



Preliminary Insights into Macroinvertebrate Communities Associated with Floating Islands in Two Rivers Under Contrasting Anthropogenic Pressures [†]

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Abstract

This study provides a preliminary baseline characterization of macroinvertebrate assemblages colonizing floating islands installed in two NE Portuguese river reaches with contrasting anthropogenic and hydromorphological conditions: the urban, weir-influenced Fervença River and the more rural, reservoir-like Côa reach within a former dam-work area. A single campaign in February 2025 combined water characterization and macroinvertebrate sampling on islands and adjacent margins. Fervença showed higher mineralization and microbiological contamination, but a more varied assemblage dominated by tolerant taxa. Côa showed better water quality but strong Astacidae dominance. Results indicate colonization only; robust replicated monitoring is needed before inferring ecological improvement.

Keywords: floating islands; macroinvertebrates; Fervença and Côa rivers

1. Introduction

Floating wetland islands (FWIs), also known as treatment floating wetlands (FTWs), are nature-based solutions that provide multiple ecosystem services, including improved water quality and enhanced biodiversity [1,2]. These vegetated structures support macrophytes in hydroponic systems, mimic natural wetland processes, and can be deployed in lakes, rivers, reservoirs, and artificial coastal environments. They offer a promising strategy to mitigate the effects of increasing anthropogenic pressure, such as urbanization and pollution by nutrients, hydrocarbons, and metals, by creating new habitats and acting as biodiversity hotspots [3,4].

Calheiros et al. [1] illustrated this ecological role in a floating treatment wetland in a rural stormwater pond in northern Portugal. The FTW was colonized by diverse aquatic and semi-aquatic fauna and supported the complete life cycle of several Odonata species,



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showing how even a small floating structure in a simplified waterbody can act as an ecological stepping stone [5]. Nevertheless, most FWI studies have focused on pollutant removal efficiency, and evidence from lotic environments under contrasting anthropogenic pressures remains scarce [1,6].

Within this context, the present study provides a preliminary baseline characterization of the macroinvertebrate assemblages colonizing floating islands in two Portuguese rivers under contrasting anthropogenic pressures, together with the physicochemical and microbiological conditions at the time of sampling. As it lacks before–after comparisons, replicated sites, and temporal replication, the study is not designed to demonstrate water-quality improvements. Instead, it represents the first step of a broader long-term monitoring project focused on the seasonal and interannual evolution of macroinvertebrate colonization on floating islands, including community structure, diversity patterns, comparison between cork agglomerate and recycled expanded polystyrene substrates, biotic indices, and species- or genus-level identification of selected groups.

2. Materials and Methods

2.1. Study Areas

The study was conducted in two distinct river reaches with contrasting anthropogenic and hydromorphological conditions: the Côa River (Figure 1A), which is less urbanized but locally characterized by predominantly lentic, reservoir lake conditions associated with a former dam construction area, and the Fervença River (Figure 1B), which is highly urbanized, structurally modified, and partially impounded by a sequence of low weirs. The Fervença rises in the Serra da Nogueira (41°48' N, 6°50' W) and crosses the city of Bragança before discharging into the Sabor [7]. The Côa is a left-bank tributary of the Douro, originating in the Serra das Mesas (40°16' N, 6°55' W) and flowing 140 km through the Beira region before discharging at Foz Côa [8].

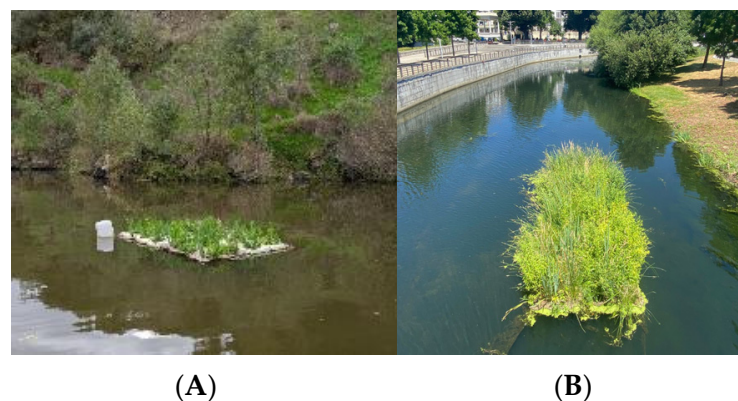


Figure 1. Floating island systems installed in the Côa River (A) and the Fervença River (B).

