Promoting the compatibility of hydropower and biodiversity

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Storage hydropower plants play a central role in balancing fluctuations in the electricity grid while remaining carbon neutral. To better reconcile electricity production with the protection of biodiversity in the long term, it is crucial that hydropower management considers not only the ecological consequences of individual hydropeaking events, but also their cumulative effects .

In view of the energy transition, storage hydropower plants are becoming increasingly important as they can compensate for highly fluctuating electricity production from other renewable energy sources such as solar and wind. According to EU forecasts, the demand for flexible electricity production will increase ninefold by 2050. Hydropower therefore contributes to climate-friendly energy generation. However, at the same time, it also exerts considerable pressure on biodiversity.

The frequent switching activation and shutdown of turbines leads to pronounced flow fluctuations in the river reaches downstream of storage hydropower plants; this is known as hydropeaking. Hydropeaking has a significant impact on the ecosystem. During low flow phases, shoreline habitats can dry up rapidly, leaving fish, aquatic insects and other aquatic life living there stranded and at risk of death. When the flow rises, the strong currents not only alter the diverse mosaic of habitats, but also sweep away animals and plants. As a result, both the number of individuals and the diversity of species decline drastically. This highlights a key challenge of the energy transition: reconciling climate-friendly electricity production with effective biodiversity conservation.

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Fish larvae gather in the shallow water with a low current velocity at the River Doubs in the canton of Jura. If this habitat falls dry during low flow, the fish larvae can become stranded and die (Photo: Nico Bätz).

So far neglected: the frequency of hydropeaking events

For years, research has been investigating how individual hydropeaking events affect the river ecosystems and how negative impacts can be mitigated. Several structural and operational solutions are already being implemented (see box). However, the pronounced frequency of the artificial flow fluctuations is an issue that has been underestimated so far. While rivers with a natural flow regime experience major flow fluctuations only once every two to eleven days on average, hydropeaking typically occurs three to four times a day.

Legal framework and the implications of hydropeaking mitigation

The Swiss Waters Protection Act requires operators of hydropower plants with hydropeaking operations to manage their flow in a way that minimises the impact on habitats and the typical species that inhabit them. In line with the principle of proportionality, the objective is to remediate the significant negative ecological impacts by 2030. Newly licensed hydropower plants must also meet these requirements. Mitigation measures, including the restoration of fish passage and bedload transport, play a central role in protecting biodiversity in river ecosystems.

At present, hydropeaking mitigation focuses mainly on managing individual events, for example by constructing compensation basins. The focus mainly is on reducing the rate of increase and decrease in the water level. Alternatively, operational measures or direct discharging into a larger body of water, such as a lake, are conceivable. In the latter case, the

hydropeaking section is transformed into a residual flow reach with constant discharge.

Cumulative effect: more than the just the sum of individual events

Researchers at the aquatic research institute Eawag, together with partners from the ETH Zurich, INRAE Lyon, ZHAW and BOKU Vienna, have been studying how frequently occurring hydropeaking events affect habitat dynamics in rivers. “Our studies show that recurring hydropeaking increases habitat dynamics – in other words, their temporal and spatial distribution – by a factor of 26 to 75 compared to the natural flow regime,” says Nico Bätz, a scientist in the river restoration research group at Eawag. Repeated flow fluctuations alter the availability, persistency and connectivity of essential habitats within a river reach, such as spawning grounds or refugia for fish and aquatic insects. The ecosystem may be able to cope with a single event. However, continuous changes to the habitats causes stress and increases the mortality of many species.

“An impressive example of the far-reaching effects of recurrent flow fluctuations are the new results from BOKU Vienna on the stranding of juvenile fish, which we recently published together”, adds Nico Bätz. A single low flow event is generally not particularly hazardous; the fish population can usually regenerate. However, if the habitats of juvenile fish dry out multiple times per day, the population can decline significantly within a short period of time. Field studies show that the frequency of daily hydropeaking events has a strong influence on the density of juvenile fish.

In river reaches in Austria with less than one flow fluctuation per day, the population density of young brown trout was on average 2.3 times higher, and of young grayling as much as 18 times higher, than in river reaches with more frequent flow fluctuations due to hydropeaking. Computer simulations also indicate that repeated flow fluctuations, depending on the hydropeaking frequency, can significantly affect the juvenile fish population within a few days or months, even if the flow is lowered slowly – a common mitigation practice. “Our research clearly shows that the cumulative effect of multiple hydropeaking events on the ecosystem is greater than the simple sum of individual events,” summarises Nico Bätz.

