Reviving Douro Basin

Task 3.2.1. Identification of Biodiversity hotspots

Manuel Lopes Lima
Project Coordinator

AIM OF THE TASK

The study was delineated to make a broad assessment of the freshwater biodiversity on the River Douro basin.

TEAM

The assessments were made by a multi-disciplinary team composed by:

- Manuel Lopes Lima (CIBIO/InBio, University of Porto, Portugal, IUCN-SSC-Molluscs Sp. Group)
- Amílcar Teixeira (CIMO-ESA, Polytechnic Institute of Bragança, Portugal)
- Ronaldo Sousa (CBMA, University of Minho, Portugal)
- Simone Varandas (CITAB-University of Trás-os-Montes e Alto Douro, Portugal)
- Duarte Goncalves (CIBIO/InBio, University of Porto, Portugal)
- Richard Lansdown (IUCN-SSC - Aquatic Plants Specialist Group)
- Aina Raventós (CIBIO/InBio, University of Porto, Portugal)
- Ana Filipa Filipe (CIBIO/InBio, University of Porto, Portugal)
- André Santos (CIIMAR-LA, University of Porto, Portugal)
- José Pedro Ramião (CIBIO/InBio, University of Porto, Portugal)
- Mário Ferreira (CIBIO/InBio, University of Porto, Portugal)
- Tiago Neves (CIBIO/InBio, University of Porto, Portugal)
- Francisco Carvalho (CBMA, University of Minho, Portugal)
- Elsa Froufe (CIIMAR-LA, University of Porto, Portugal)
- Fernando Teixeira (CIMO-ESA, Polytechnic Institute of Bragança, Portugal)
- Fernando Miranda (CIMO-ESA, Polytechnic Institute of Bragança, Portugal)
- Joana Nogueira (CIBIO/InBio, University of Porto, Portugal)
- Filipa Martins (ICETA/CIBIO), University of Porto, Portugal

WORK PLAN

Site selection

A total of 175 sampling sites were selected by using a Principal component multivariate analyses to encompass the whole range of environmental features (climate, topography), human impact (human footprint index) and other characteristics (distance to the mouth and source and river order). Additionally, 35 of these sites were specifically chosen within designated KBAs for the assessment of their efficacy in representing important areas for conservation.

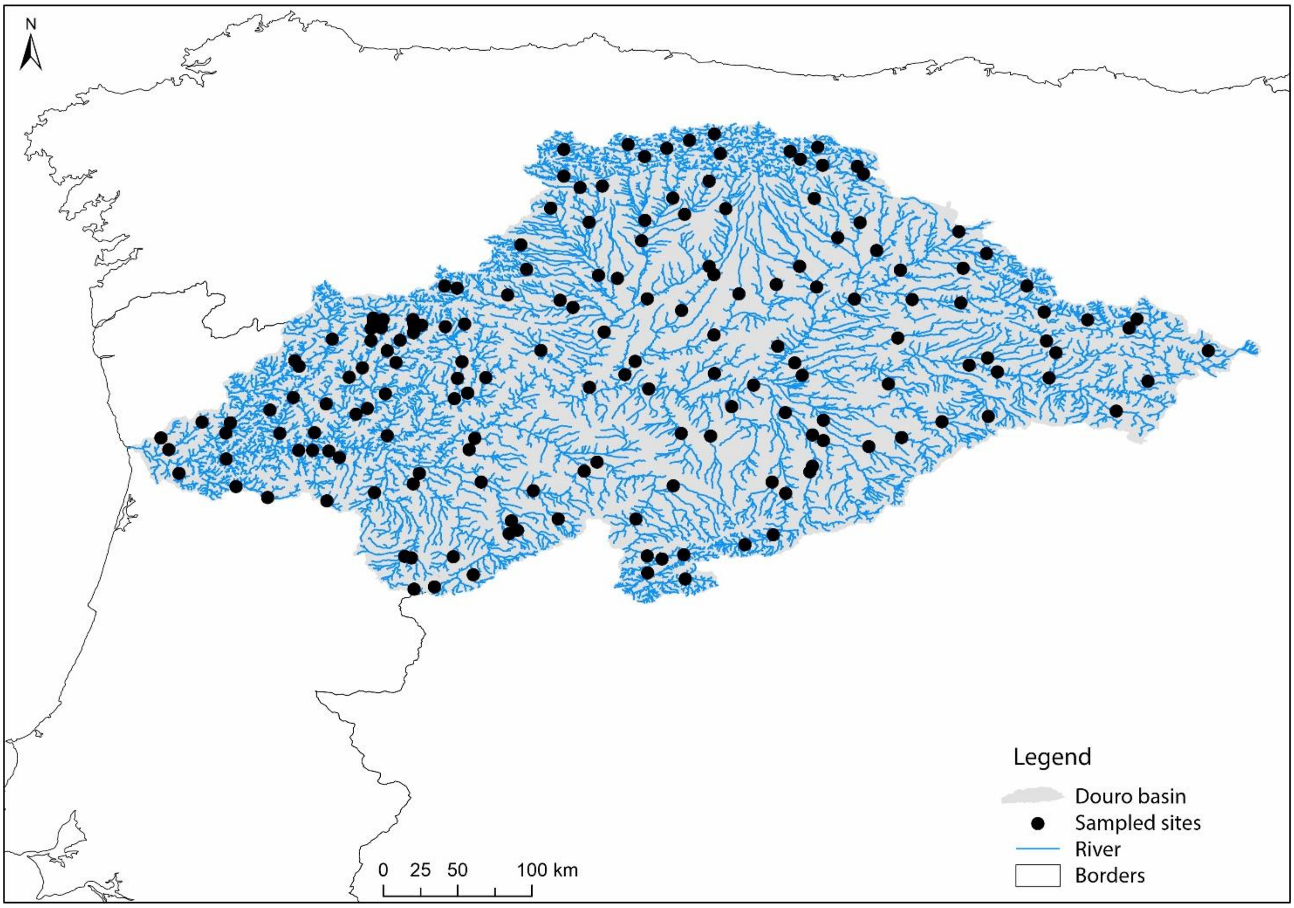


Figure 1. Study area and sampling points.

Fieldwork

The fieldwork was accomplished in three main campaigns:

The first between 1 and 30 June 2017, and the second between 1 and 30 June 2018.

The third campaign was completed in the Summer of 2019 to fill in the sampling gaps of the proposed scheme.

Surveys

All selected sites were visited for potential surveys on fish, macroinvertebrates including special surveys for crayfish, molluscs, and dragonflies. However, not all taxa were surveyed on all 175 sites but only those that could potentially be present in specific freshwater habitats (Supplementary Table 1). Furthermore, several of the selected sites were dry or partially dried and only suitable for very few taxonomic groups (Table 1). The surveys were then complemented with River Habitat Surveys, and standard water physical-chemical features to evaluate ecological integrity and anthropogenic modification of each site. Two water samples were also collected on a selected site per KBA for eDNA metabarcoding to verify if the methodologies used were capturing the whole diversity of each target taxa.

Methodologies

. Fish were assessed using electrofishing following INAG 2008.

. Freshwater molluscs were assessed using a Rapid Bioassessment for freshwater molluscs by Cummings et al. (2016) and complemented with the macroinvertebrates' assessment.