In both systems, floating islands were installed to serve as experimental habitats. Two square floating mats of 4 m² each (2 × 2 m) were used to construct the Bio Islands: one made of recycled expanded polystyrene (REP) and the other of cork agglomerate. These structures are 60 mm thick and weigh 1.1 kg each, with alternating holes for plant insertion. The plant species selected for the Bio Islands were purple loosestrife (*Lythrum salicaria*), spreading rush (*Juncus effusus*), and yellow iris (*Iris pseudacorus*). These species were chosen because they occur in Fervença and Côa rivers and because of their ability to remove nutrients from the water, such as phosphorus, whose presence has been confirmed in both rivers [9,10]. The floating islands were installed on 30 July 2024 in the Fervença River and on 22 August 2024 in the Côa River. Consequently, the structures were available for

colonization for approximately seven months in the Fervença River and six months in the Côa River before the sampling campaign conducted in February 2025.

2.2. Physicochemical and Microbiological Sampling of Water

Water sampling was carried out during a single baseline campaign, on 25 February 2025 in the Côa River and on 26 February 2025 in the Fervença River. In each river, physicochemical measurements were performed at three points: upstream of the floating islands, in the area influenced by the island root systems, and downstream of the islands. These measurements were intended to provide a punctual characterization of local water conditions at the time of macroinvertebrate sampling.

Water quality was assessed through in situ measurements with a HI98194 multiparameter probe (Hanna Instruments, Woonsocket, RI, USA), including pH, dissolved oxygen, electrical conductivity, temperature, and practical salinity unit (PSU). Laboratory analyses determined phosphates, nitrates, nitrites, and five-day Biochemical Oxygen Demand (BOD₅), and were performed according to the procedures of the accredited laboratory, under NP EN ISO/IEC 17025 [11]. Microbiological quality was assessed using the Most Probable Number (MPN) method to estimate indicator microorganism abundance, namely total coliforms, fecal coliforms and *Escherichia coli* and compare the sanitary status of both rivers.

2.3. Macroinvertebrate Sampling and Identification

Macroinvertebrate sampling was carried out in February 2025, following the criteria of the Portuguese Environment Agency [12], in accordance with the Water Framework Directive (WFD), with methodological adaptations to the specific characteristics of the floating islands. Given the adapted timed hand-net sampling and the use of composite samples by substrate type, the macroinvertebrate data were treated as semi-quantitative and used for descriptive comparisons among habitats and substrates.

Each floating island was divided into eight quadrants, four corresponding to the cork agglomerate platform and four to the recycled expanded polystyrene (REP) platform. In each quadrant, sampling was performed with a hand net (500 µm mesh) for 2 min, at approximately 15 cm depth beneath the island. For each substrate type (cork and REP), a composite sample was obtained by pooling the four subsamples collected in the corresponding quadrants (Figure 2). In parallel, macroinvertebrates were also sampled along the adjacent riverbank, to allow comparison between the floating island habitat and the natural marginal habitat. Abundance data were expressed as semi-quantitative counts per sample and were not standardized per m².



Figure 2. Macroinvertebrate sampling procedure carried out on floating islands.

After collection, samples were sieved in the field through a 500 µm mesh sieve, transferred to 500 mL polyethylene bottles, properly labelled, and preserved in 98% ethanol. In the laboratory, samples were rinsed again with running water through a 500 µm mesh sieve and subsequently sorted in white trays with a small amount of water, using tweezers to separate the organisms. After sorting, specimens were preserved in 70% ethanol. Taxonomic identification was performed using an OLYMPUS SZX10 stereomicroscope (Olympus Corporation, Tokyo, Japan) (10–230×), with the aid of appropriate taxonomic keys [13,14]. Identification was carried out, whenever possible, to family level.

3. Results and Discussion

The results suggest apparent differences between the two river systems in terms of their physicochemical, microbiological, and biological characteristics. Given the single-campaign design and absence of true replicates, these differences are described qualitatively and should be interpreted as descriptive patterns rather than statistically validated contrasts.

3.1. Physicochemical Parameters

Regarding physicochemical parameters, data from the Côa River showed low mineralization and well-oxygenated conditions (Table 1), particularly as reflected by low conductivity and high dissolved oxygen levels at all sampling points. These conditions suggest limited ionic enrichment and favourable oxygen availability for aquatic life at the time of sampling. However, the relatively high phosphate and total phosphorus concentrations indicate that nutrient enrichment cannot be excluded and should be interpreted with caution, especially given the single-campaign design.

