Comparison and Validation of Hydrological E-Flow Methods through Hydrodynamic Modelling

Alban Kuriqi (1), Rui Rivaes (2), Alvaro Sordo-Ward (3), António N. Pinheiro (1), and Luis Garrote (3)
(1) Civil Engineering Research and Innovation for Sustainability (CERIS), Instituto Superior Técnico, Universidade de Lisboa, Lisbon 1049-001, Portugal, e-mail: alban.kuriqi@tecnico.ulisboa.pt, (2) Forest Research Center, Instituto Superior de Agronomia, Universidade de Lisboa, Tapada da Ajuda, 1349-017 Lisboa, Portugal, (3) Department of Civil Engineering: Hydraulics, Energy and Environment, Technical University of Madrid, Madrid 28040, Spain

Abstract

Flow regime determines physical habitat conditions and local biotic configuration. The development of environmental flow guidelines to support the river integrity is becoming a major concern in water resources management. In this study, we analysed two sites located in southern part of Portugal, respectively at Odelouca and Ocreza Rivers, characterised by the Mediterranean climate. Both rivers are almost in pristine condition, not regulated by dams or other diversion construction. This study presents an analysis of the effect on fish habitat suitability by the implementation of different hydrological e-flow methods. To conduct this study we employed certain hydrological e-flow methods recommended by the European Small Hydropower Association (ESHA). River hydrology assessment was based on approximately 30 years of mean daily flow data, provided by the Portuguese Water Information System (SNIRH). The biological data, bathymetry, physical and hydraulic features, and the Habitat Suitability Index for fish species were collected from extensive field works. We followed the Instream Flow Incremental Methodology (IFIM) to assess the flow-habitat relationship taking into account the habitat suitability of different instream flow releases. Initially, we analysed fish habitat suitability based on natural conditions, and we used it as reference condition for other scenarios considering the chosen hydrological e-flow methods. We accomplished the habitat modelling through hydrodynamic analysis by using River-2D model. The same methodology was applied to each scenario by considering as input the e-flows obtained from each of the hydrological method employed in this study. This contribution shows the significance of ecohydrological studies in establishing a foundation for water resources management actions.

Keywords: ecohydrology, e-flow, Mediterranean rivers, river conservation, fish habitat, River-2D, Hydropower.
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(1) Civil Engineering Research and Innovation for Sustainability (CERIS), School of Engineering, University of Lisbon, Portugal, e-mail: alban.kurigi@tecnico.ulisboa.pt
(2) Forest Research Center (CEF), School of Environmental Engineering, University of Lisbon, Portugal
(3) Department of Civil Engineering, Hydraulics and Environment, University of Technology, Madrid, Spain

1 Background and Motivation

Run-off River (RoR) Hydropower is a widespread non-consumptive use water that causes alteration of aquatic ecosystems. Taking into account the increasing numbers of constructed and ongoing projects of RoR hydropower (Kelly-Richards et al., 2017), the cumulative impact on the ecosystem per unit generated electricity may be increasing. Since the RoR hydropower is not associated with any regulation system, their power production is directly interconnected with the upstream flow requirements of the river reach downstream the diversion weir. Thus, it is critical to define the trade-off between the fraction of flow allocated as instream flow, and the fraction of flow allocated for electricity generation, which is a desirable renewable energy resource. Flow regime determines physical habitats and local biotic configuration. The development of environmental flow guidelines to support the river integrity is becoming a major concern in water resources management. This study presents an analysis on implications and reliability of seven hydrological based e-flow methods in the electricity generation and fish habitat alteration.

2 Methodology


2.2 Energy Model • The potential energy is computed according to following formula: P = 0.5 * Q * g * h, where Q is the power output, g=9.81 the acceleration due to gravity (m s-2), g is the density of water (1000 kg m-3), Q is the discharge in (m3 s-1) and h is the overall efficiency of the system. Assumed installed power is approx. 1.6 MWE.

2.3 Reliability Index (RI) Analysis of EFMs • This index is computed as the fraction of time when natural flow exceeds the flow suggested by EFMs (Fig. 1).

2.4 Indicators of Hydrological Alteration (HHA) • RI HAA and 34 Environmental Flow Components (EFCC, IEA software, v.7.1; Richter, et al, 1996).

2.5 Hydrodynamic Modelling • Two flow regimes: inter-annual mean low flow and 3-day min flow in October to January (natural and altered). • Three eelgrass fish species, two life stages (i.e. juvenile and adult). • River 2D V. 0.95 was used to conduct the hydrodynamic modelling.

2.6 Habitat Alteration Index Due to Flow Alteration (HAIQ) • This index is measured by using (Eq.2). WUA=Weighted usable area, natural flow \( WUA_{\text{nat}} \); natural and altered flow \( WUA_{\text{alt}} \).

A brief description of methodology applied in this study is given in the following sections while the procedures followed are presented schematically (Fig. 1).

3 Study Site and Data

We considered one study site in the Ocreza River, East Portugal (Fig. 2). The river drains a watershed of 1429 km² with 90 km length and mean annual flow of 16.5 m³/s.

- Flow Data - i.e., 29 year daily mean), from Portuguese Water Information System (SNIRH)
- Hydraulic Data - i.e., flow velocities and depths, measured along the study site, considering several cross sections measured with ruler and probe (model 002, Valeport) positioned at 60% of the depth below the surface.
- Riverbed Topography - surveyed in 2013 using a combination of a Nikon DTM30 total station and 30 A Global Positioning System (GPS).
- Fish Species, Preference Curves - Barbel, Calamino (Bivolta) and Heron Straight-mouth Noise (Boggs), two life stages (i.e., juvenile and adult). Sampling conducted during 2012 and 2013, October at unobstructed or minimally disturbed sites, Ocreza river (Boards et al., 2013).
- Substrate Composition - it was visually assessed and represented to define the effective roughness heights along the riverbed.

4 Results

4.1 Environmental Flow Methods to satisfy natural flow regime (Fig. 1).

4.2 Influences of environmental flow methods to satisfy natural flow regime (Fig. 2).

4.3 Sensitivity with higher weightable value WUA, for fully and low flow regimes (Fig. 3).

4.4 Influence of environmental flow methods to satisfy natural flow regime (Fig. 4).

4.5 Habitat Alteration Index due to flow changes natural and altered flow regimes, 10% Daily is the only method that provides a range of change similar to that of natural flow (Fig. 5). All EFM showed increase in the alteration index due to flow changes mae, usable area and natural flow Q80% Rise rate Q75% NMQ August Q80% L.M 10% MAF NNQ 10% Daily Life Stages E-Flow Methods

5 Conclusions

- Reliability: The six of the tested EFMs are not fully reliable, with failure rates of 28.9, 12.6, 18.4, 23.9, 44.8 and 12.6 % respectively. 10% Daily is the only fully reliable method, with 0% failure.
- Flow Regime: 10% Daily method is the only method which provides a range of change (increase or fall) to the natural flow regime, by maintaining natural flow regime components.
- Flow Alteration: In terms of quantity, all methods allocate almost similar flow discharges as e-flow, except 10% MAF which provides slightly higher flow, but not a significant difference.
- Energy Generation: 10% MAF provides relatively low energy generation, while six other methods provides similar energy generation amount.
- Habitat Sensitivity: 10% MAF and 10% Daily show the highest performance related to WUA and the lower HAIQ, 10% MAF has performance similar to the natural flow regime.

References


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