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Ecohydraulics of Thermopeaking in Alpine Streams

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Abstract

In Alpine regions, hydroelectricity generation is increasingly becoming a key power source and its ability to quickly and inexpensively respond to short-term changes in demand make it the suitable tool for answering to the necessities of the deregulated energy market. This economical need is reflected in the temporal patterns of dam operations with consequences for the water bodies that receive downstream releases in the form of ‘hydropeaking’, typically consisting in sharp releases of water in the river reaches below dams. The unsteadiness related to this highly intermittent phenomenon has cascading effects on both the biotic and abiotic compartments. Hydropeaking may also significantly affect the thermal regime of rivers. Indeed, especially in mountain areas, releases from high-elevation reservoirs are often characterized by a markedly different temperature from that of the receiving body, thus causing also sharp water temperature variations which can therefore be named ‘thermopeaking’. The aim of the present study is threefold. First, to provide a detailed quantification of the ‘thermopeaking’ using data from the Noce River (Northern Italy), a typical hydropower-regulated Alpine stream, where the water is stored in a high-altitude reservoir. The analysis is based on a river water temperature dataset that has been continuously collected for 1 year at 30-min intervals in four different sections along the Noce River. The study highlights the relevance of investigating a variety of short-term alterations at multiple time scales for a better quantitative understanding of the complexity that characterizes the river thermal regime. Secondly, to illustrate the relevant processes of the propagation of the hydrodynamic and thermal waves, within the framework of a one?dimensional mathematical model governed by the Saint Venant equations coupled with a thermal energy equation. While interacting with external forcing, the waves propagate downstream with different celerities such that it is possible to identify a first phase of mutual overlap and a second phase in which the two waves proceed separately. Finally, to investigate the thermopeaking effects on benthic invertebrate drift by simulating abrupt thermal shifts in experimental flumes. Two cold thermopeaking and two warm thermopeaking simulations are conducted by quickly cooling the water by 3–4°C during the warm season and by warming the water by 2–3°C during the cold season at a rate of about 2.4×10^{1}°C min^{1}. This rate is very similar to those associated with hydropeaking waves in rivers in the same watershed as the experimental flumes. Although the achieved changes in temperature were within a tolerability range for benthic invertebrates, their drift increased threefold and fivefold, and twofold and fourfold in the two cold and two warm thermopeaking experiments, respectively.