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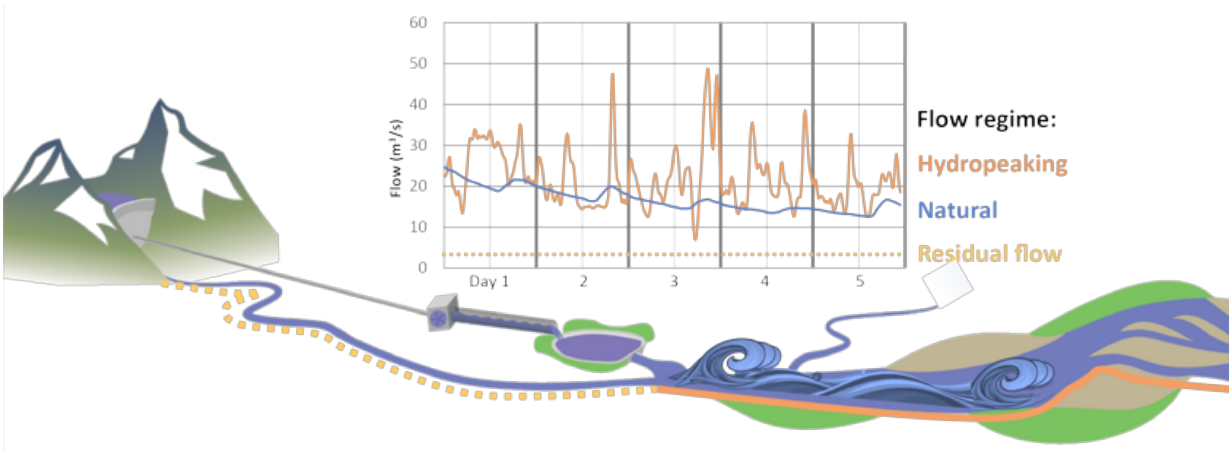

Rivers affected by hydropeaking due to storage hydropower plants, have significantly more frequent and more pronounced flow fluctuations than rivers with a natural flow regime (Graphic: based on Philipp Meier, revised by Nico Bätz).

New approaches to quantifying the effects of recurring hydropeaking

To better understand the effects of recurring hydropeaking on habitat dynamics, the researchers developed three new metrics.

Habitat probability: This metric indicates the likelihood that certain habitat types, such as shallow water or areas with low flow velocity, are available. Integrated over time, this metric describes the dominant habitat conditions to which organisms are exposed to due to flow fluctuations.

Habitat shifts: This metric tracks how often habitat types shift at a specific location. The frequency of changes in habitat conditions is of particular importance for organisms with limited mobility, such as plants and most aquatic insects, which cannot change their habitat or can only do so slowly. Frequent shifts in habitat conditions can severely affect these organisms and reduce their survival.

Spatial shifts of habitats: This metric indicates the extent to which habitats relocate over time. It is of particular relevance for mobile organisms such as adult fish, which must change location in response to flow fluctuations to find a suitable habitat conditions. Frequent relocation increases the risk of stranding, but also affects the energy balance of mobile organisms and can impair their long-term survival.

Making hydropower plants as environmentally friendly as possible

To maintain the long-term resilience and biodiversity of our rivers, hydropower management should consider not only the consequences of individual hydropeaking events, but also their cumulative effects. A stronger integration of this issue can help to better account of the potential impacts that storage hydropower plants may have on biodiversity. “Our metrics can complement existing approaches, such as those proposed in the hydropeaking mitigation guidelines of the Federal Office for the Environment (FOEN), to ensure a balance between hydropower as the backbone of the energy transition and the conservation of biodiversity,” says Nico Bätz. The researchers therefore recommend that the frequency of flow fluctuations

caused by hydropeaking be explicitly taken into account in hydropower management. Proposals are currently being developed on how this can be considered in refurbishing, expansion or building new as well as in new concessions.

Cover picture: The discharge fluctuations due to hydropeaking are clearly visible along the banks of the River Saane in the Canton of Fribourg. The light line in the water shows the water level during a low-flow phase, while the peak flow maximum is also clearly visible from the wetted part of the gravel bank (Photo: Christine Weber).

Original publication

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Cooperations

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Related Links

Eawag research project Hydropeaking Mitigation – Synergies between research and practice

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