. Crayfish were assessed by the combined effort of macroinvertebrate sampling plus electrofishing for fish

. Adult Odonata were assessed by using the protocol for site count and complemented by the macroinvertebrates' assessment for the larval stages. All dragonflies present at the time of the assessment are counted for 1 hour. Not only dragonflies along and above the water, but also the adjacent vegetation is checked. Special attention is paid to micro-habitats which are sun-exposed and that give some protection against the wind. Pay special attention to exuviae, empty larval skins left behind after emergence on the vegetation or stones (only KBA sites).

. Aquatic plants were assessed by walked surveys of selected river reaches and selected parts of the margins and water column of standing water bodies. The numbers employed indicate the percentage cover (only KBA sites).

. Macroinvertebrates were collected following the European Water Framework Directive protocol

. Fish and Bivalves metabarcoding using water eDNA, followed Miya et al. (2015).

. Fluvial audits were performed at each site with the River Habitat Survey Methodology

. Water temperature, dissolved oxygen, conductivity, and pH were measured at each site with a YSI EXO 2 multi-parameter probe.

. Water samples were collected for nutrients content and immediately brought to the laboratory for analyses. Nutrients concentration (silicate (SiO_4^{4-}), phosphate (PO_4^{3-}), nitrite (NO_2^-), nitrate (NO_3^-) and ammonium (NH_4^+)) were then determined colorimetrically using methods described in Grasshoff et al. (1983).

RESULTS

FISH

Except for anadromous fish, long gone from most of the Douro River Basin since the construction of the first large dams, most of the fish species (13) were found across the whole basin (Supplementary table 1). However, the present study revealed great asymmetries across the fish distribution (Figs. 2 and 3).

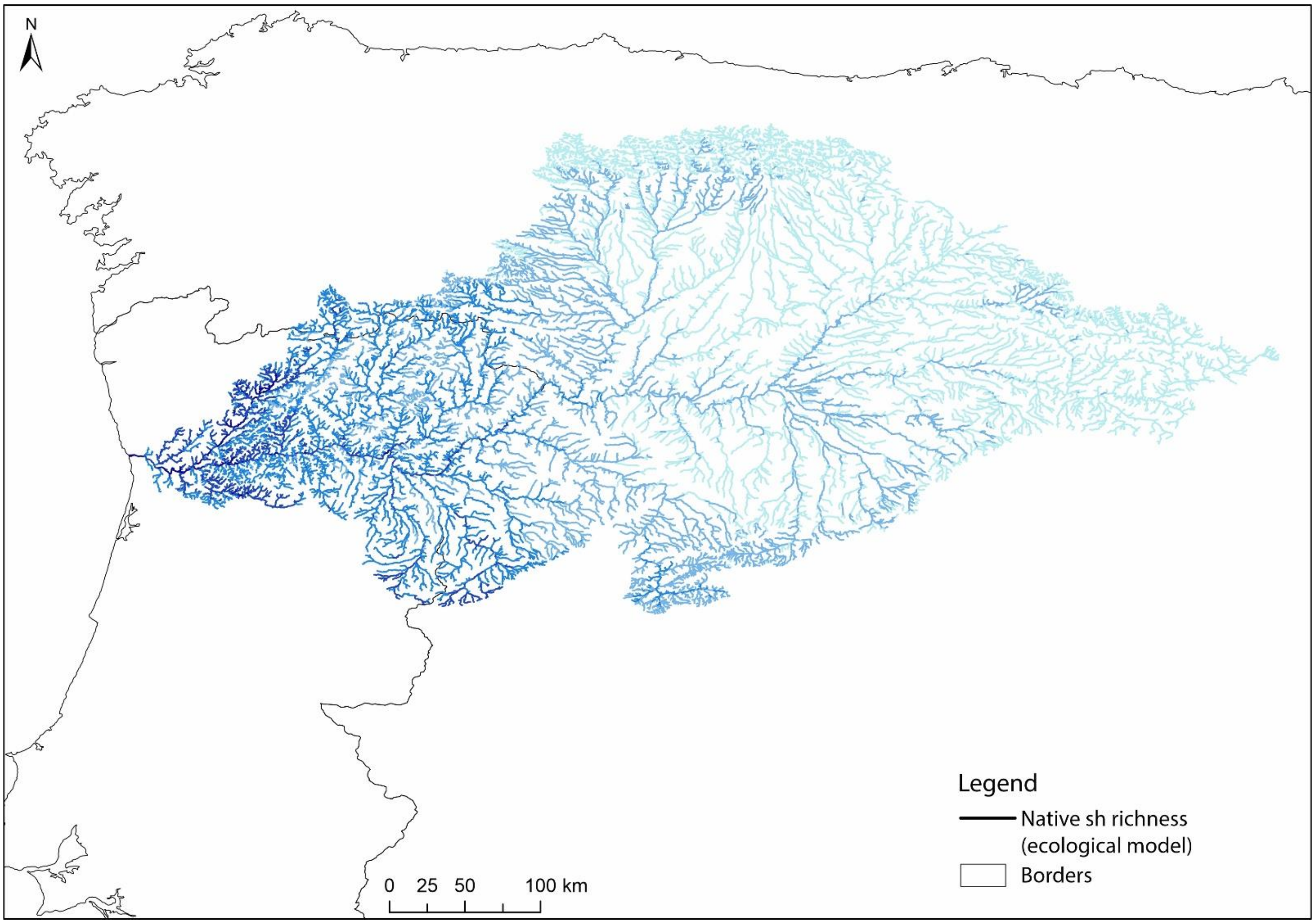


Figure 2. Ecological model of native fish richness per river stretch. Model predictions were constructed using the occurrence and abundance data and on the following: topography (altitude, slope), bioclimatic variables, human footprint, landcover, and river order (Strahler) level.