Table 1. Physicochemical parameters of the water in the Côa and Fervença River, measured upstream of the islands (Point 1), in the area where the roots of the floating islands are located (Point 2), and downstream of the islands (Point 3).

Parameters	Côa River 25 February 2025			Fervença River 26 February 2025		
	Point 1	Point 2	Point 3	Point 1	Point 2	Point 3
pH	6.53	6.1	6.8	7.48	7.03	7.6
Dissolved Oxygen (%)	104.3	109.09	102.5	110.4	109.5	99.1
Dissolved Oxygen (ppm)	11.36	11.77	11.15	11.68	11.52	10.7
Conductivity (µS/cm)	65	67	67	179	184	186
Total Dissolved Solids (ppm)	33	33	33	90	92	93
Temperature (°C)	11.57	12.11	11.53	9.19	9.08	8.73
Turbidity (FNU)	3.81	3.85	4.48	0.78	1.5	1.24
Practical Salinity Unit (PSU)	0.03	0.03	0.03	0.09	0.09	0.09
Phosphate PO ₄ ^{3−} (mg/L)		0.562			0.014	
Nitrite (mg/L)		0.023			0.157	
Nitrate NO ₃ [−] (mg/L)		0.7			1.36	
Total Phosphorus (mg/L)		3.91			2.51	
BOD ₅ (mg O ₂ /L)		3.02			1.17	
Ammonia		ND			ND	

The low conductivity values recorded in the Côa River are broadly comparable to those reported by [1] for a rural stormwater pond with a floating treatment wetland (pH ≈ 6.8; EC ≈ 56 µS/cm; NO₃[−]-N ≈ 1.1 mg/L), supporting the interpretation of this site as a less mineralized system. Nevertheless, direct comparisons should be made cautiously because the systems differ in hydromorphology, land use and sampling design.

In contrast, the Fervença River appeared to have higher conductivity, total dissolved solids and practical salinity values than the Côa River (Table 1), indicating greater mineralization. Nitrite and nitrate concentrations were also higher in the Fervença River, which is consistent with the influence of urban runoff and wastewater inputs commonly associated with urban watercourses. Dissolved oxygen remained relatively high, indicating that oxygen depletion was not observed during this sampling campaign.

Overall, the physicochemical data suggest contrasting local water conditions between the two systems, with the Fervença showing greater mineralization and nitrogen enrichment, while the Côa showed lower conductivity but tended to show higher phosphorus concentrations.

3.2. Microbiological Quality

Regarding microbiological quality, the results further reinforce the distinction between the two rivers at the time of the sampling. In the Côa River, the values obtained using the Most Probable Number method indicate moderate microbiological contamination, with approximately 460 MPN/100 mL for total and fecal coliforms, and lower values for *Escherichia coli* (Table 2).

Table 2. Results of the microbiological analysis of the Côa and Fervença rivers, obtained in the laboratory using the Most Probable Number (MPN) method.

Parameters	Results	
	Côa River (25 February 2025)	Fervença River (26 February 2025)
Total Coliforms (MPN/100 mL)	460	>1100
Fecal coliforms (MPN/100 mL)	460	>1100
<i>Escherichia coli</i> (MPN/100 mL)	75	>1100

Note: Values are expressed as the combination of positive tubes in the three-tube MPN series (e.g., 3-3-1) followed by the corresponding Most Probable Number per 100 mL, obtained from the McCrady table. ">1100" indicates a result above the upper detection limit of the three-tube MPN method.

In contrast, the Fervença River showed descriptively higher microbiological contamination, exceeding 1100 MPN/100 mL for all indicators analyzed, indicating a strong influence of fecal pollution, compatible with urban wastewater inputs or diffuse contamination in an urban catchment. These data indicate poorer sanitary conditions in the Fervença River during the sampling campaign.

