Assessing mesoscale habitat availability in relation to discharge in braided river reaches

Évaluation de la disponibilité des habitats à méso-échelle en fonction du débit dans les tronçons de rivières tressées

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RÉSUMÉ

Ressources en eau, la conservation de la nature, la planification de la restauration des rivières et l'évaluation de l'impact. Dans diverses applications de gestion des ressources en eau, le cœur de la modélisation de l'habitat réside dans la courbe d'évolution de l'habitat en fonctionne du débit, qui met en relation la surface d'habitat disponible pour une espèce biologique ou un stade de vie donné avec le débit dans un tronçon de rivière particulier. Cette relation est généralement obtenue par des études de terrain intensives, qui sont complétées par l'application de modèles hydrauliques 2D et de techniques de télédétection / de détection proximale dans des tronçons de rivière plus importants présentant des morphologies complexes.
Cette étude explore la modélisation de l'habitat dans les systèmes fluviaux en tresse, en se concentrant sur la rivière Piave (Italie) et la rivière Sarantaporos (Grèce, Albanie). Ces tronçons morphologiquement dynamiques posent des défis et des opportunités uniques pour la modélisation de l'habitat. Une méthodologie hybride combinant des mesures ciblées sur le terrain et la modélisation hydraulique a été appliquée pour surmonter les limites des approches traditionnelles. La photogrammétrie à haute résolution réalisée par des drones, appuyée par des points de contrôle au sol, a permis d'obtenir des orthophotos détaillées et des modèles numériques de terrain (MNT) corrigés.
Des simulations hydrauliques sur une gamme de débits ont été réalisées à l'aide des MNT corrigés, ce qui a permis d'identifier les unités hydro-morphologiques (UHM) et de dériver des courbes débit-habitat à l'aide du logiciel Sim Stream Web.
Les résultats préliminaires indiquent que la relation habitat-débit dans les tronçons tressés diverge du modèle à pic unique observé dans les systèmes à canal unique. Dans les rivières en tresses, l'augmentation du débit déclenche initialement une alternance entre des conditions d'habitat adéquates et inadéquates en raison de l'activation de canaux supplémentaires et de la redistribution du débit. Cependant, à des débits très élevés, l'adéquation de l'habitat diminue car le canal commence à se décrépir en raison d'une fusion due à un niveau d'eau élevé. Ces résultats mettent en évidence l'interaction complexe entre l'hydrologie, la morphologie du chenal et la dynamique de l'habitat dans les rivières en tresses.
En faisant progresser notre compréhension de la disponibilité de l'habitat dans des conditions de débit variables, cette étude fournit des indications précieuses pour améliorer la gestion et la conservation des écosystèmes des rivières en tresses.

ABSTRACT

Habitat modelling in rivers is increasingly being applied in both research and practical contexts for water resources management, nature conservation and river restoration planning and impact assessment. Especially in various water resources management applications, the core of habitat modeling lies in the so called "habitat - discharge rating curve", which relates the available habitat area for a target biological species / life stage with the flowing discharge in a particular river reach of interest. Such relation is generally obtained through intensive field surveys, which are complemented by the application of 2D hydraulic models and remote / proximal sensing techniques in larger river reaches with complex morphologies.
This study explores habitat modeling in braided river systems, focusing on the Piave River (Italy) and the Sarantaporos River (Albania/Greece). These morphologically dynamic reaches pose unique challenges and opportunities for habitat modelling. A hybrid methodology combining targeted field measurements with

hydraulic modeling was applied to overcome the limitations of traditional approaches. High-resolution photogrammetry from drone surveys, supported by ground control points, provided detailed orthophotos and corrected Digital Terrain Models (DTMs). Hydraulic simulations across a range of discharges were conducted using the corrected DTMs, enabling the identification of Hydro morphological Units (HMUs) and the derivation of flow-habitat curves using Sim Stream Web software.
Preliminary results indicate that the habitat-discharge relationship in braided reaches diverges from the single-peak pattern observed in single-channel systems. In braided rivers, increasing discharge initially triggers an alternation between suitable and unsuitable habitat conditions due to the activation of additional channels and redistribution of flow. However, at very high discharges, habitat suitability declines as the channel start to decries due a merging for the hight water level. These findings highlight the intricate interplay between hydrology, channel morphology, and habitat dynamics in braided rivers.
By advancing our understanding of habitat availability across varying flow conditions, this study provides valuable insights for improving the management and conservation of braided river ecosystems.