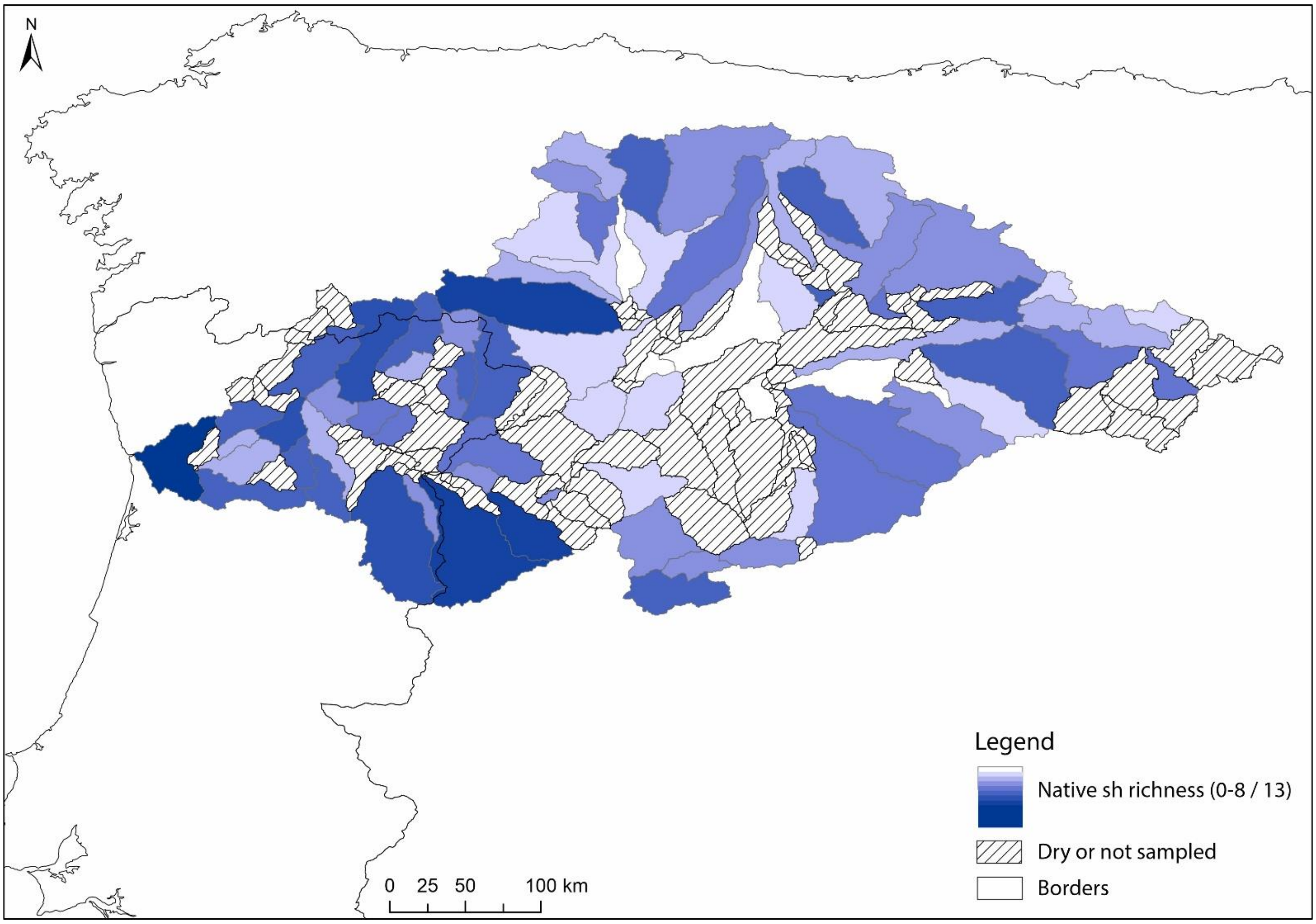


Figure 3. Native fish species richness per sub-basin (Level-8 Hydrobasins).

Native and Invasive fish show a remarkable contrasting pattern. The fish communities of the middle and lower sections of their main River Douro tributaries in Spain are now mostly composed of invasive species, both in number of species and in number of individuals (Figs. 2 and 3). In this region, most of the once more abundant freshwater fishes in the Douro basin, the Iberian Barbel *Luciobarbus bocagei*, the northern straight-mouth nase *Pseudochondrostoma duriense* and the northern Iberian chub *Squalius carolitertii* have only been collected in a handful of places.

This reported decline is probably due by the synergistic effects of the "lentification" of freshwater habitats by dams and barriers, the effects of eutrophication and increased conductivity due to intense agriculture practices, to the bad river management practices that transformed many of these rivers into irrigation channels with almost absent riparian cover. Further impacts are the proliferation of invasive species, that being more resilient to all these negative impacts have now almost completely replaced the native fauna in these areas.

The headwaters of these basins exhibit in general higher diversity. The Spanish rivers in the Western part of the basin near the border with Portugal and those in Portugal seem to be now the stronghold of the Douro River native fish species and highlights the conservation value of these habitats (Figs. 2 and 3).

Given that most of the fish species native to the Douro River Basin are threatened, the total species richness pattern is similar to the threatened species one. Both maps highlight the high importance of the Tera, Yeltes, and Tormes River Basins in Spain and the Tua, Coa and terminal tributaries of the Douro basin such as the Sousa, Paiva and Arda rivers.

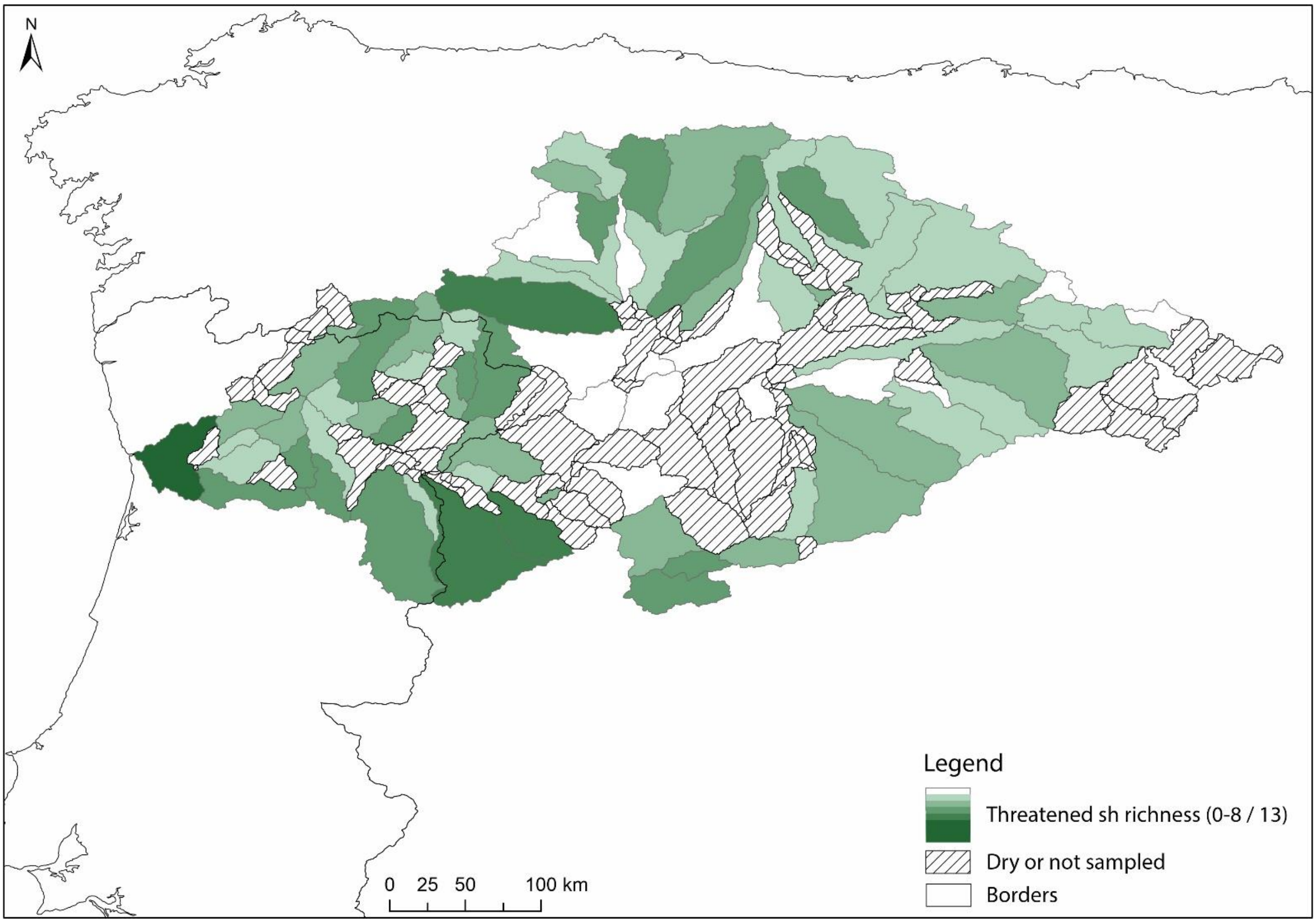


Figure 4. Threatened fish species richness per sub-basin (Level-8 Hydrobasins).

