Influence of small in-line structures on the longitudinal connectivity and habitat availability for brown trout (*Salmo trutta*) populations

Influence des structures hydrauliques sur la connectivité longitudinale de petits cours d'eaux et l'accès aux habitats pour les populations de truite commune (*Salmo trutta*)

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RÉSUMÉ

L'impact des barrages sur les populations piscicoles en rivière a été démontré à travers de nombreuses études. L'impact de plus petites structures apparaît moins important mais exerce néanmoins une pression importante sur les populations piscicoles. Cette étude évalue l'impact de ces structures sur la connectivité longitudinale de petits cours d'eaux, présents en bassin calcaire (River Rib, UK). Elle se focalise plus spécifiquement sur la connectivité vis à vis des populations de truite commune (*Salmo trutta*). L'approche menée combine modélisation hydraulique et analyse terrain afin de quantifier la franchissabilité de différentes structures, qualifiées d'obstacle aux écoulements, par ces populations et estimer les variations saisonnières. Des données de quantification d'habitats, présents le long du cours d'eau, ont été combinées aux valeurs de franchissabilité, afin d'obtenir un Indice Dendritique de Connectivité à l'échelle du bassin versant pour différents stades de développement des poissons. Les résultats indiquent que ces structures ont un impact important sur la connectivité du cours d'eau due à de faibles valeurs de franchissabilité. De faibles hauteurs saisonnières d'eau, caractéristiques des bassins calcaires, ainsi que la présence limitée d'habitats pour différents stades de développement accroissent la pression sur les populations piscicoles. Ces résultats mettent en avant la nécessité d'évaluer l'impact de structures qui, présentes au sein de larges cours d'eau, ont un impact limité mais relativement important au sein de plus petits cours d'eau.

ABSTRACT

The impact of low-head inline structures in rivers (e.g. small weirs) may appear less significant for fish populations than large dams, but have the potential to exert a substantial and widespread pressure. This study evaluated the impact of small in-line structures on the longitudinal connectivity of small streams for a fish population. A combination of fieldwork and hydraulic modelling was conducted to quantify structure passability and estimate how it varies seasonally for a series of weirs, sluices and culverts in a small lowland chalk stream (River Rib, UK) with a resident brown trout population (*Salmo trutta*). Passability was then combined with existing network scale data on habitat to assess network connectivity using the Dendritic Connectivity Index for different life stages of the brown trout populations. The results indicate that these low-head weirs, sluices and culverts have a significant impact on connectivity due to low passability in such a shallow river, particularly in the summer, and the poor habitat condition. The results emphasise the need to evaluate all inline structures in small streams, even low-head ones that may be passable by fish in deeper rivers, for their impact on fish populations.

KEYWORDS

Barriers, connectivity, fish passage, habitat fragmentation, river networks

1 INTRODUCTION

River systems have been heavily modified over time through channel fragmentation and flow regulation, caused in large part by the construction of dams, weirs and other in-line structures. While the ecological impact of large dams has been well documented, increasing attention is being placed on the impacts of smaller in-line structures. The in-channel disturbance caused by these low-head structures may appear less significant than large dams, but they have the potential to exert a substantial and widespread pressure on fish populations.

This study assesses the impact of small low-head, in-line structures on the longitudinal connectivity of small streams for a fish population. Connectivity is defined as the combination of the passability of the structures and the diversity, quality and spatial distribution of habitat along the network.

2 MATERIALS AND METHODS

This study used a combination of fieldwork and hydraulic modelling to quantify structure passability and estimate how it varies seasonally for a series of weirs, sluices and culverts in a small lowland chalk stream with a resident brown trout population (*Salmo trutta*). We integrated the estimates of passability with existing network scale data on habitat to assess network connectivity using the Dendritic Connectivity Index for different life stages of the brown trout populations.

2.1 Study area

The focus of the study is the River Rib, located in Hertfordshire, England, UK. The River Rib catchment sits atop a chalk bedrock geology that is overlaid by glacial sand, gravel and boulder clay. As a result, river flows exhibit the characteristic annual hydrograph of a baseflow dominated chalk stream, though with increased responsiveness to rainfall. River discharge is modest (Q50: 0.286 $m^3 s^{-1}$) with the greatest flows in winter and spring, and lowest in late summer and autumn. Along the 27.5 km study section, there are six weirs, a culvert and a sluice.

