Hydropeaking and oviposition habitat availability of mayfly in a large river: towards new evaluation of aquatic organism vulnerability to dewatering

Eclusées et disponibilité de l'habitat de ponte des Ephémères au sein d'une rivière : vers une nouvelle évaluation de la vulnérabilité des organismes aquatiques à l'assèchement

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RÉSUMÉ

Les éclusées énergétiques modifient fortement les conditions hydrauliques de la rivière, entraînant une variation (infra)-journalière de la vitesse de courant et du niveau d'eau. La réponse des insectes aquatiques à ces variations a été principalement évaluée pour le stade larvaire et moins pour les stades adulte et oeuf. Pour les taxons avec un comportement de ponte sélectif, comme les éphémères du genre Baetis, ces variations artificielles peuvent induire un échec du recrutement et créer un goulot d'étranglement sur la taille de la population dû à une disponibilité insuffisante d'habitats de ponte et à la mortalité des oeufs asséchés. Notre étude vise à déterminer à l'échelle d'un tronçon de 38 km de la basse rivière d'Ain 1) la quantité d'habitat de ponte disponible pour ces éphémères en fonction du débit et 2) la quantité d'habitat favorable asséché lors d'une baisse brutale du débit. L'habitat disponible est quantifié à partir des simulations hydrauliques d'un modèle en deux dimensions étalonné et validé sur l'ensemble d'un tronçon (1,9 million de mailles). L'habitat de ponte potentiel représentait jusqu'à 6,6 % de la surface mouillée à 30 m3.s-1 avant de diminuer progressivement à moins de 1 % après 165 m3.s-1. Les diminutions artificielles de débit observées dans la rivière régulée (2012-2022) ont entraîné l'assèchement de 98 % (médiane) des habitats de ponte potentiel disponible lors des débits de pointe. Ces résultats soulèvent la question de la pertinence d'évaluer la quantité d'habitat de ponte utile à la population d'éphémères en place dans une rivière régulée pour en connaître la sensibilité aux éclusées, et principalement à la mise en assec.

ABSTRACT

Hydropeaking strongly changes the hydraulic conditions of the river, leading to a (sub)-daily variation of flow velocity and water level. The response of stream insects to these variations has been mainly evaluated for the larval stage and less for the adult and egg life stages. For taxa with high selective oviposition behaviour, such as mayflies of the genus Baetis, these artificial variations may induce a recruitment failure and bottleneck on the population size by a short supply of oviposition habitat and egg mortality by dewatering them. This study aims to determine, over a 38 km sector of the lower Ain river, 1) the quantity of oviposition habitat available for these mayflies versus the discharge and 2) the quantity of favourable habitat dewatered during a sudden drop in discharge. The available habitat was quantified using hydraulic simulations of a two-dimensional model calibrated and validated over an entire sector (1.9 million meshes). The potential oviposition habitat represented up to 6.6 % of the wetted area at 30 m3.s-1 before gradually decreasing to less than 1 % after 165 m3.s-1. The artificial flow decreases observed in the regulated river (2012-2022) resulted in the dewatering of 98 % (median) of the suitable oviposition habitat available at peak flows. These results raise the question of the relevance of assessing the quantity of oviposition habitat useful to the mayfly population in a regulated river to determine its sensitivity to hydropeaking, and in particular to dewatering.

KEYWORDS

Assec, Hydroélectricité, Insectes aquatiques, Œuf, Survie

Drying, Egg, Hydroelectricity, Stream insects, Survival

Introduction

Hydropeaking, a widespread type of management, induces (sub)-daily variation of discharge (Moog, 1993) which modifies the hydraulic conditions downstream of the point of water release. The ecological impact of hydropeaking has been mainly assessed on fish and secondary on larvae of stream insects (Bipa et al., 2024). While adult and egg life stages are essential for stream insect population recruitment (Downes et al., 2021), their response to flow regulation has been explored only recently (e.g. Kennedy et al., 2016). Several stream insect taxa have a highly selective oviposition behaviour, such as mayfly genus *Baetis,* by laying their egg masses on emergent substrates in shallow fast-flowing water (e.g. Peckarsky et al., 2000), whose availability depends on the hydraulic conditions. This high selectivity makes them sensitive to flow regulation, which may both submerge oviposition habitats (Wahjudi et al., 2024) and cause egg mortality by dewatering them (Kennedy et al., 2016). To our knowledge, no study has yet evaluated the influence of flow regulation on the availability and dewatering of stream insects oviposition habitats at the river sector scale (for fish see (Burman et al., 2021). Our study focuses on the mayfly genus *Baetis*, as study organism. Our aims here were *(i)* to estimate the availability of *Baetis* oviposition habitat at the river sector scale versus the discharge, and *(ii)* the proportion of oviposition habitat dewatered due to hydropeaking events. To simulate hydraulic conditions versus discharge we used a 2D hydrodynamic model.