Most of the fish communities in the middle and lower sections of the main Douro River tributaries in Spain is now composed by invasive species, like the European common bleak *Alburnus alburnus*, the North American Pumpkinseed sunfish *Lepomis gibbosus* or the pyrenean gudgeon *Gobio* *lozanoi* (Figs. 5 and 6). This is especially true in the lentic sections impacted by dams and irrigation channels where almost no native fish were collected.

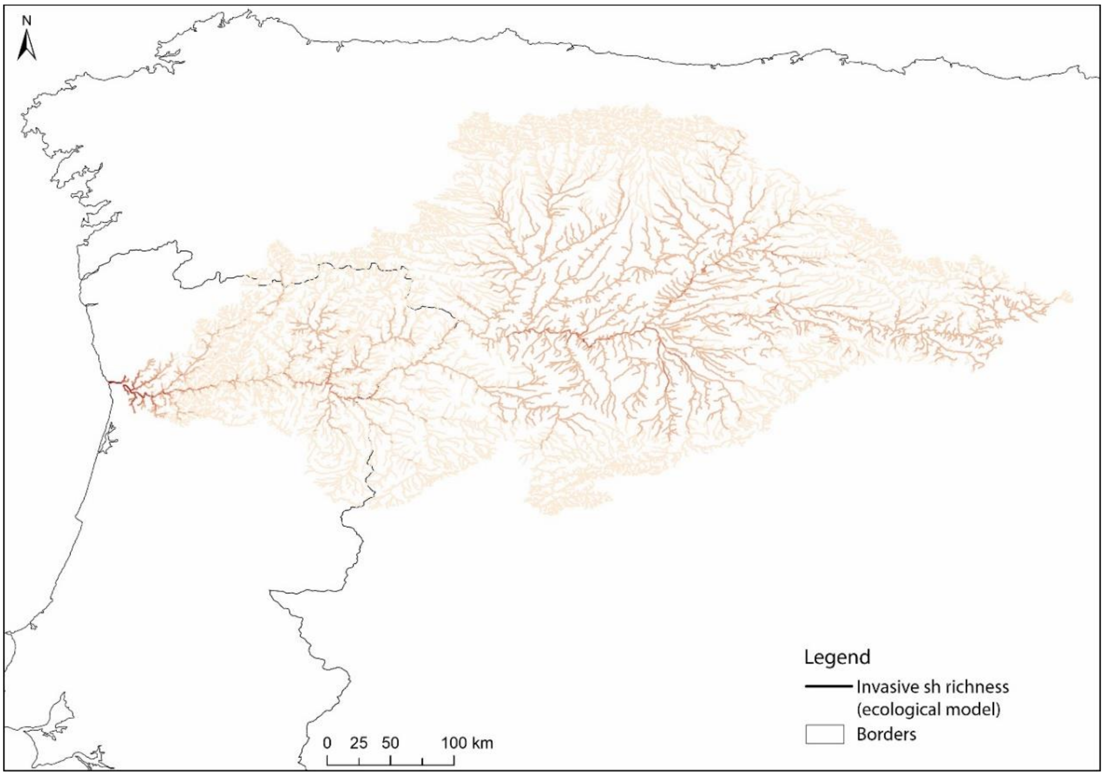


Figure 5. Ecological model of invasive fish richness per river stretch. Model predictions were constructed using the occurrence data and the following variables: topography (altitude, slope), climate, human footprint, landcover, and river order (Strahler) level.

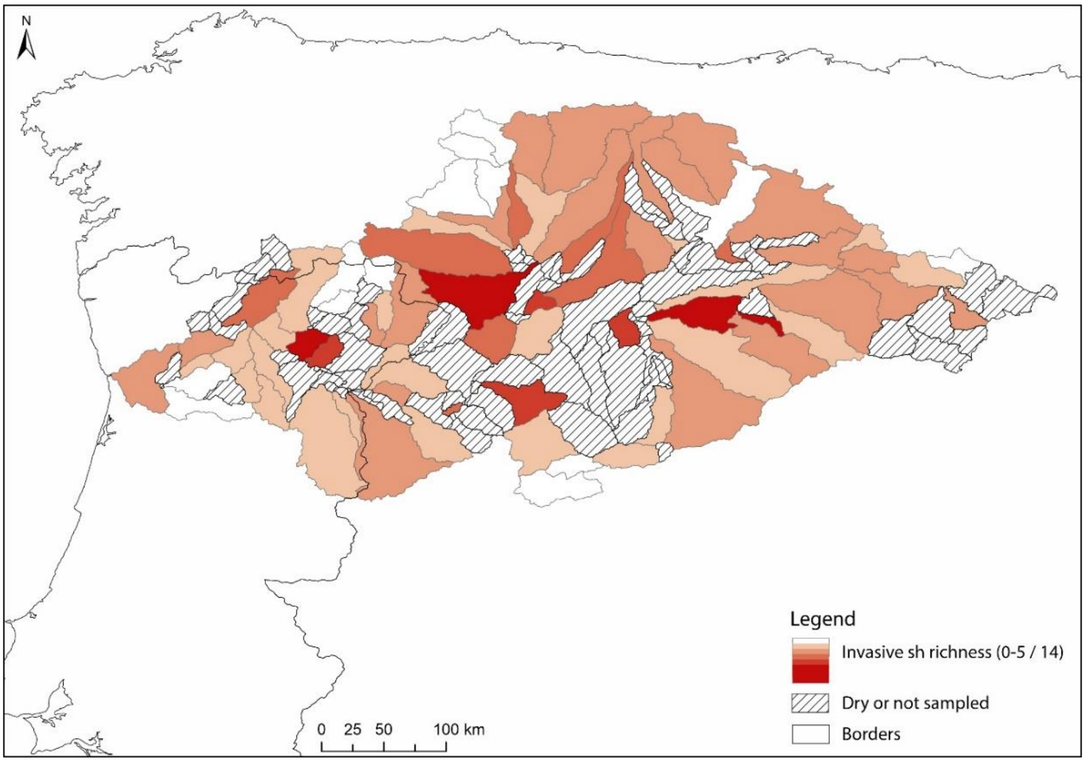


Figure 6. Native fish species richness per sub-basin (Level-8 Hydrobasins).

INVERTEBRATES

The data gathered on the macroinvertebrate communities, including molluscs and odonata, reveal a similar pattern to the fish diversity. The central area of the Douro River basin in Spain reveals an exceptionally low diversity when compared to the headwater's sections. The Macroinvertebrate diversity is in general much higher in the western section of the basin. The Tua, Tera, Yeltes and Tormes River basins again are the more important regions considering their biodiversity (Figs 7 and 8).

As for the most sensible groups to habitat degradation and impact, the mayflies (Ephemeroptera), the caddisflies (Trichoptera), and the stoneflies (Plecoptera), the pattern is similar but the contrast between the central area of the Douro Basin in Spain and its headwaters and western sections is even more pronounced which suggests that the lack of diversity of this region is mainly due to the strong cumulative effects of the several distinct impacts affecting this region.

