fluviale : des structures construites provoquant des discontinuités longitudinales, verticales ou latérales qui interrompent ou modifient les processus naturels tels que l'écoulement de l'eau, le transport des sédiments, ainsi que les déplacements et migrations de la faune aquatique. L'objectif de cet article est de discuter d'une méthodologie d'évaluation intégrée (développée dans le cadre du projet Rollin'Rivers) visant à améliorer la connectivité fluviale en priorisant les actions de suppression des barrages et de réhabilitation. Cette méthodologie repose sur une approche de notation et de classement des barrières, impliquant l'évaluation individuelle des barrières selon des critères auxquels sont attribuées des notes spécifiques. Ces notes permettent de prioriser les suppressions en fonction d'un ensemble d'objectifs spécifiques. Les résultats présentent une liste priorisée de barrières obsolètes, permettant de déterminer le potentiel de restauration des tronçons fluviaux dans le sous-bassin de l'Alviela, en intégrant des critères écologiques, socio-culturels et économiques. Nous concluons que le processus de priorisation est essentiel pour soutenir la prise de décision et qu'il fournit un cadre systématique pour identifier et traiter les barrières critiques. Cette approche garantit que les efforts de restauration maximisent les bénéfices écologiques tout en tenant compte des besoins des communautés locales et de la faisabilité économique.

ABSTRACT

The importance of river restoration and free-flowing rivers is increasingly recognized by European environmental policy, namely EU Biodiversity Strategy. Much of the anthropogenic pressures on river ecosystems are originated by barriers to river connectivity - built structures causing longitudinal, vertical or lateral discontinuity that interrupt or modify natural processes as the flow of water, the transport of sediments and the fish and wildlife movements and migrations.

The aim of this paper is to discuss an integrated assessment methodology (developed within the framework of Rollin'Rivers project) to improve river connectivity by prioritizing dam removal and rehabilitation actions. This methodology is based on a scoring and ranking approach for barriers, which involves evaluating individual barriers using criteria assigned specific scores. These scores enable prioritization for removal, considering a particular set of objectives. The results show a prioritised list of obsolete barriers that allows us to determine the restoration potential of river stretches in the Alviela Subbasin, integrating ecological, socio-cultural, and economic criteria. We conclude that the prioritization process is essential for supporting decision-making and that it provides a systematic framework for identifying and addressing critical barriers. This approach ensures that restoration efforts maximize ecological benefits while considering local community needs and economic feasibility.

KEYWORDS

Dam Removal, Ecological Assessment, Mediterranean Freshwater ecosystems, River Connectivity, River Restoration

Connectivité fluviale, Écosystèmes d'eau douce méditerranéens, Évaluation écologique, Restauration des rivières, Suppression des barrages

1 INTRODUTION

The importance of river restoration and free-flowing rivers is increasingly recognized in European environmental policy. The EU Biodiversity Strategy, for instance, has set an ambitious target: by 2030, at least 25,000 km of rivers should be restored to free-flowing conditions through the removal of primarily obsolete barriers and the restoration of floodplains and wetlands (Van de Bund, 2024).
While Europe has committed to restoring river ecosystems and enhancing their connectivity, Portuguese rivers remain highly threatened. Over 13,000 barriers impede river connectivity, compounded by the loss of native species, the spread of invasive species, pollution, and a lack of effective legal protection. Despite these challenges, Portugal lacks comprehensive technical-scientific studies on the longitudinal barriers, as well as effective political strategies and programs for river restoration and removal of obsolete barriers.
River connectivity refers to the transfer of matter, energy, or organisms, mediated by water, within or between elements of the hydrological cycle (Pringle, 2001; Rodeles *et al*., 2020). It encompasses longitudinal connectivity (from the river's source to its mouth), lateral connectivity (linking riparian and floodplain habitats to the river channel), vertical connectivity (between surface and groundwater), and temporal connectivity (related to the timescale of the hydrological cycle). This connectivity is vital for maintaining the integrity of river ecosystems (EC, 2022; Van de Bund et al., 2024). Enhancing river connectivity facilitates natural processes essential for achieving a good ecological status in water bodies. These processes include the free movement of water, sediments, nutrients, and organisms throughout river basins (Rodeles et al., 2020). However, disruptions to connectivity, often caused by artificial barriers, can have severe negative effects on aquatic biodiversity and ecosystem resilience (Rodeles et al., 2020).
A barrier to river connectivity is any artificial physical structure that disrupts the natural longitudinal, lateral, or vertical flow of water (Van de Bund et al., 2024). Such barriers adversely affect river hydrology, geomorphology, and ecology, leading to impacts like habitat fragmentation or altered sediment flow. Sediments often accumulate upstream of barriers, contributing to habitat degradation and reduced water quality.
This paper aims to develop a tool to advance river restoration efforts in Portugal by proposing a methodology for river connectivity assessment. The methodology seeks to support the removal of obsolete barriers, enhance ecological connectivity, and contribute to achieving the objectives of the Water Framework Directive (WFD) by improving the ecological status of water bodies.

