Nervous habitats: effects of hydropeaking on habitat persistency at the patch scale

Habitats erratiques : effets des éclusées sur la persistance des habitats à l'échelle du patch

Habitats nerveux : les effets hydrologiques sur la persistance de l'habitat à l'échelle de la parcelle ??

Bätz Nico[1], Judes Clarisse[2], Davide Vanzo[3], Weber Christine[1]

1. Eawag, Swiss Federal Institute of Aquatic Science and Technology, Surface Waters – Research and Management, Kastanienbaum, Switzerland. (nico.baetz@eawag.ch & christine.weber@eawag.ch)
2. INRAE RiverLy, Institut national de la recherche agronomique, Villeurbanne, France ; EDF R&D LNHE, Laboratoire National d'Hydraulique et Environnement, Chatou, France. (clarissejudes@gmail.com)
3. VAW, Laboratory of Hydraulics, Hydrology and Glaciology, ETH Zürich, Zürich, Switzerland (vanzo@vaw.baug.ethz.ch)

RÉSUMÉ

Les modifications du régime hydrologique des cours d'eau dues à la production d'hydroélectricité par intermittence (c'est-à-dire les éclusées) entraînent une perte de biodiversité et une dégradation des écosystèmes dans le monde entier. Cependant, notre compréhension mécanistique de la façon dont la fréquence des éclusées affecte les processus écologiques est encore limitée. Nous utilisons la modélisation pour simuler les impacts liés à la modification de la fréquence des variations de débit et de leurs durées relatives sur la persistance des habitats aquatiques. Nous explorons de nouvelles approches et métriques pour quantifier l'impact des modifications du régime sur les habitats à l'échelle du patch, étant donné qu'il s'agit de l'échelle qui a reçu le moins d'attention dans la recherche et la gestion. Nos résultats suggèrent que (i) la persistance de l'habitat peut être décrite en utilisant une approche de séries temporelles afin de rendre compte de la nature multi-événementielle des éclusées; (ii) aborder la persistance de l'habitat à l'échelle du patch semble être une approche prometteuse pour représenter la perspective des organismes aquatiques vivant et se déplaçant dans leur environnement. Toutefois, la signification écologique et les seuils environnementaux potentiels de la persistance des patches sont encore peu étudiés et devraient faire l'objet de recherches plus approfondies à l'avenir.

ABSTRACT

Alteration in the river flow regime due to intermittent hydropower production (i.e. hydropeaking) leads to biodiversity loss and ecosystem degradation worldwide. However, our mechanistic understanding of how the frequency of repeated hydropeaking affects ecological processes is still limited. Here, we use modelling to simulate the impacts of altered flow frequency and relative flow duration on the persistency of aquatic habitats. We explore novel approaches and metrics to quantify the impact of flow regime alterations on the patch-scale, being this a scale that has received less attention in hydropeaking research and practice. Our findings suggest that (i) habitat persistency can be well described using a time-series approach so as to account for the multi-event nature of hydropeaking; (ii) addressing habitat persistency at the patch scale appears to be a promising approach to represent the perspective of aquatic organisms living and moving in their environment. However, the ecological relevance and potential environmental thresholds of patch persistency are still poorly studied and will need further investigation.

KEYWORDS

Flow alteration, habitat assessment, habitat dynamics, habitat modeling, time-series

1 THE SHIFTING HABITAT MOSAIC UNDER HYDROPEAKING

The diversity, arrangement and temporal persistency of patches within the habitat mosaic are driven by the interactions between the flow regime and the river reach morphology. As the flow fluctuates in time, patches of the habitat mosaic shift with the flow, be it during floods or flow pulses (*sensu* Tockner et al. 2000). Organisms have evolved and adapted their life history to the natural local habitat dynamics over millennia and developed strategies to deal with predictable (e.g. seasonal) disturbance and change in spatio-temporal habitat patch dynamics and persistency (e.g. Winemiller et al. 2010).