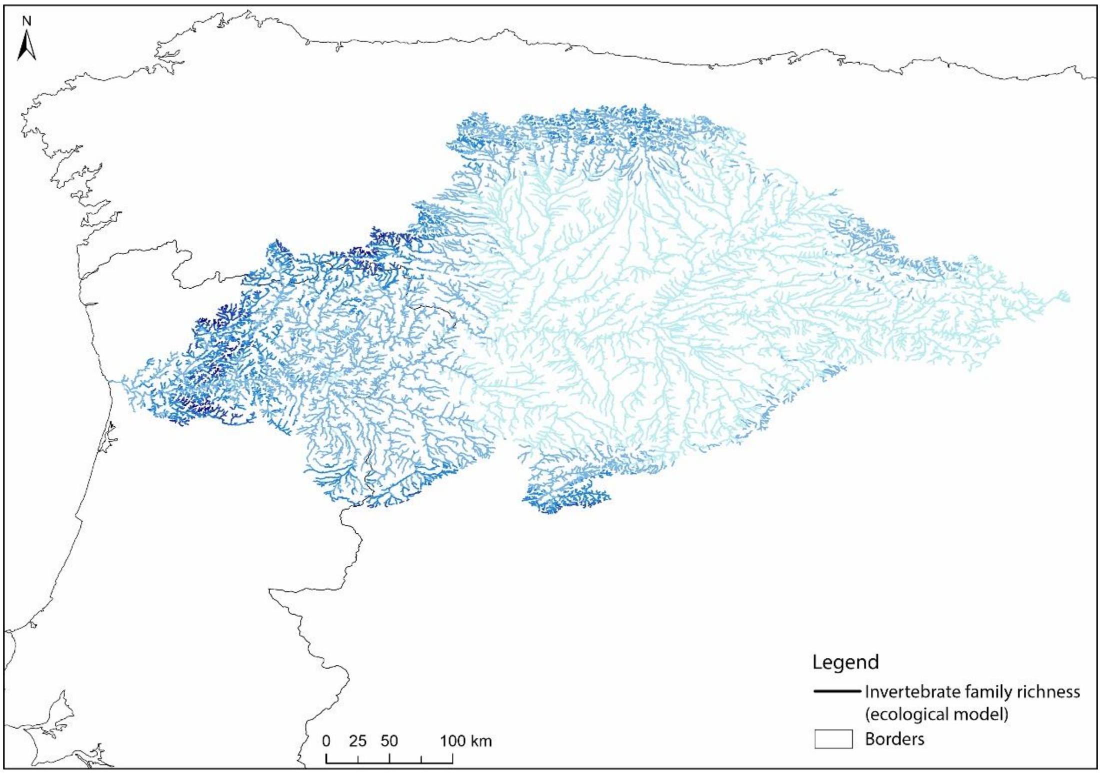


Figure 7. Ecological model of total macro-invertebrate's family richness. Model predictions were constructed using the occurrence data and the following: topography (altitude, slope), climate, human footprint, landcover, and river order (Strahler) level.

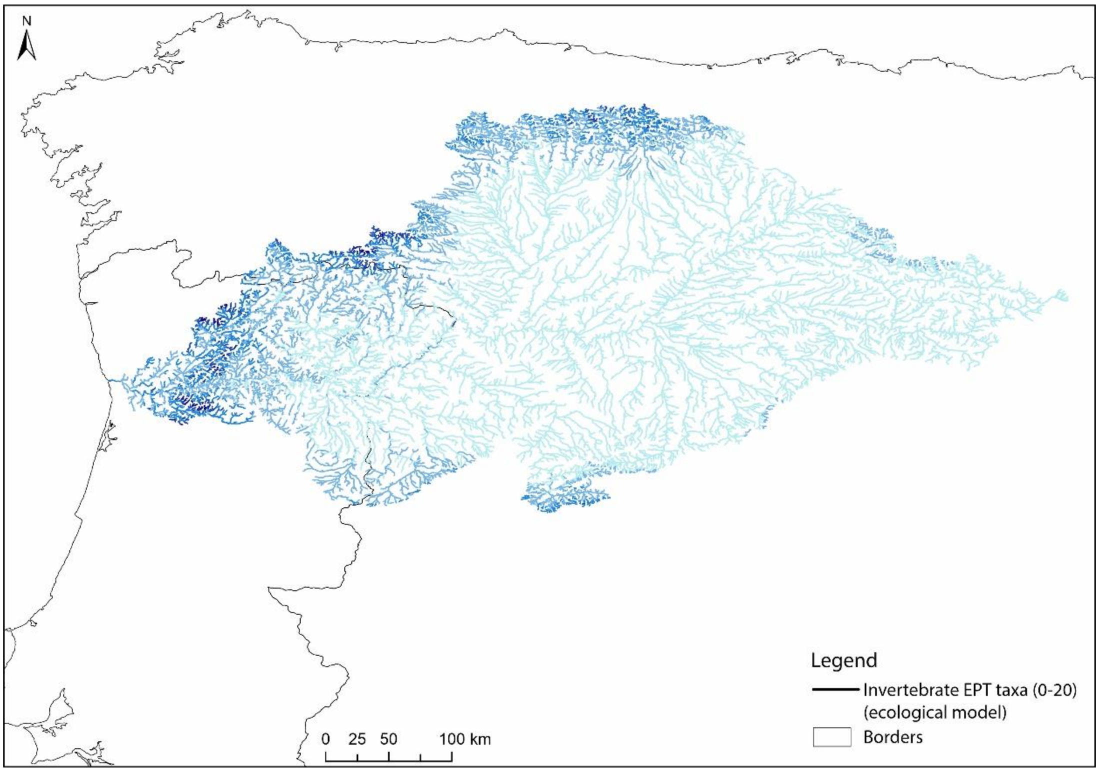


Figure 8. Ecological model of the most sensible EPT (Ephemeroptera, Plecoptera and Trichoptera) groups per river stretch (BOTTOM). Model predictions were constructed using the occurrence data and the following: topography (altitude, slope), climate, human footprint, landcover, and river order (Strahler) level.