Method

A 2D hydrodynamic model (Rubar20) calibrated and validated on the lower part of the Ain River (a tributary of the Rhône river) over 38 km-long stretch downstream of the lowest power-plant, was used (detailed in e.g. Judes et al., 2022). The model calculates the water level, water depth and flow velocity at different discharges for 1 900 000 centroids of rectangular meshes (mean area: 7.6 ± 3.2 m^2). To limit the computational time, the model was run as a steady state for the following discharges: 12, 16, 20, 25, 30, 45, 60, 75, 90, 105, 120, 135, 150, 165, 180, 195, 210, 225, 240, 255, 270, 285 $m^3.s^{-1}$. Earlier field study showed that preferential oviposition habitat of *Baetis* spp. females on the lower Ain river was the emergent mineral substrate of]9.05 - 25.6 cm] of diameter and a surface flow velocity of 5 -

75 cm.s^{-1}. We assumed that the gravel banks and their water margin (at 12 m^3.s^{-1}) were the potential areas with preferential oviposition substrate size for *Baetis* females. Only meshes with a water level of [0.05 - 0.30 m] which could allow the emergence of the substrate were considered as potential oviposition habitat for a flow velocity of [0.05 - 0.75 m.s^{-1}]. The availability of potential oviposition habitat relative to the wetted area at discharge *i* was the ratio between the number of meshes considered as potential oviposition habitat and the number of wetted meshes (water level ≥ 0.05m). For each decrease of discharge in the Ain river (for the 2012-2022 period), we calculated the ratio between the number of meshes considered as potential oviposition habitat at peak flow and their numbers dewatered at base flow (water level < 0.05 m). The hydraulic conditions for these peak and base flows were estimated by linear interpolation with the nearest upper and lower discharge for which hydraulic simulations were available.

Results

The potential oviposition habitat available for *Baetis* females in the lower Ain river represented 3.9 % of the wetted area at 12 m^3.s^{-1}, increased up to 6.6 % at 30 m^3.s^{-1} and gradually decreased to less than 1 % after 165 m^3.s^{-1} (Figure 1). The artificial flow decreases observed in the Ain River resulted in the dewatering of 98 % (median) of the suitable oviposition habitat available at peak flows.

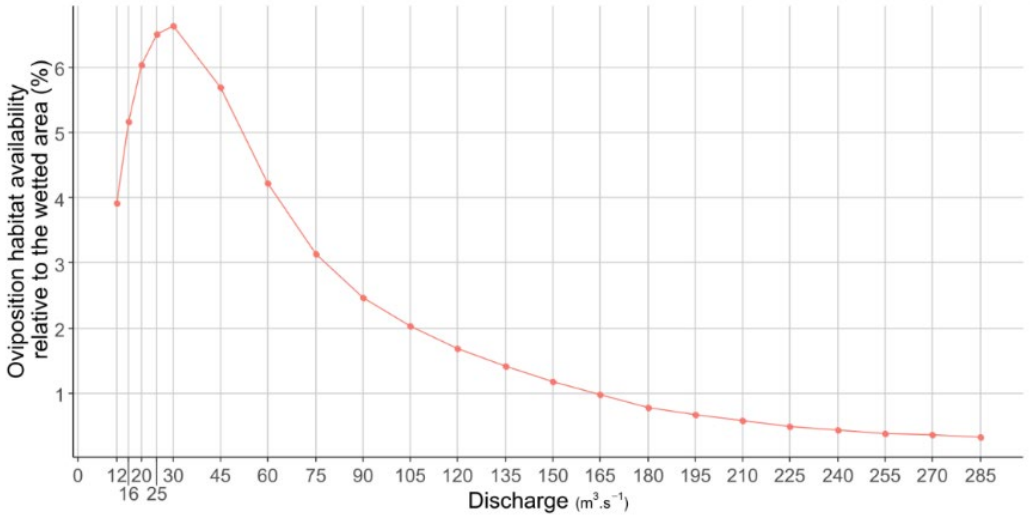

Figure 1: Availability of potential oviposition habitat for *Baetis* females as the percentage of the wetted area simulated for different discharges on the 38 km-long stretch of the lower Ain river. Note that potential oviposition habitats were within gravel bars which we defined as hotspots of potential oviposition habitat (e.g. 13 % of the whole wetted area of the 38 km long study stretch at 30 $m^3.s^{-1}$).

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