Intermittent hydropower production causes hydropeaking, which is characterized by unnaturally rapid and frequent sub-daily flow fluctuations. Hydropeaking affects flow shift frequency (i.e. the number of times the flow shifts into a given flow range) and relative duration of flows (i.e. duration of the flow in a specific flow range). If for each flow range we assume a specific arrangement of habitat patches, then hydropeaking may have a significant impact on the number of shifts and the persistency of single patches of the overall habitat mosaic, with consequences on the organisms living in these altered ecosystems.

In this contribution we explore how hydropeaking affects habitat persistency at the patch scale and explore new avenues for quantification. We consider the patch scale, being this the scale at which organisms live and move in their environment (e.g. Winemiller et al. 2010). Moreover, instead of assessing the impact of a standardised single hydropeak, as commonly done in hydropeaking mitigation projects, we quantify the impact of the multi-event nature of hydropeaking, with single events being nested within a time-series of multiple events.

In the presentation, detailed results of the study case will be shown. However, due to the limited space, we first briefly illustrate here the methods to quantify shifts of habitat patches and then present a conceptualization of our findings.

2 QUANTIFYING SHIFTS OF HABITAT PATCHES

To assess the effect of hydropeaking on habitat persistency at the patch scale, we used the results of a hydraulic model for a channelized reach of the Aare River (Innertkirchen, Switzerland). Two flow time-series were used for comparison of habitat persistency, one from the Aare River (hydropeaking) and one from the Lütschine (natural regime). Both types of regimes are typical for the alpine region.

2.1 Modelling

The methodology consists of an adaptation of the time-series analysis proposed by Capra et al. (1995) but adapted to the patch-scale. Results from hydraulic modelling were used to classify habitats at different flows, with the flow covering the entire range of the natural and hydropeaking regime. Relationships between habitat metrics and flow were developed. These metric-flow relationships were then applied to both, the natural and the hydropeaking flow time-series. This resulted in a time-series for each individual metric applied and was evaluated to assess the effect of hydropeaking on the habitat patch persistency.

2.2 Habitat patch metrics

In a river with a natural flow regime, habitats and related patches are typically defined based on dominant ambient properties (e.g. dominant current velocity) since flow conditions stay fairly constant over a day, week or season, with floods often regarded as punctual disturbances (e.g. Tockner et al. 2000). In contrast, the flow in hydropeaking rivers varies so frequently and rapidly that the assumption of a patch matching typical or dominant ambient conditions fails. Accordingly, a decoupling of the geographically defined patch from physically defined dominant habitat properties must be presumed. We therefore studied i) “habitat shifts within patches” representing the conditions an organism in its respective life cycle stage would perceive if persisting in a patch; and ii) ”spatial shifts of habitats” representing the perspective of a mobile organism that can follow its habitat preferences.

3 CONCEPTUALISING SHIFTS OF HABITAT PATCHES

“Habitat shifts within patches” represent the perspective of organisms that have a low degree of mobility (in relation to the rate of change) and that need to persist in a patch. This perspective is therefore closely related to the habitat persistency. Aquatic invertebrates have a comparatively lower degree of mobility, most of them drifting from their patches when ambient conditions are no longer met. In Figure 1, we represent this type of shifts with an invertebrate. The natural regime (Figure 1B) just shows minor flow pulses, with low flow shift frequency and long relative flow durations. This causes the habitat patches to be very persistent, allowing invertebrates to inhabit this patch (invertebrates marked in green in Figure 1C). Under hydropeaking (Figure 1E), however, flow changes so often and so quickly that habitat conditions for invertebrates are only met twice in the selected patch (invertebrates marked in green in Figure 1D), while during the other time steps either high shear stress (leading to drift) or dry conditions limit colonisation (invertebrates marked in red in Figure 1D).

”Spatial shifts of habitats” represent the perspective of organisms that can follow their preferred habitat conditions. Most adult fish would fall in this category and are potentially able to move when local habitat conditions change in space. In Figure 1, we represent this type of shift with a fish and the associated moving distance with a dotted line. Under natural regime, habitat conditions do not change, allowing the fish to stay at one position along the cross-section. Under hydropeaking regime however, the fish needs to change position, as preferred habitat conditions bounce back and forth following the hydropeaks. In other words, a fish under hydropeaking would have to travel a greater distance than under natural regime, potentially affecting his overall energy budget. However, consider that fish may also be reluctant to move, in which case the perspective of “Habitat shifts within patches” applies.