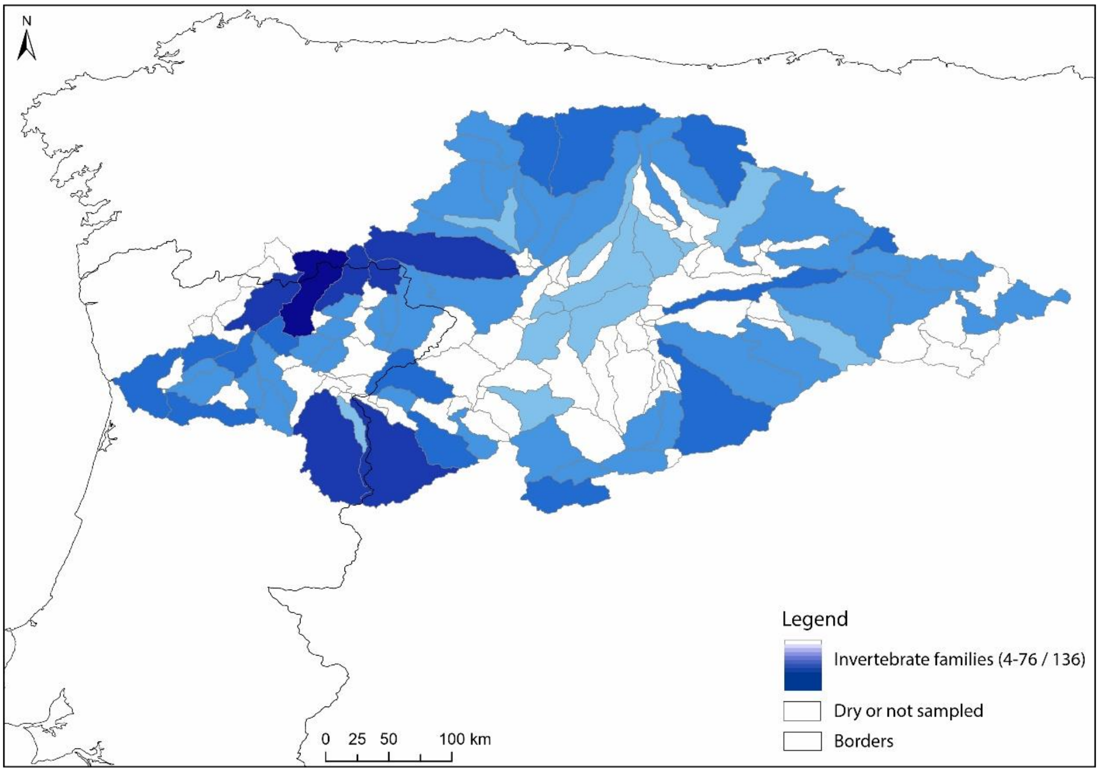


Figure 9. Invertebrate families richness per sub-basin (Level-8 Hydrobasins).

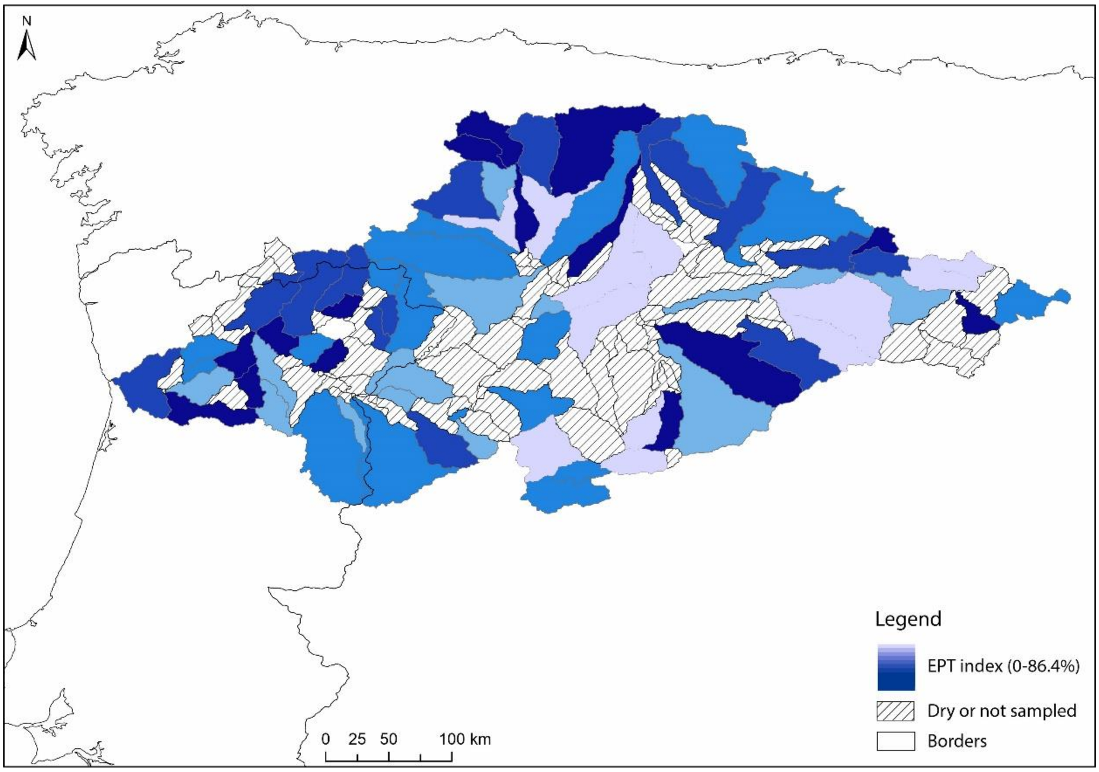


Figure 10. Family richness per sub-basin (Level-8 Hydrobasins) of the most sensible macroinvertebrate groups, EPT (Ephemeroptera, Plecoptera and Trichoptera.

HABITAT MODIFICATION AND QUALITY

Two main indexes can be extracted from the River Habitat Survey fluvial audits for the characterization of each river stretch across the Douro River basin: the Human Modification Score (HMS) and the Habitat Quality Score (HQS).

While, the HMS indicates the level of modification of a riverine system by man, the HQS indicate the quality of the habitat for maintaining freshwater biodiversity.

The HMS map shows that the whole basin has been thoroughly transformed, with hundreds of barriers, and other physical structures like bridges and levees. Many of the rivers of the River Douro valley in Spain were transformed into irrigation channels, and the natural meanders straightened. Most of these watercourses do not have any vegetation cover on the banks, making them highly susceptible to the introduction of inert materials from soil erosion and to the lixiviation of pesticides and other toxic runoffs. The lack of the natural meandering of the riverine habitats may lead to a decrease in the number of refuges for freshwater taxa from flooding events and making it difficult for populations to establish along the banks.

