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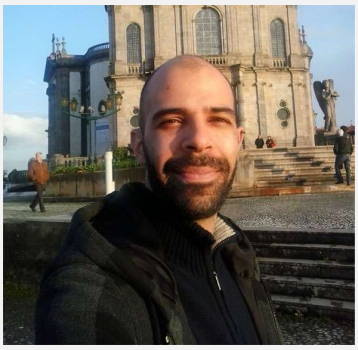
# Mitigation of hydropeaking impacts on fish: towards sustainable hydropower management



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## Summary

Hydropeaking is an artificial regime that results from the strong discharge fluctuations downstream of hydropower plants. These variations, which result from the sudden increase of electricity demands or from its decrease, may affect the fish assemblages of that river stretch. This thesis is divided in two parts, focusing the two types of measures for mitigating hydropeaking impacts on fish: direct measures, which include operational (e.g. discharge operational management) and structural measures (e.g. the construction of retention basins and/or diversion tunnels); and indirect measures, which address river morphological intervention (e.g. by creating refuge habitats for fish).

In the first part, for the direct measures assessment, an extensive literature review was conducted, where the scientific outputs regarding flow thresholds for hydropeaking operational measures were aggregated, and the status-quo of worldwide legislation and regulations dealing with the hydropeaking problematic were assessed. The variables that must be considered when designing mitigation plans and the research needs were also identified and described. Additionally, the available information regarding operational measures for the salmonids fish family allowed proposing the establishment of flow operational rules for hydropeaking impacts mitigation, based on life-stages of salmonid fish and their relationship with key parameters of the hydrograph. Different hydrological parameters (such as flow increase or decrease and maximum and minimum flows) have distinct impacts, not only directly over fish biota but also on fish habitats, and, therefore, different operational mitigation actions are enforced for each life-stage at different hydrological-related impacts. Moreover, also in the first part of this thesis, a power plant named "GKI", which is under construction in the Inn River at the Alpine region (Tyrol, Austria) was analyzed as a case-study for the implementation of direct mitigation measures. Flow operational scenarios in the GKI weir were tested, based on the stranding impacts mitigation for the salmonid fish species grayling (Thymallus thymallus), and a new hydropeaking impact assessment scheme grounded in 1D-based modelling was developed.

For the second part, indirect mitigation measures were carried out in a flume at the IST Hydraulic Lab. In this study the potential of an overhead cover and velocity-refuge structure for the native cyprinid Iberian barbel (Luciobarbus bocagei) was assessed, by analyzing the species behavior (structure use) and their physiological responses (blood lactate and glucose) under experimental hydropeaking conditions. A lab-scale LUNKERS-type structure was designed and tested with two different materials: wood, creating an opaque shelter, and acrylic, a totally transparent refuge. In this way its attraction potential was tested separately, for base-flow (7 L/s) and hydropeaking (60 L/s) events. Although the physiological responses were not significantly different between both events neither between the tested structures, behavioral results were markedly distinct for both structures usage. The transparent structure was barely used by fish when compared to the opaque one. Behavioral results evidenced a higher usage frequency of the wood structure during hydropeaking events on all metrics, where individual behavior and swimming activity also increased. The experimental results suggested that, under the simulated conditions, there were no advantages on using only a hydraulic mitigation structure for L. bocagei, without creating an opaque refuge acting as a shaded shelter. Likewise, the wood structure proved to trigger flow-refuging behavior on L. bocagei individuals during the hydropeaking events, while at the same time promoted shaded sheltering during the low-flow periods. The visual factor was the major trigger for this species to find the flow-refuge. It was shown that LUNKERS-type structures may act as an effective hydropeaking mitigation refuge for L. bocagei species.

## Keywords

Discharge fluctuations, pulsed flows, Salmonids, 1D hydrological modelling, thymallus thymallus, fish behavior, flow-refuge, physiology, *Luciobarbus Bocagei*, LUNKERS.