2.2 Passability, habitat and connectivity

The Dendritic Connectivity Index (DCI), developed by Cote et al. (2009) and modified by Shaw et al. (2016) for potamodromous fish populations, was applied to the River Rib. DCI considers the passability of structures and the quantity of habitat in the river network. Passability was assessed using a field screening method adapted from the IEC Protocol (Baudoin et al. 2014), which considers the hydraulic head and slope to estimate a minimum downstream pool depth, and fish length to estimate burst swimming capacity. Seasonal variations in flow conditions and passability were estimated using a 1-D hydraulic model for the river, developed in HEC-RAS using topographical data from a field survey, longitudinal profiles provided by the Environment Agency, and hydrological records from the Centre for Ecology and Hydrology. Passability was estimated for flow duration curve deciles (Q10-Q90). The quantity of habitat was assessed using River Habitat Survey data recorded in 2004 by the Environment Agency, interpolated to cover lengths of the river not covered by the 500m surveys. The quantity of habitat for spawning, juveniles and young trout was based on the extent of gravel bed, runs and riffles, while habitat for adult was estimated based on the extent of gravel bed and pools for three flow conditions (Q10, Q50, Q90). DCI was calculated for juvenile, young and spawning trout (DCI_y), and separately for large adult trout >300 mm in length (DCI_o).

3 RESULTS AND DISCUSSION

The field screening of structure passability indicated that four out the eight structures are completely impassable at all discharges (W1, W3, W6 Culvert). One weir (W2) has good passability, which increases with fish length. Two weirs have limited passability, and the sluice was found to be completely passable. Variations in discharge are estimated to impact passability for three of the weirs (W2, W4, W5). The quantity of habitat varied substantially along the river network with minor differences predicted at the different flow conditions. DCI was found to vary substantial by fish length, and age/stage of the fish (e.g. juvenile vs adult, spawning vs non-spawning adult), as well as by river discharge (Figure 1). DCI was lowest for juvenile fish at low discharge (Q10), but was relatively consistent for larger juvenile trout. For adult trout, DCI was low for small adult trout (300 mm long) at all discharges, but were substantially greater for larger fish.

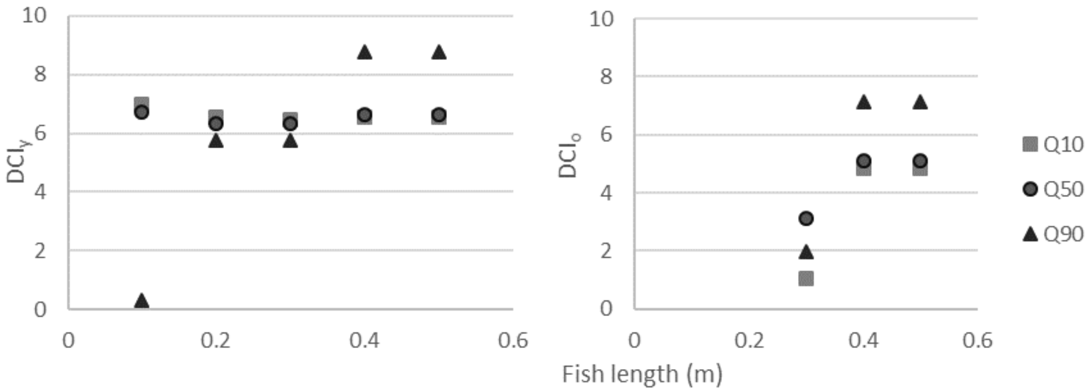

Figure 1: Dendritic Connectivity Index for the River Rib for juvenile, young and spawning trout (DCIy), and separately for large adult trout >300 mm in length (DCIo).

By combining the barrier effects of in-line structures and poor habitat, this study was able to estimate the longitudinal connectivity of a brown trout population in a small stream with small in-line structures. We found that these low-head weirs, sluices and culverts have a significant impact on connectivity due to the low passability of these solid structures in such a shallow river and the poor habitat condition. The results emphasise the need to evaluate all inline structures in small streams, even low-head ones that may be passable in deeper rivers, for their impact on fish populations.

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