MOTS CLÈS

Rivières en tresses, modélisation de l'habitat, gestion des rivières, morphologie, restauration des rivières

KEYWORDS

Braided rivers, habitat modelling, river management, morphology, river restoration

1 INTRODUCTION

Habitat modelling in rivers is increasingly being applied in both research and water resources management, for nature conservation, river restoration planning and impact assessment of hydro-morphological alterations. Many different methods are available to assess the amount (area) of suitable habitats in rivers for target biological species at different flow stages. River habitat models are typically used to estimate a quantitative relation between the available habitat area for a target species and the flowing discharge. This can be viewed as a "habitat-discharge rating curve", which depends on: (i) the species preferences for the relevant environmental descriptors of habitat (e.g. f flow depth, velocity, substrate classes, presence/absence of refugia/cover) and on (ii) the spatial distributions of these environmental descriptors, which are fundamentally controlled by the channel morphology and by its dynamics. Most studies on habitat modelling so far focus on its application on selected case studies or on their methodological development, while few studies systematically address the extent to which the habitat-flow rating curves depend on the channel morphology. The present work focuses especially on fish habitat availability in multi-thread braided rivers, for which also single case applications are less compared to single-thread streams. To this aim we employ the MesoHABSIM methodology (Parasiewicz et al. 2013), to assess habitat conditions for target fish species at the river reach scale. The MesoHABSIM model has primarily been applied to single-channel reaches (Vezza et al. 2014), where the flow-habitat curve typically displays on distinct single peak. In these cases, as flow increases, habitat availability initially rises, reaching an optimum for low to intermediate discharge values and then declines as higher discharges determine unsuitable habitat conditions for most species mainly due to rising flow velocities. Little information is available instead on the characteristics of flow-habitat curves in braided river reaches. The hypothesis behind our study is that at lower flows, which are mostly concentrated in one single main channel, habitat availability increases with discharge, reaches a peak, and may not show a monotonously decreasing trend for higher flow rates, because of the progressive activation of multiple, smaller branches. The study investigates how flow-habitat curves interact with the unique characteristics of braided rivers to enhance our understanding of these systems and improve their management.

2 STUDY AREAS AND METHODOLOGIES

2.1 Study areas

For this analysis, we examined two braided river reaches: the Piave River in Italy and the Sarantaporos River at the Albania-Greece border. The Piave River reach is located at the foothills of the Alps, stretching approximately 2 kilometers in length and ranging from 200 to 650 meters in width. Upstream, the river is

heavily regulated by a complex network of hydraulic infrastructure, primarily for hydropower generation and irrigation purposes. The flow-habitat curves were analyzed for fish species that are typical of the site: Salmo marmoratus (marble trout), Cottus gobio (European bullhead), Barbus spp. (barbel). Field measurements were conducted in the framework of the national experimental phase for the implementation of the 2017 national law on Ecological Flows, in collaboration with the Veneto Environmental Protection Agency (ARPAV). The wild and ungauged Sarantaporos River reach flows along the Albania-Greece border, approximately 2 kilometers upstream of its confluence with the Vjosa/Aoos River, which has been designated as Europe's first Wild River National Park. The Vjosa River is renowned for its near-natural state and minimal anthropogenic pressures. Its study reach is 1 kilometer long, with a width ranging from 150 to 350 meters. Field measurements for this site were conducted during the 2024 Science Week, organized by Riverwatch in collaboration with the NGOs MedINA (The Mediterranean Institute for Nature and Anthropos) and EcoAlbania.

