INTEGRATED MODELLING AND MONITORING OF E-FLOWS REGULATION IN A SWISS ALPINE RIVER

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Research and implementations of environmental flows (e-flows) have grown significantly in the last decades, aiming at identifying flow conditions for both sustainable ecosystems and human needs. In this context, the Canton Ticino (Switzerland) designed a 5-year modelling and monitoring program to design and assess the ecological benefits of novel e-flow regulations in several rivers in the region, based on a set of biological and physical indicators. In this work we present the workflow, challenges, and preliminary results of the hydrodynamic and habitat modelling part of the program. We investigated five reaches within the basin of Maggia river (Switzerland), having different hydro-morphological conditions, as representative of the entire basin. Two-dimensional hydrodynamic and habitat conditions were simulated for a range of discharges, spanning between existing and new e-flow conditions, for different target species. Eventually this study highlights some challenges in the modelling workflow but also proposes a repeatable, comprehensive workflow, applicable to other river basins for the design of ecological flows.

1 INTRODUCTION

Most of the Alpine rivers have been subjected to multiple anthropogenic stressors over the centuries, leading often to degradation of their ecological status [1]. Environmental flows gained relevance in the last decades as sustainable management approach to improve ecological conditions of river with impaired hydrological regime. Nevertheless, the definition and implementation of such e-flows is challenging, as the suitable values change with the river morphology, the time of the year, and the target species.

In this context, the Canton Ticino, Switzerland, designed a 5-year modelling and monitoring program to assess the ecological benefits of new e-flow regulations in several rivers in the region, based on a set of biological and physical indicators [3]. The quantification of such indicators makes use of integrated approaches, ranging from numerical modelling of hydraulic and habitat conditions to field-based biological and water quality surveys.

In this work we present the workflow and preliminary results of the modelling phase, where a number of indicators are evaluated based 2D hydrodynamic simulations and habitat modelling. The study focuses on five different reaches within the basin of Maggia river (Switzerland) [2,4]. The hydrological regime of the basin is impaired by 8 dams (reservoirs) and more than 30 water abstractions that collect almost all the run-off, leaving the main stem of the basin with a constant residual flow throughout the year.

2 METHODOLOGY

2.1 Study sites

The five study sites are in the Maggia river catchment (Switzerland), which is 568 km^2 and has an elevation ranging between 200 and 3300 m a.s.l (see Figure 1). The Maggia river flows for about 30 km (from Bignasco) north to south into Lake Maggiore. Two of the study reaches are located in tributaries of the main river, namely Lavizzara (LA2) and Melezza (ME2). They are single-thread channels with an averaged width of 40 m and slope of 0.01, characterized by gravel-pebble up to boulders riverbeds. The other three investigate reaches (MA5, MA4, MA2) are located in the main Maggia river stem, having morphologies from single channel to a wandering/braiding system, with the sediment composed by coarse gravel and average slope of 0.006**.**

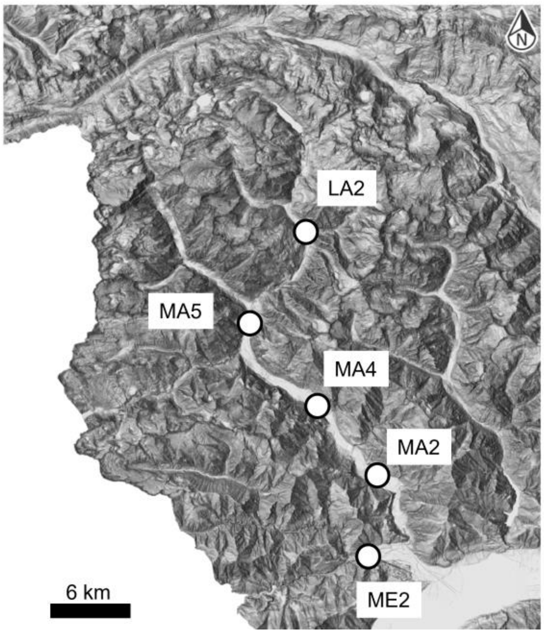

Figure 1: Map of the river basin Maggia with the approx. locations of the study sites.