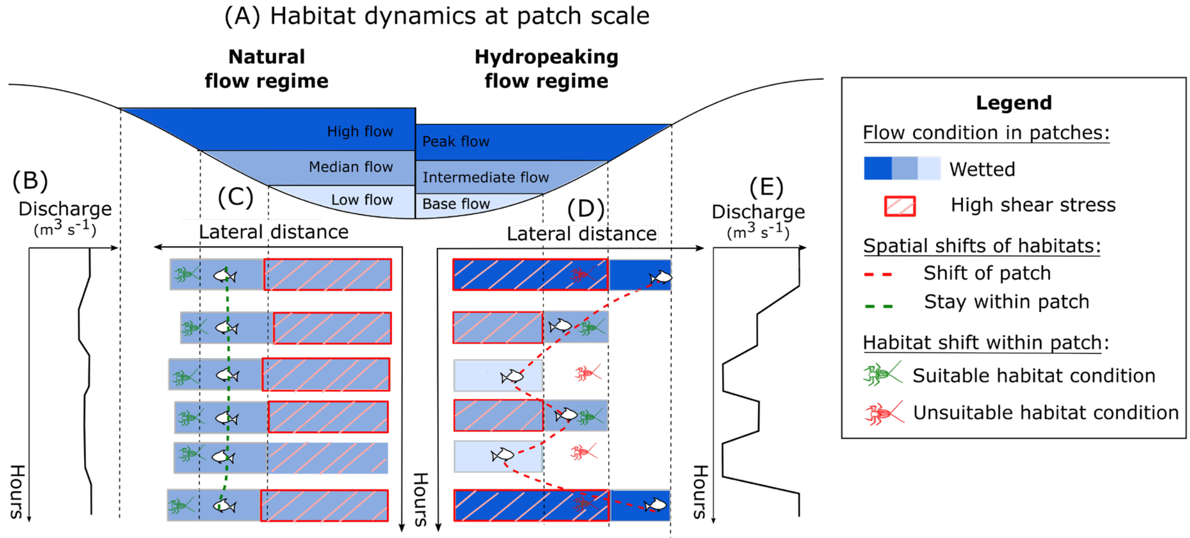

Figure 1: Conceptual representation of habitat persistency at the patch scale under natural and hydropeaking regime. A) representation of the water stage for the two regime types for a river cross-sections. B, E) flow time-series of the natural and hydropeaking regime. C, D) representation of the “habitat shifts within patches” (invertebrate with limited mobility) and ”spatial shifts of habitats” (mobile fish) based on the cross-section for the flow time-series of the two regimes.

4 CONCLUSIONS

The effects of multi-event hydropeaking on the habitat persistency can be well described using a time-series approach. This allows to capture the effect of hydropeaking on the flow shift frequency and relative flow duration.

Considering the patch scale is a promising approach to represent what organisms perceive in natural and altered regimes, with “habitat shifts within patches” capturing habitat persistency and ”spatial shifts of habitats” representing the potential moving distance with varying flow.

However, the ecological implications of reduced patch persistency due to hydropeaking are still poorly investigated (e.g. impact of increased patch dynamics on the energy balance of organisms) and need further investigation.

LIST OF REFERENCES

Capra H, Breil P and Souchon Y. (1995). A new tool to interpret magnitude and duration of fish habitat variations. Regulated Rivers: Research & Management 10: 281-289.

Tockner K, Malard F. and Ward J.V. (2000). An extension of the flood pulse concept. Hydrological Processes 14: 2861-2883.

Winemiller KO, Flecker AS, Hoeinghaus DJ. 2010. Patch dynamics and environmental heterogeneity in lotic ecosystems. Journal of the North American Benthological Society 29: 84-99.