Passage Efficiency of Downstream Moving Fish at a Bypass Gate with Bottom and Top Opening

Maximilian Kastinger[(1)], Ismail Albayrak[(1)], Luiz G. M. Silva[(2)], Robert M. Boes[(1)]

[(1)] Laboratory of Hydraulics, Hydrology and Glaciology (VAW), ETH Zurich, Zurich, Switzerland

[(2)] Institute of Environmental Engineering, ETH Zurich, Zurich, Switzerland

Email corresponding author: lumartins@ethz.ch

ABSTRACT: Fish guidance racks (FGRs) with adjacent bypass systems (BSs) are effective solutions for safe downstream passage at different types of HPPs and water intakes for many fish species. The function of a BS is to effectively attract and safely transport fish to the downstream reach of the river. Various field and laboratory studies indicate that a gradual velocity increase into the bypass leads to enhanced acceptance. To reduce electricity generation loss and control the bypass discharge, a vertical axis flap gate with local openings has been in use at the bypass inlets of many FGR-BSs. However, such gates create high velocity gradients and absolute flow velocities that may affect the movement behavior of approaching fish.

To investigate fish acceptance at local bypass inlet openings, live-fish tests with brown trout (*Salmo trutta*) and barbel (*Barbus barbus*) were conducted in a 30 m long and 1.5 m wide ethohydraulic flume at the Laboratory of Hydraulics, Hydrology and Glaciology (VAW) of ETH Zurich. The physical model featured part of a FGR with foil-shaped vertical curved bars (f-CBR) with a horizontal approach flow angle of 30° and a clear bar spacing of 50 mm. At the downstream end of the FGR, a bypass inlet gate (W x H = 0.7 x 0.9 m) with a bottom (W x H = 0.18 x 0.25 m) or top opening (W x H = 0.18 x 0.3 m) was installed. The spacings between bars at the upstream side of the FGR were covered with a net to ensure 100% fish guidance to the bypass, given that the experimental design was focused on determining the efficiency of the bypass design for fish acceptance and passage. The experiments were conducted at three different discharges and resulting approach flow velocities. Flow fields were mapped by measuring three velocity components with an acoustic Doppler velocimeter (ADV) probe in a densely spaced measurement grid. Fish behavior and movement was obtained by visual observation and video camera recordings.

The two fish species often showed an avoidance behavior to high velocity gradients around the bypass opening. Barbel showed greater sensitivity to high velocity gradients compared to brown trout. Bypass passage efficiency (BPE) of the top opening was less than or equal to 21% for both species and all approach flow velocities. BPE of the bottom opening was significantly higher than for the top opening. The results illustrate that bypass inlet gates with local openings to regulate discharge can affect bypass acceptance and thus fish guidance efficiency of the overall FGR-BS. Hence, a thorough design of the bypass inlet is crucial for an environmentally sustainable and economic operation of HPPs in the future. The present contribution will give an overview on the current bypass designs, present the hydraulic and live-fish results of the laboratory tests, and give an outlook on the future investigation of effective bypass designs.