2 METHODS

The case study is located in the Alviela sub-basin, approximately 100 km north of Lisbon (Fig. 1). The Alviela River originates in the Serra da Mendiga and flows into the Tagus River, covering a length of about 40 km. The Alviela hydrographic basin, with an area of approximately 300 km², spans several municipalities. Historically, the Alviela has been of great significance both within the Tagus River Basin and on a national scale. It is deeply embedded in local memory as a river with clean water, teeming with fish of various species. Once navigable, the river was abundant with barbels, cyprinids, and eels. However, increasing contamination levels and the construction of numerous longitudinal barriers have led to the degradation and fragmentation of its ecosystems.

Figure 1 – Location of Alviela sub-basin

As part of the "Rollin' Rivers – People, Knowledge, and Action to Enhance River Restoration in Portugal" project (January 2023 - December 2025), a methodology for river connectivity assessment was developed to prioritize barriers in the context of river rehabilitation through the removal of obsolete structures. This methodology is intended to be replicable at the national level, promoting the systematic removal of barriers throughout Portugal, in line with similar efforts in other countries.

The methodology consists of two main phases:

1. **Inventory and Characterization of Existing Barriers** (including identification of obsolete ones)
2. **Prioritization of Obsolete Barriers for Removal**

In the first phase, we identified 33 obsolete barriers, as shown in Figure 2, using remote sensing data and field validations. An individual file was created for each barrier, incorporating several criteria such as territorial location, typology (e.g., dam, weir, dyke, road crossing, breakwater, bed and/or bank lining, fixed fishery), current and past function, state of conservation, construction materials, height, and width.

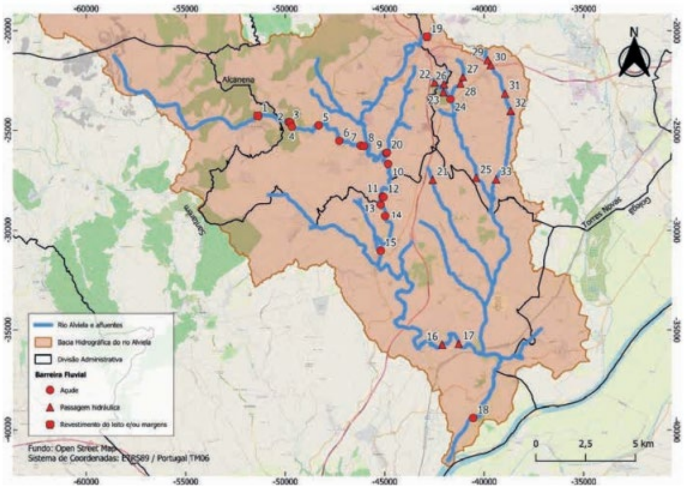

Figure 2 - Map of longitudinal obsolete barriers at Alviela River

After identifying and characterizing the barriers, those deemed ineligible for removal were excluded. Specifically, the following barriers were eliminated from consideration: those serving irreplaceable functions; those for which evidence indicates that removal would not significantly enhance connectivity; and those with notable cultural, heritage, or social significance. In the second phase, we develop a methodology for prioritising the removal of obsolete barriers integrating several ecological criteria.