3.3. Macroinvertebrate Communities

The Fervença River showed a more taxonomically varied macroinvertebrate community than the Côa, including Ephemeroptera, Odonata, Trichoptera, Diptera, Heteroptera, Crustacea, Gastropoda, Hirudinea and Turbellaria (Figure 3; Table A1). However, several taxa, particularly Asellidae, Chironomidae and some Baetidae, are commonly associated with disturbed or organically enriched environments, so the greater richness should not be interpreted as better ecological quality. It likely reflects the combined influence of urban disturbance, habitat heterogeneity, slow-flowing conditions created by weirs, and the artificial surfaces and root systems provided by the floating islands. This agrees with previous studies showing that floating habitats increase local habitat availability for macroinvertebrates, but that colonization patterns depend strongly on local environmental conditions, habitat structure, plant development, plant species composition and interactions with the surrounding fauna [1,15].

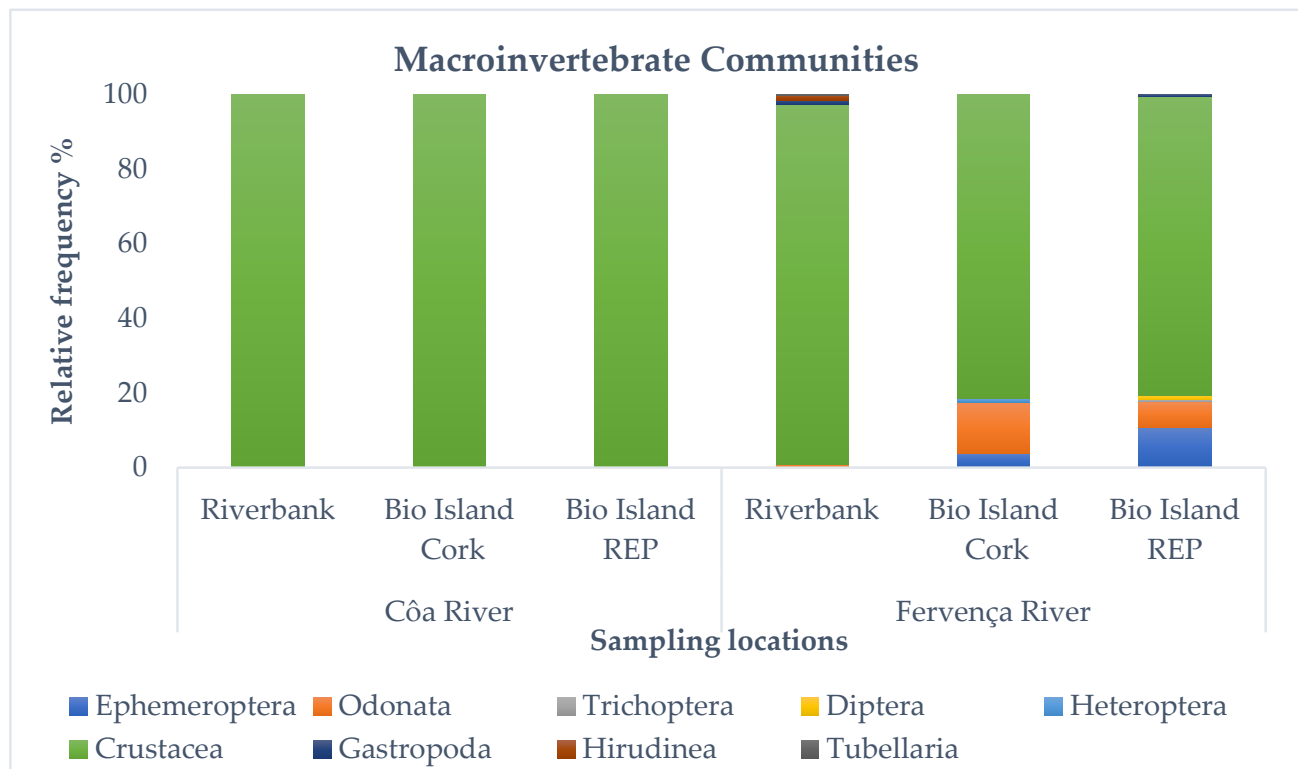


Figure 3. Taxonomic groups of macroinvertebrates identified on the floating islands and adjacent areas of the C  a and Ferven  a rivers.

In contrast, assemblages in the C  a River were strongly dominated by Astacidae (Figure 3; Table A1). Although invasive crayfish are known to reduce macroinvertebrate diversity through predation and habitat modification [16], family-level identification did not allow discrimination between native and non-native species, and the single campaign, single station and limited number of sampling points may have underestimated true diversity.