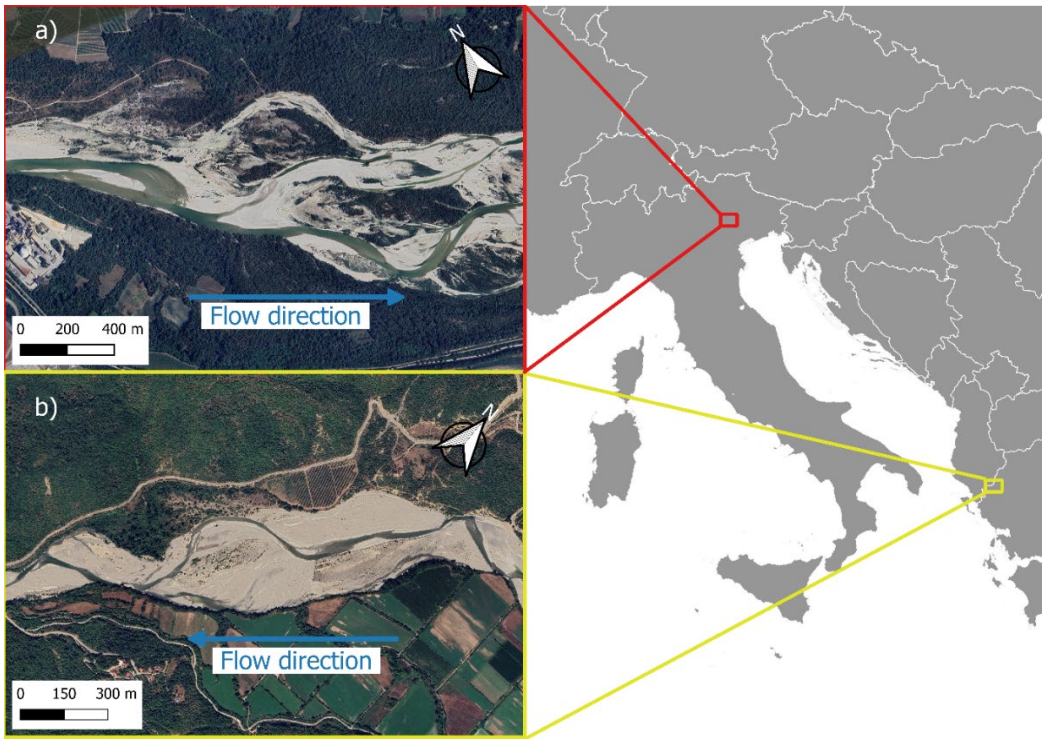

Figure 1:Illustration of the study reaches used for the analysis : a) Piave river, Italy; b) Sarantaporos river, Greece/Albania

2.2 Methods

The MesoHABSIM methodology has been implemented through a hybrid approach that combined targeted fieldwork with hydraulic modeling, image analysis and a clustering / segmentation procedure. The chosen reach is divided into hydromorphologically uniform units, wherein velocity, depth, and substrate classes distributions are assessed, together with the presence/absence of cover/refugia. Field activities included: a drone survey to obtain high-resolution imagery and a DTM of the reach through photogrammetry, supported by Ground Control Points (GCPs) carefully surveyed across the area to enhance spatial accuracy, enough for subsequent analyses. Flow measurements were conducted at key cross-sections to determine discharge conditions. Grain Size Distribution (GSD) analyses were also performed on several units. The DTM required additional corrections to account for bathymetric variations (Dietrich et al. 2017) which enabled the accurate representation of submerged terrain within the hydraulic model. Hydraulic simulations were conducted using Basement (Vetsch et al.,2024) under fixed-bed conditions at steady-state for a series of incrementally increasing discharges, thus providing water depth and velocity distributions, which were then used to identify Hydromorphological Units (HMUs) within the study reach, following Farò et al. (2022). Substrate classifications were obtained for the entire reach from the orthophoto following Soto Parra et al. (2024). Habitat – discharge rating curves were obtained through the MesoHABISM method using the the *SimStreamWeb* platform, available at the ISPRA Ambiente web portal (National Italian Environment Protection Acengy). This tool already incorporates habitat preferences models for the selected fish species. The habitat-discharge rating curves are the key output of the analysis, allowing to test our initial hypothesis.