The ecological significance of obsolete barriers was assessed by calculating a value derived from the weighted sum of scores assigned to various key ecological criteria: *Continuous Water Body Extension* (m); *Physico-Chemical Quality; Biological Quality – Phytobenthos (Diatoms)* - the assessment of this criterion is based on the calculation of one of two indices (IPS - Index of Specific Pollution Sensitivity or CEE index, depending on the type of river), the results of which are then expressed as an Ecological Quality Ratio (EQR); *Biological Quality – Benthic Macroinvertebrates* - the assessment of this criterion is based on the calculation of an index of two indices (IPtIN - Portuguese Index of Northern Invertebrates or IPtIS - Portuguese Index of Southern Invertebrates, depending on the typology of the river) whose results are subsequently expressed as an Ecological Quality Ratio (EQR); *Hydromorphological Quality (HMS Index)* - assessed using the River Habitat Survey (RHS) methodology and its indicators: Habitat Modification Score (HMS) and Habitat Quality Assessment (HQA), which respectively indicate the degree of modification of the river segment and its habitat quality; *Presence in National Classified Areas System (SNAC)*; *Natural Habitats* - the classification of natural habitats refers to habitats defined by the Habitats Directive (92/43/EEC) of 21 May 1992; *Priority Habitats* - the classification of priority habitats refers to habitats defined by the Habitats Directive (92/43/EEC); *Riparian Gallery Continuity and Composition* - when the gallery is or should be naturally present, with the observation of woody formations along the river, the continuity of the riparian gallery refers to the coverage of the banks by riparian vegetation. This assessment should be carried out up to 50 metres downstream and 50 metres upstream of the barrier being analysed; *Presence of threatened or migratory fish species* - species with threatened status are particularly relevant from a conservation point of view because they present a greater risk of extinction. On the other hand, endemic species are equally relevant since they have a very restricted geographical distribution; *River Continuity Index (RCI)* - is an index that makes it possible to expeditiously assess the upstream transposability of an obstacle by fish fauna; *Fish Passage Structures* - fish passage devices are structures that allow or facilitate fish to cross the barrier, usually in an upstream direction, thus reducing river discontinuity for this group; *Invasive Aquatic Species* - just as they prevent or hinder the dispersal of native species, barriers can hinder or prevent the dispersal of exotic species, and this should be a factor of valorisation; *Barrier Location Impact* - a dam that is located further downstream of a river can be a more significant obstacle, as it blocks the connection between the entire upstream hydrographic network and possible sources of repopulation, such as higher-order rivers. In this sense, the position of the barrier strongly influences the movements of migratory fish species, so eliminating these barriers promotes the conservation and sustainability of these species; *Sediment Accumulation* - the transport of sediment from upstream to downstream is part of the natural hydrological dynamics of watercourses, so its accumulation in barriers can affect the biological communities and hydromorphology of the river downstream (Kondolf et al., 2014); *Barrier Type*; *Main River Course* - a barrier located in the main course of the river basin will tend to have a greater impact than a barrier located in a tributary or sub-tributary. This is because the main course carries a greater volume of water and is generally longer, resulting in a greater availability of habitat and organisms.

3 RESULTS AND DISCUSSION

The methodology for assessing longitudinal connectivity has allowed obsolete barriers to be prioritised, taking into account ecological, social and cultural criteria. With this process, barriers to river connectivity in the Alviela Sub-basin are identified, mapped and characterised and restoration potential is determined for river stretches in the Alviela Subbasin. This contribute to enhance ecological restoration improving river connectivity and biodiversity recovery, enhancing habitat for native and endangered species namely native and endangered species like portuguese-boga (Iberochondrostoma lusitanicum), eel (Anguilla anguilla) and southern squalius (Squalius pyrenaicus).

As challenges and limitations, we identify that the focus on longitudinal connectivity revealed a need for future integration of lateral and vertical connectivity assessments to address all dimensions of river connectivity. Data limitations, particularly regarding sediment dynamics, invasive species, and fish passage structures, highlight areas for further research and refinement.

4 CONCLUSION

The Alviela River case study demonstrates the critical need for a structured approach to enhance river connectivity and restore freshwater ecosystems in Portugal. Through the development and application of a systematic methodology for identifying and prioritizing barriers for removal, the study underscores several key conclusions.

The removal of obsolete barriers presents significant ecological advantages, including improved water flow, sediment transport, and enhanced movement of aquatic organisms. The methodology highlighted critical factors such as the presence of migratory and threatened fish species, habitat quality, and hydromorphological conditions, which are crucial for achieving the ecological goals outlined by European environmental policies.

The methodology developed integrates a wide range of criteria, encompassing ecological, hydromorphological, and socio-economic factors. This holistic approach ensures that decisions are informed by the multifaceted impacts of barriers, balancing ecological restoration with socio-cultural and economic considerations.

By prioritizing barriers based on their ecological and socio-economic relevance, the methodology provides a robust framework for directing limited resources toward the most impactful restoration actions. This is especially relevant for large river basins with extensive networks of barriers.

The replicable nature of this methodology offers a valuable tool for scaling up river restoration efforts across Portugal. It aligns with international best practices and supports compliance with the EU Water Framework Directive (WFD), contributing to improved ecological status of water bodies.

By systematically addressing river connectivity, the methodology not only provides a pathway to restore ecological integrity in the Alviela River but also serves as a model for similar efforts across Portugal, enhancing the resilience and sustainability of freshwater ecosystems.

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