Influence of hydropeaking on young-of-the-year fish abundance: a field study of Austrian alpine rivers

Influence des éclusées sur l'abondance des poissons juvéniles: une étude de terrain sur les rivières alpines autrichiennes

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RÉSUMÉ

Les éclusées (fluctuations rapides et infra-quotidiennes du débit) résultant de la production d'énergie hydraulique constituent un défi majeur pour les écosystèmes aquatiques, tels que les rivières alpines. L'importance croissante des sources d'énergie renouvelables pourrait intensifier ce problème. Les premiers stades de vie des poissons, qui préfèrent les habitats proches des berges, sont particulièrement vulnérables aux effets des fluctuations rapides du débit. De plus, leur capacité à nager et donc à gérer des vitesses d'écoulement élevées est encore moins développée que chez les poissons adultes. Cette étude compare l'abondance des truite brune (*Salmo trutta*) et des ombres communs (*Thymallus thymallus*) juvéniles dans les rivières alpines autrichiennes afin de déterminer si l'effet des éclusées est un facteur dominant par rapport à d'autres paramètres anthropiques et naturels, y compris l'utilisation des terres, la morphologie, l'hydrologie, la connectivité et la typologie. Les résultats montrent que l'abondance des truites brunes et des ombres communs juvéniles est influencée par une combinaison de la fréquence et de l'intensité des éclusées. Alors que la réponse de l'ombre commun est principalement influencée par les paramètres des éclusées, l'abondance de la truite brune est également influencée par la dimension de la rivière, avec une préférence pour les petits cours d'eau d'amont. Les résultats obtenus dans le cadre de cette recherche sont liés à la directive autrichienne sur l'atténuation des éclusées et ainsi appellent à une meilleure gestion de ces dernières, en particulier durant les premiers stades du cycle de vie des poissons, lorsqu'ils sont les plus vulnérables.

ABSTRACT

Hydropeaking (rapid sub-daily flow fluctuations) resulting from hydroelectric power generation is a major challenge for aquatic ecosystems, such as alpine rivers. The increasing importance of renewable energy sources could intensify this problem. Early life stages of fish are particularly vulnerable to the effects of rapid flow fluctuations due to their preference for habitats close to the riverbank. Also, their ability to swim and therefor ability to handle high flow velocities is still less developed than in adult fish. This study compares the abundance of young-of-the-year brown trout (*Salmo trutta*) and European grayling (*Thymallus thymallus*) in Austrian alpine rivers to determine whether the effect of hydropeaking is a dominant factor when other anthropogenic and natural parameters, including land use, morphology, hydrology, connectivity and typology are considered. The results show that the abundance of young-of-the-year brown trout and European grayling is influenced by a combination of hydropeaking frequency and intensity. While the response of European grayling is mainly influenced by hydropeaking parameters the abundance of Brown trout is further influenced by river dimension, with a preference for smaller headwater streams. This research feeds into the Austrian hydropeaking mitigation guideline and calls for better hydropeaking management, especially during early life cycle stages where fish are most vulnerable.

KEYWORDS

Brown trout (*Salmo trutta*), European grayling (*Thymallus thymallus*), , flow ramping, multi-river study, sub-daily flow fluctuations

augmentation du debit, étude multi-filières, fluctuations infra-quotidiennes du débit, ombre européen (*Thymallus thymallus*), truite brune (*Salmo trutta*)

1 INTRODUCTION

Hydropeaking, characterized by rapid flow fluctuations due to hydroelectric power generation, poses significant challenges to aquatic ecosystems, particularly in alpine rivers (Bunn and Arthington 2002; Poff and Zimmerman 2010; Hayes et al. 2022). Fish are one of the organism groups most affected by the adverse effects of hydropeaking (Hunter 1992; Young et al. 2011; Moreira et al. 2019). The key mechanisms that work on fish are on the one hand drift which leads to a displacement of fish because of higher flow velocities during increased flows, and on the other hand stranding which occurs when fish shift with the rising water level but can't return quickly enough to the permanently wetted zone during decrease in flow (Shirvell 1994; Saltveit et al. 2001; Auer et al. 2014; Auer et al. 2017; Führer et al. 2024). The early life stages of fish are particularly affected by stranding and drift because they prefer shallow habitats with low flow velocity, which are mainly situated along the river bank (Heggenes and Traaen 1988; Young et al. 2011; Moreira et al. 2019).
This study investigates the impact of hydropeaking on the abundance of young-of-the-year fish, specifically brown trout (*Salmo trutta*) and European grayling (*Thymallus thymallus*), across multiple alpine rivers in Austria. The study aims to determine whether hydropeaking is a dominant factor influencing young-of-the-year fish abundance when other parameters such as land use, morphology, hydrology, connectivity, and typology are also considered.

2 METHODS

The study was conducted in nine alpine rivers in Austria. Of these, five rivers are affected by hydropeaking, the other four rivers exhibit no hydropeaking impact. We conducted fish sampling at multiple sites along each river. Rivers affected by hydropeaking were sampled along a gradient downstream of the hydropeaking source and upstream of the hydropeaking source as a reference site (Zeiringer et al. in prep.). Fish sampling was conducted using backpack electrofishing along the riverbanks. The fish were determined to species level, measured and then released back to the river. The abundance of young-of-the-year fish was standardized to individuals per 100 meters. Hydrological data with a resolution of 15 minutes were used to calculate event-based hydropeaking metrics for a period half a year prior to the sampling date, including the life cycle stages of gravel emergence and larvae rearing. The hydrological metrics included the frequency of down-ramping events, the median maximum down-ramping rate, as well as the median amplitude and flow ratio of the down-ramping events (Greimel et al. 2016). Further multiple parameters describing the morphology, typology, land use and connected tributaries were calculated to account for confounding factors.

A combination of random forest models and generalized linear models (GLM) was used to identify key variables explaining the young-of-the-year fish abundance. Random forest models were employed for exploratory data analysis, while GLMs were used for quantitative analysis and inference. Graphical methods were further used to show the results with the untransformed data. Further, a GLM of the most influential variables excluding hydropeaking variables was calculated and the residuals of the model plotted against a combined hydropeaking pressure to examine the effect of hydropeaking excluding other relevant factors.

3 RESULTS

The study found that hydropeaking is a key stressor affecting the abundance of young-of-the-year fish. The median fish abundance was lower at sites affected by hydropeaking compared to hydrological controls. In detail, young-of-the-year fish abundance was influenced by a combination of hydropeaking frequency and intensity. Brown trout abundance was additionally influenced by the size of the river, with smaller rivers showing higher abundances.

4 DISCUSSION & CONCLUSION

The findings of this study indicate that hydropeaking has an impact on the abundance of young-of-the-year European grayling and brown trout in alpine rivers, even when environmental parameters are taken into account. This highlights the necessity for the implementation of guidelines and management strategies with the aim of enhancing the ecology of alpine rivers. Furthermore, this study results emphasise the importance of implementing mitigation measures to reduce the adverse effects of hydropeaking, particularly during the vulnerable early life stages of fish. Research should test to which extent young-of-the-year fish abundance constitutes a useful indicator for pre- and post-monitoring of hydropeaking mitigation measures.

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