New approaches for a sustainable hydropeaking management: The HEM-Peak model and the role of channel evolution, river morphology and sediment dynamics

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ABSTRACT: Hydropeaking is one of the major hydropower-related disturbances of natural processes in river systems. The artificial flow fluctuations that are caused by the on-demand production of electricity are known for their severe impacts on aquatic ecosystems. These particularly affect those species and life stages that are not able to adjust their habitat selection to rapid up- and downramping rates. To date, the stranding risk has both experimentally and numerically mainly been investigated with variable hydropeaking graphs over stable river bathymetries. There is a lack of knowledge on how single, discrete peaking events vary concerning their impact on the stranding risk when the river morphology changes in the long-term and channel evolution perspective. The channel evolution is a crucial factor, which vary among European hydropeaking rivers but provides decisive boundaries for (i) possible adaption of aquatic species to the different hydraulic and sediment compositions (without hydropeaking) and (ii) mitigation measure design (with hydropeaking). The present study precisely addresses this knowledge gap by investigating (i) channel evolution processes and (ii) more in detail morphological changes on the reach scale over a period of 20 years and the related variability of the lateral ramping velocity as a proxy for stranding risk. For the latter, two alpine gravel bed rivers impacted by hydropeaking over decades were tested by applying a one-dimensional and two-dimensional unsteady modelling approach. Both the Bregenzerach River and the Inn River exhibit alternating gravel bars on the reach scale. The results of the morphological development, however, showed different developments in the period 1995–2005. The Bregenzerach River displayed continuous aggradation (uplift of river bed) over the various selected submonitoring periods. In contrast, the Inn River showed continuous incision (erosion of river bed). The stranding risk exhibited high variability on a single cross-sectional basis. However, on the reach scale, no significant changes in stranding risk were calculated for either river reach.

Moreover, another aim of the presented study is to introduce a new habitat modelling approach for (i) the assessment of hydropeaking impacts and (ii) for the design of hydropeaking mitigation measures based on the "hydraulic habitat stability analysis" (HHSA). The so called HEM-Peak model. Based on two-dimensional depth-averaged hydrodynamic-numerical modelling the HHSA is (i) applied, (ii) explained and (iii) discussed for several hydropeaking reaches in Austria, with hydro-morphological-diversity on the reach scale. The applied hydropeaking scenarios are related to seasonal variability in base flow and maximum discharge of the installed capacity of the different hydropower plants upstream.