2.2 Indicators

The whole monitoring program is composed by a total of 22 indicators, which aim at characterizing the impact of the e-flows on the river hydraulic conditions, habitat quality of multiple species, fish migration, groundwater level, and riparian vegetation. The program aims to evaluate the ecological status of the investigated reaches *ante* (i.e. actual conditions) and *post* (i.e. new flow conditions) modification of the e-flow regulation (see example in Figure 2). The first group of indicators (Table 1) relates with the hydrodynamic and habitat quantity and quality and is the focus of the present work.

Indicator	**Methodology**
Wetted area	Application of a 2D hydrodynamic numerical model (BASEMENT [5])
Water depth and velocity distribution	
Fish migration	
Fish habitat suitability (adult and juvenile)	Microhabitat model approach based on preference curves (HABBY [7])
Fish spawning habitat	
MZB habitat	

Table 1: List of indicators from all the modelling part to evaluate the effect of e-flow regulation change

2.3 Modelling workflow

We constructed a Digital Elevation Model (DEM) of the 5 investigated reach integrating Lidar and in-site topographical (RTK-GPS) surveys. We subsequently generated the different computational unstructured mesh, having computational cells between 0.2 and 2 m^2 on average. Mesh generation was done with the free QGIS plugin BASEmesh [6]. The construction of a reliable DEM and computational is particularly challenging when aiming at the simulation of low flow conditions, and in presence of macroscopic river bed elements, such as boulders.

The hydrodynamic conditions for the different investigated discharges were simulated with BASEMENT [5], a two-dimensional river hydro-morphodynamic simulator (freeware). The different models were calibrated against the wetted area extension (via aerial images) and/or local measurements of flow velocity and water table elevations at known discharge conditions.

The habitat analysis was conducted with the open-source tool HABBY [7], using a microhabitat modelling approach based on preference curves. The target species and life stages, as well as the specific suitability curves, were defined by fish and biology experts, based on existing literature and dataset available for the Maggia basin.

The specific results obtained in the 5 reaches will be upscaled at basin scale to inform the cantonal authorities on the relation between flow discharge and habitat quantity/quality.

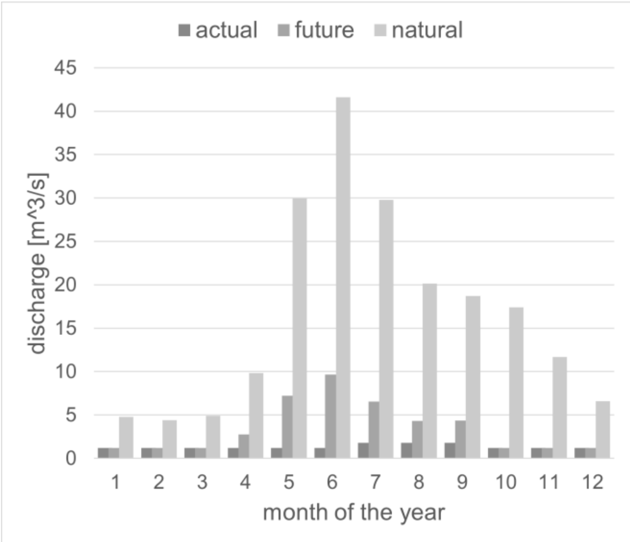

Figure 2: Reference discharge values at the river reach MA5 at the present condition, in the future and the average natural monthly values.