The ecological differences between the C  a and Ferven  a rivers cannot be explained solely by the dominance of Astacidae. The studied stretch of the C  a is predominantly lentic, whereas the Ferven  a represents a lotic environment, and these contrasting hydromorphological conditions naturally influence macroinvertebrate composition. Lentic and lotic ecosystems respond differently to environmental pressures and should be interpreted separately, since the factors governing their assemblages differ between habitat types [17].

Savi   et al. [17], in addition to highlighting the ecological differences between lentic and lotic systems, also demonstrated that species-level identification is essential for detecting subtle ecological responses. In their study, two species of the same genus (*Mideopsis orbicularis* and *M. crassipes*) exhibited contrasting responses to urbanization, with one associated with rural habitats and the other with urban environments.

Despite these limitations, the rapid colonization of floating islands observed in both rivers agrees with previous studies that demonstrate that floating swamps quickly establish themselves as suitable habitats for aquatic macroinvertebrates as soon as the root systems of the plants develop in the water column. Some studies have reported significantly higher abundance, taxonomic richness, and diversity of macroinvertebrates in floating littoral habitats compared to adjacent banks exposed to water level fluctuations, highlighting the importance of structurally complex habitats for sustaining aquatic communities. Their findings further indicated that floating habitats support taxa with longer life cycles and

lower mobility, suggesting that these systems function as relatively stable habitats rather than mere temporary refuges [18].

Overall, floating islands promoted macroinvertebrate colonization under contrasting environmental conditions, including sensitive groups such as Ephemeroptera and Odonata, consistent with studies describing floating marshes as biodiversity hotspots and ecological stepping stones even in highly modified aquatic environments [1,4,5].

4. Conclusions

This preliminary study observes that in both systems, the structures were colonized, but the composition of the associated assemblages differed between the rivers. In the more urbanized Fervença River, the assemblage included a more taxonomically varied set of groups, largely composed of pollution-tolerant taxa, which is consistent with the greater mineralization and microbiological contamination recorded in the water. In the Côa River, where the physical–chemical and microbiological quality of the water was better, the assemblage was markedly dominated by Astacidae, a result that justifies identification at the species level to confirm whether an invasive crayfish species is involved.

The observed differences cannot be attributed solely to the presence of the floating islands. The study was based on a single sampling campaign, without before-and-after comparisons, replicated sites, temporal replication, or standardized biotic indices. Moreover, the two systems differ in hydromorphological setting, habitat structure, and regional species pools, which further limits direct comparison between them.

Overall, the results indicate that floating islands can provide structured habitat available for colonization by macroinvertebrates under contrasting environmental conditions, including in modified aquatic systems. However, colonization alone should not be interpreted as evidence of ecological recovery or improved ecological quality. Therefore, future work should include seasonal and long-term monitoring, species-level identification, supported by molecular approaches such as environmental DNA metabarcoding.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Semi-quantitative abundance of macroinvertebrate taxa identified on the floating islands and adjacent riverbanks of the Côa and Fervença rivers, expressed as number of individuals per sample.

Taxonomic Name	Fervença River			Côa River		
	Riverbank 26 February 2025	BI-Cork	BI-REP	Riverbank 25 February 2025	BI-Cork	BI-REP
Asellidae	832	84	141	0	0	0
Aeshnidae	0	2	1	0	0	0
Astacidae	0	0	0	200	200	200
Baetidae	0	4	19	0	0	0
Chironomidae	0	0	2	0	0	0
Coenagrionidae	3	12	11	0	0	0
Corixidae	0	1	0	0	0	0
Dugesiidae	1	0	0	0	0	0
Ephemerellidae	2	0	0	0	0	0
Glossiphoniidae	11	0	0	0	0	0
Heptageniidae	1	0	0	0	0	0
Hydrobiidae	6	0	0	0	0	0
Limnephilidae	1	0	0	0	0	0
Physidae	2	0	1	0	0	0
Planorbidae	3	0	0	0	0	0
Polycentropodidae	0	0	1	0	0	0
Total	862	103	176	200	200	200

Note: Values correspond to semi-quantitative counts per sample. For floating islands, each value represents the pooled sample obtained from the corresponding substrate type, cork agglomerate or recycled expanded polystyrene (REP). Riverbank values correspond to the adjacent marginal habitat sample. Values are not standardized per m². Astacidae abundances in the Côa River (value = 200) correspond to a visual field estimation, given the very high densities observed; all remaining taxa were counted individually in the laboratory.

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