3 PRELIMINARY RESULTS

Through multiple simulations across a range of discharges, the model effectively captured the interaction between flow conditions, morphological features, and habitat suitability. This enabled a comprehensive assessment of how habitats in a braided river. Preliminary results are reported in Figure 2. The increasing discharge initially leads to a rise in the number of active channels, resulting in a higher braided index. However, at very high discharges, the braided index decreases as exposed bars are submerged. This behaviour, which is well known for braided rivers, is reflected in the observed dynamics of habitat suitability and in the shape of the habitat-discharge rating curve. At low flow conditions habitat increases with discharge up to a peak, when only one or two channels are wet. Further discharge increase determines unsuitable conditions for the main channel, but activates new channels where habitat conditions move from unsuitable to suitable. At higher discharges, habitat suitability then declines in parallel with the reduction in hydro-morphological diversity and the drop in the braiding index. This relationship provides some support to the initial hypothesis of the complex interaction between hydrology and habitat dynamics in braided rivers. Application to other braided rivers is presently ongoing to complete the study.

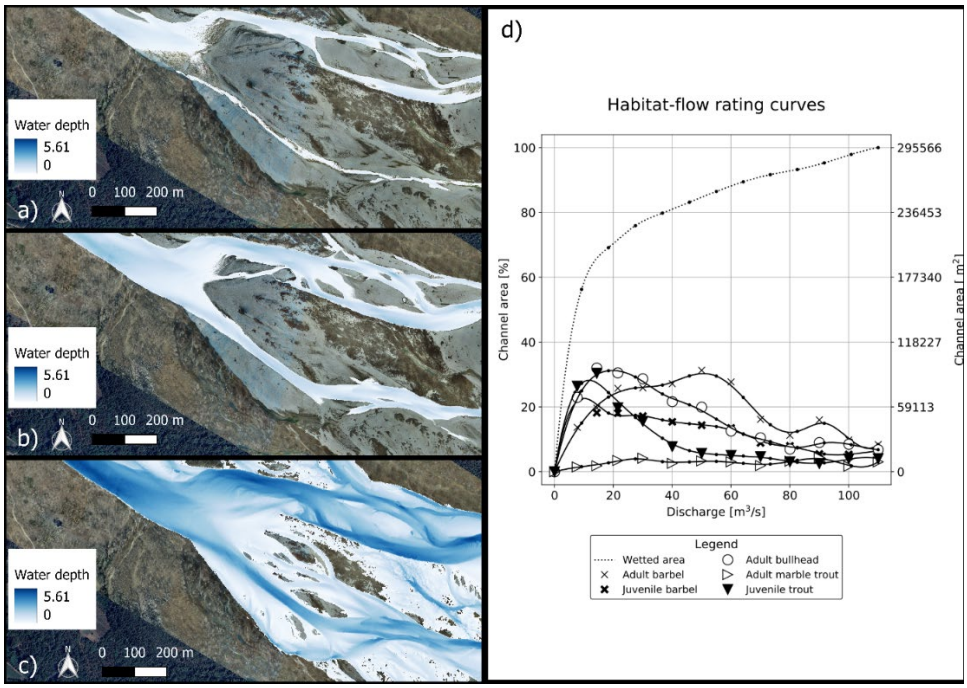

Figure 2:Hydraulic simulation and habitat flow rating curves of the Piave river. a) Water depth with Q=10 m^3/s ;b) Water depth with Q=100 m^3/s;c) Water depth with Q=1000 m^3/s; d)Habitat flowrating curves of target species

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