3 RESULTS

Figure 1Figure 3 show an example of the results of the habitat model for two species at different life-stages in terms of weighted usable area (WUA) for the river reach MA5 (see Figure 1). *Barbus plebejus* and *Telestes multicellus* were selected as target species (among others). Results show that for *Barbus plebejus* at adult and juvenile stages the habitat suitability increases with discharge, while it has an optimal peak around 10 m^3/s for fry and decreases for higher values. For *Telestes multicellus*, the adult WUA shows an optimal value for a discharge of 20 m^3/s, while at juvenile stage decreases almost linearly with discharge.

By comparing these results with the discharge regime (see Figure 2), we find that the actual e-flow is particularly detrimental for adult fish stages, while does not impact the juvenile (for *Barbus plebejus*) and fry (for *Telestes multicellus*) stages. Considering discharges in June for instance, the new e-flows (9.7 m^3/s) plans to increase the discharge of about one order of magnitude with respect to actual conditions (1.8 m^3/s), which would lead to double the WUA for *Barbus plebejus* at both juvenile and adult stages and *Telestes multicellus* at adult stages. However, e-flows during winter, which will remain un-altered (1.2 m^3/s), do not provide suitable habitat for adult stages especially.

These preliminary results will be extended considering other target species and repeated for all the reaches along the catchment, providing solid evidence on how river morphology, hydraulics and habitat are inter-connected and how e-flow regulations could provide ecological benefits looking at the catchment scale.

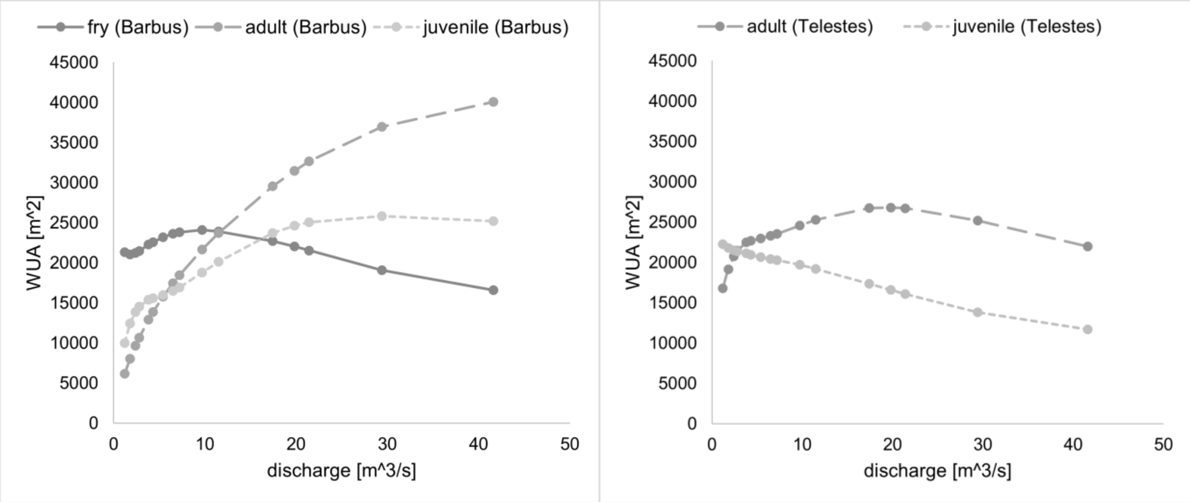

Figure 3: Weighted usable area (WUA) at different discharge values in the reach MA5, for two target species: *Barbus plebejus* and *Telestes multicellus*.

4 OUTLOOK AND CONCLUSIONS

The outcomes from the modelling phase of the program will provide indication of the expected potential benefits, but also allow for the identification of critical hotspots, where the monitoring program can be extended and improved. Moreover, the comparison of the five different reaches allows for a more upscaled and integrated evaluation of the e-flow benefits in the Maggia river basin. Challenges has been faced in the generation of solid DEM, but also on the hydrological analysis for the different discharge scenario definition. Eventually, this study offers an example of a repeatable, comprehensive workflow, applicable to other river basins for the design of ecological monitoring programs and restoration projects.

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