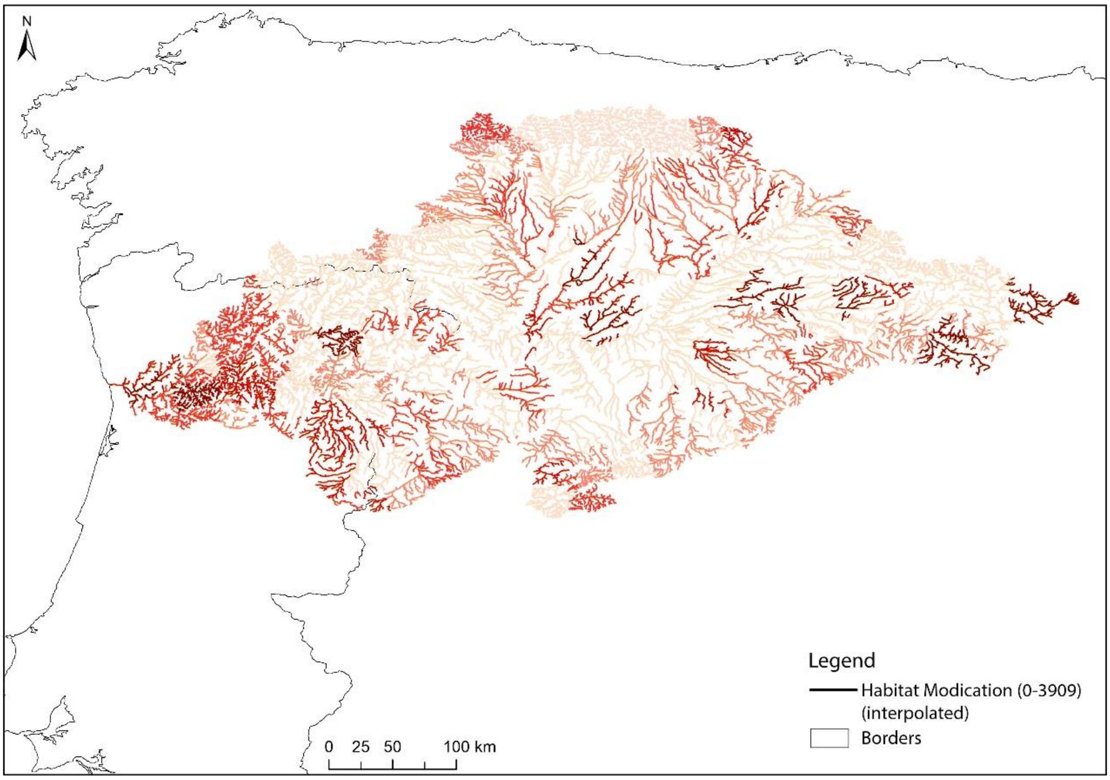


Figure 11. Human Habitat Modification map over the Douro Basin Hydrographic network. The HMS values were estimated among the values of each sampling site using Near Neighbour Interpolation.

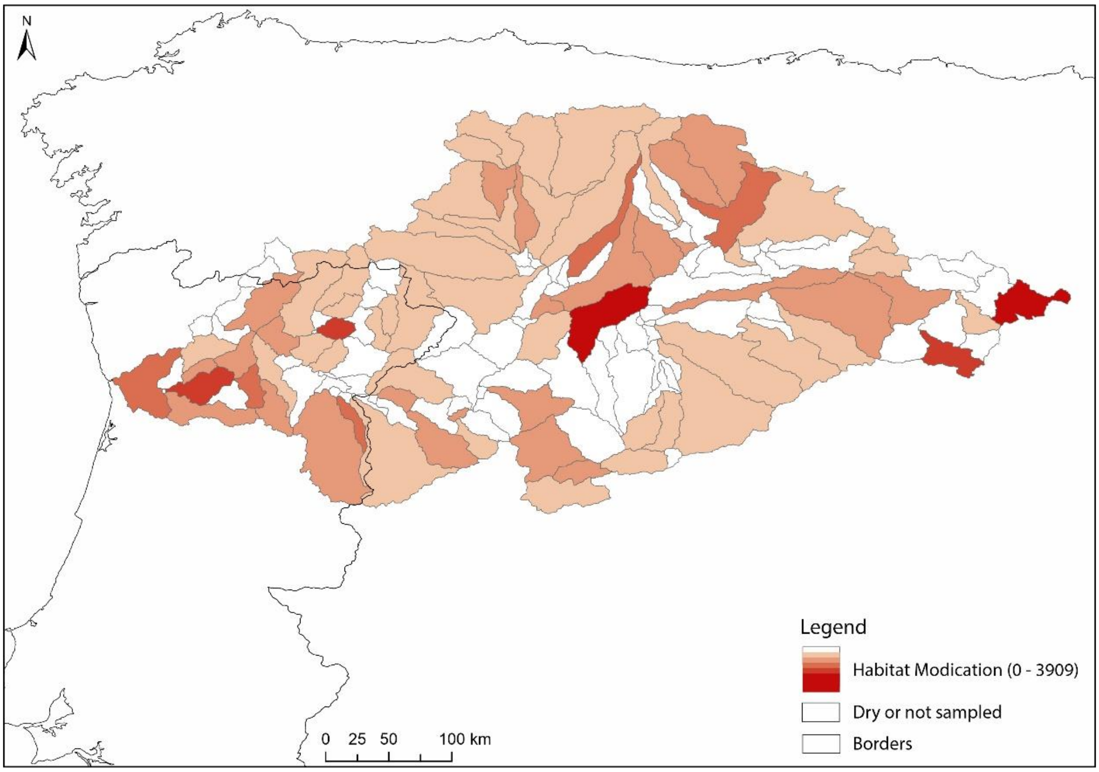


Figure 12. Average Human Habitat Modification per sub-basin (Level-8 Hydrobasins).

The habitat quality reveals again the similar pattern with the regions in the western and upper catchment sections having a higher quality than the central Douro valley in Spain. Interestingly, the Eastern upper catchment show revealed increased quality, this suggests that the low diversity values obtained in this area might be due to factor other than habitat degradation.

The sub-basins evidencing higher habitat quality and therefore capable of hosting a higher biodiversity are again the Yeltes and Tormes basins in Spain and the Tua and Paiva basins in Portugal.

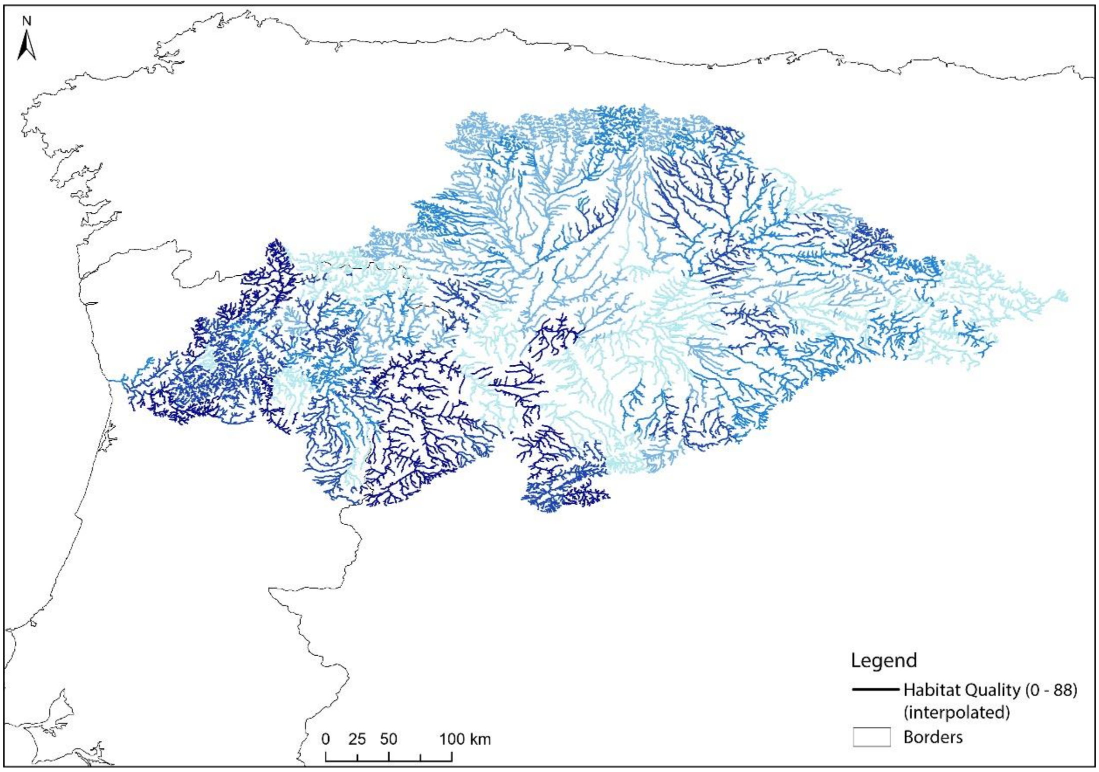


Figure 13. Habitat Quality Score map over the Douro Basin Hydrographic network. The HQS values were estimated among the values of each sampling site using Near Neighbour Interpolation.

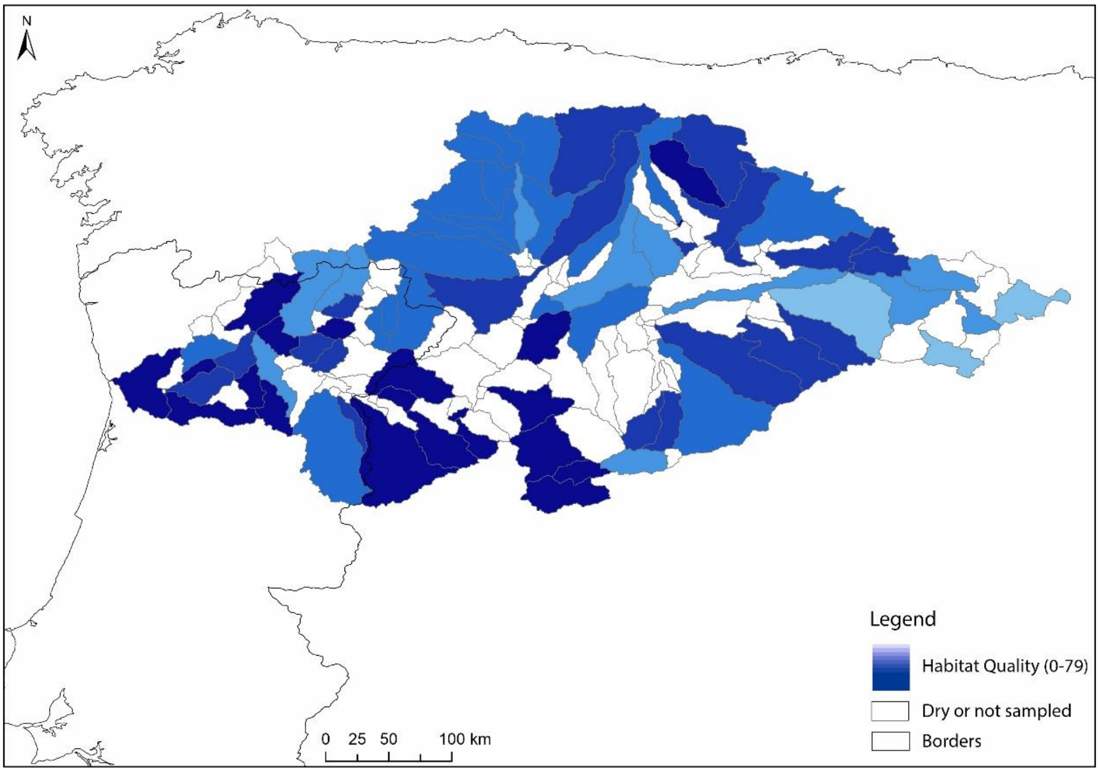


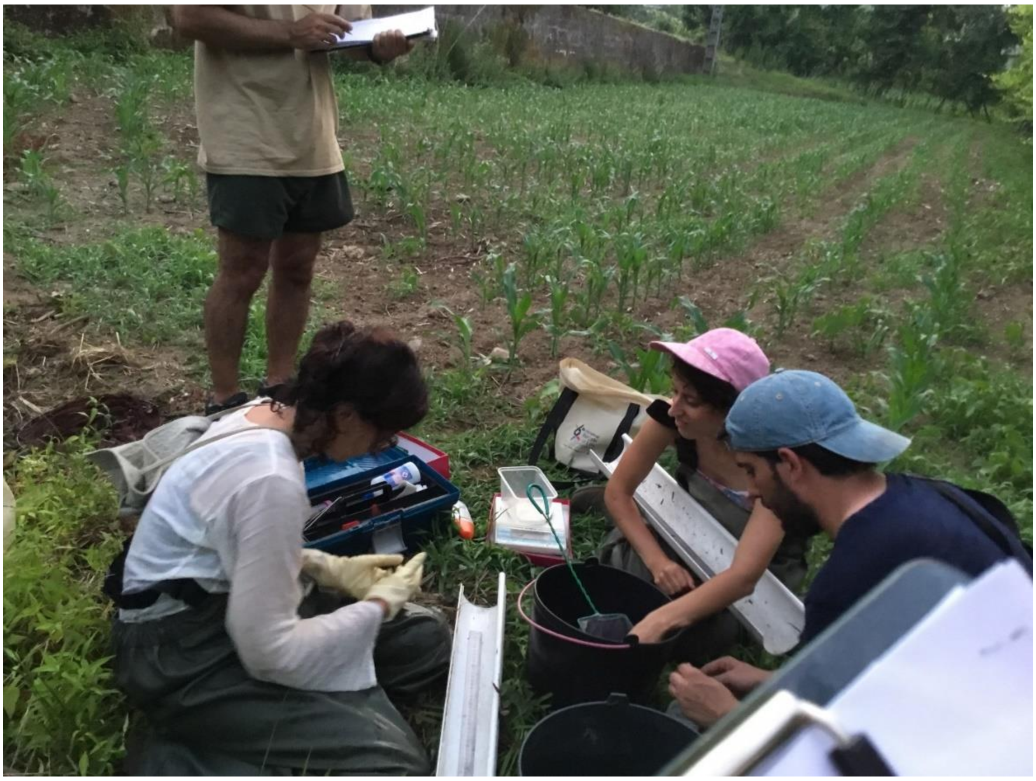
Figure 14. Average Habitat Quality Score per sub-basin (Level-8 Hydrobasins).

FINAL CONSIDERATIONS

The present report indicates a strong decline of biodiversity on the central area of the Douro River basin in Spain. This might have resulted from an accumulation of multiple stressors. The intense agriculture practices for wine, wheat and corn have impacted not only the river network physically by the intense transformation of the watercourses but also by dramatically reducing the water quantity for maintaining healthy freshwater habitats. Furthermore, the increased eutrophication and conductivity of these rivers is mainly a product of the substantial runoffs of nutrient-rich fertilizers and inert materials into the rivers that lost their riparian buffer abilities. The presence of the numerous physical barriers and dams slows the natural water flow, leading to the "lentification" of rivers and streams and to increased evaporation rates. During the summer, temperature in small reservoirs increases dramatically with consequent oxygen drops. The natural migration of the native fauna is also slowed or completely stopped by these barriers and many of the locked taxa are unable to escape desiccated areas, that become ecological traps. The last stressor seems to be the appearance of multiple invasive species that seem to be much more resilient to these lentic conditions and now dominate both in number of species and individuals. Several sub-basins are here highlighted as sanctuaries of freshwater biodiversity, the river basins in Portugal or in Spain near the Portuguese borders host the higher diversity of both fish and invertebrates and show the higher quality. The upper catchment of the whole basin also shows an improved water quality, possibly by the low human pressure of these highland regions. Specifically, the Tua, Coa, and lower river Douro tributaries the, Arda, and Paiva basins, show high biodiversity levels. In Spain, the Tera river basin in the Northwest and the Yeltes and Tormes basins in the southwest are the most diverse.

SAMPLING PHOTOS

River Sousa, Portugal



River Coa, Portugal

River Adaja, Spain

River Duraton, Spain

River Tormes, Spain