Downstream fish guidance systems with horizontal bars

J. Meister, H. Fuchs, I. Albayrak, R. Boes

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

1. Motivation and objectives

The natural behavior of many fish species involves the migration of up to hundreds of kilometers within river systems. This migration is impeded since the construction of hydropower plants (HPPs). Therefore, the European Water Framework Directive (WFD) and the Swiss Water Protection Act (WPA) demand to restore the free up- and downstream migration. While many HPPs were already successfully equipped with upstream passage facilities, downstream fish passage facilities are still under development.

The “Fishfriendly Innovative Technologies for hydropower” project (FIThydro) was launched as part of the Horizon 2020 EU Research and Innovation program to promote the development of innovative technologies for sustainable and fish-friendly operation of hydropower plants in Europe. As one part of FIThydro, the current research project focuses on the hydraulics and fish guiding efficiency of horizontal bar rack bypass systems (HBR-BSs). Operational aspects like clogging with organic fines will be investigated and live fish experiments will be conducted to quantify the fish guiding efficiency.

2. Introduction to HBR-BSs

HBR-BSs are considered state-of-the-art of fish downstream migration in Europe (Ebel, 2016). They consist of two main elements: (1) the bar rack itself to prevent fish from entering the turbines and (2) the bypass to safely guide the fish to the downstream reach (Fig. 1). To keep the hydraulic losses low, automated rack cleaning systems are used to minimize clogging. Although a number of HPPs were equipped with HBR-BSs in the last decade at small- to medium-sized HPPs (Q_d < 88 m³/s), there is still a lack of systematic studies on the optimization and verification of these state-of-the-art downstream fish passage facilities.

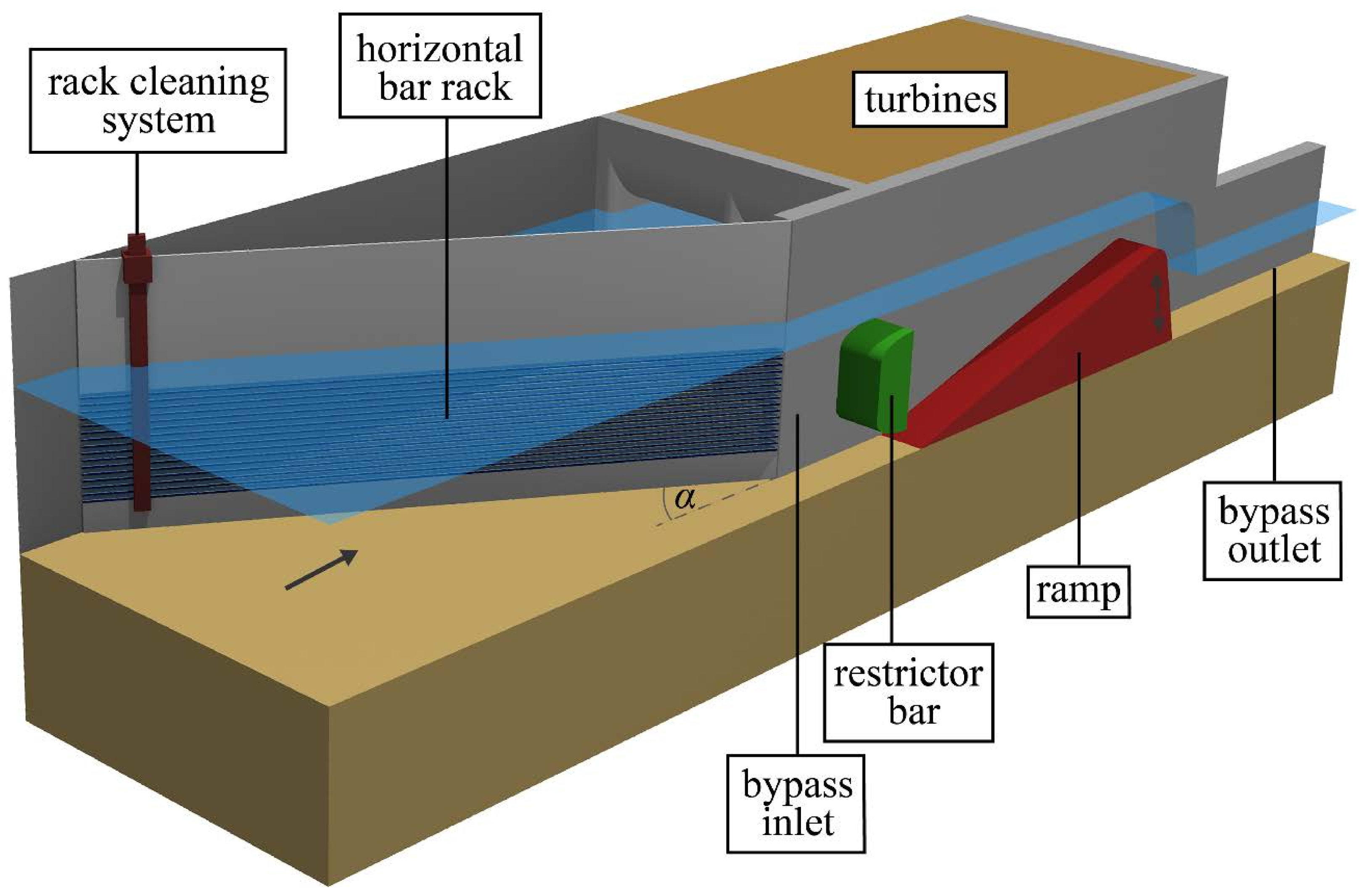

Fig. 1: Principle sketch of a HBR-BS, adapted from Ebel (2016)

3. Experimental setup

To fill the described research gaps, hydraulic experiments with horizontal bar racks (HBRs) are conducted in a laboratory flume (Fig. 2a). The flow depths upstream h_o and downstream h_{ds} of the rack are measured using Ultrasonic Distance Sensors (UDSs) and the velocity field is measured using an Acoustic Doppler Velocimeter (ADV). The governing parameters are the horizontal approach flow angle to the rack α, the clear bar spacing s_b, the bar depth d_b and the cross-sectional bar shape (Fig. 2b). Additional bottom and top overlays can be used to enhance the guiding efficiency for bottom and surface orientated migrating fish.

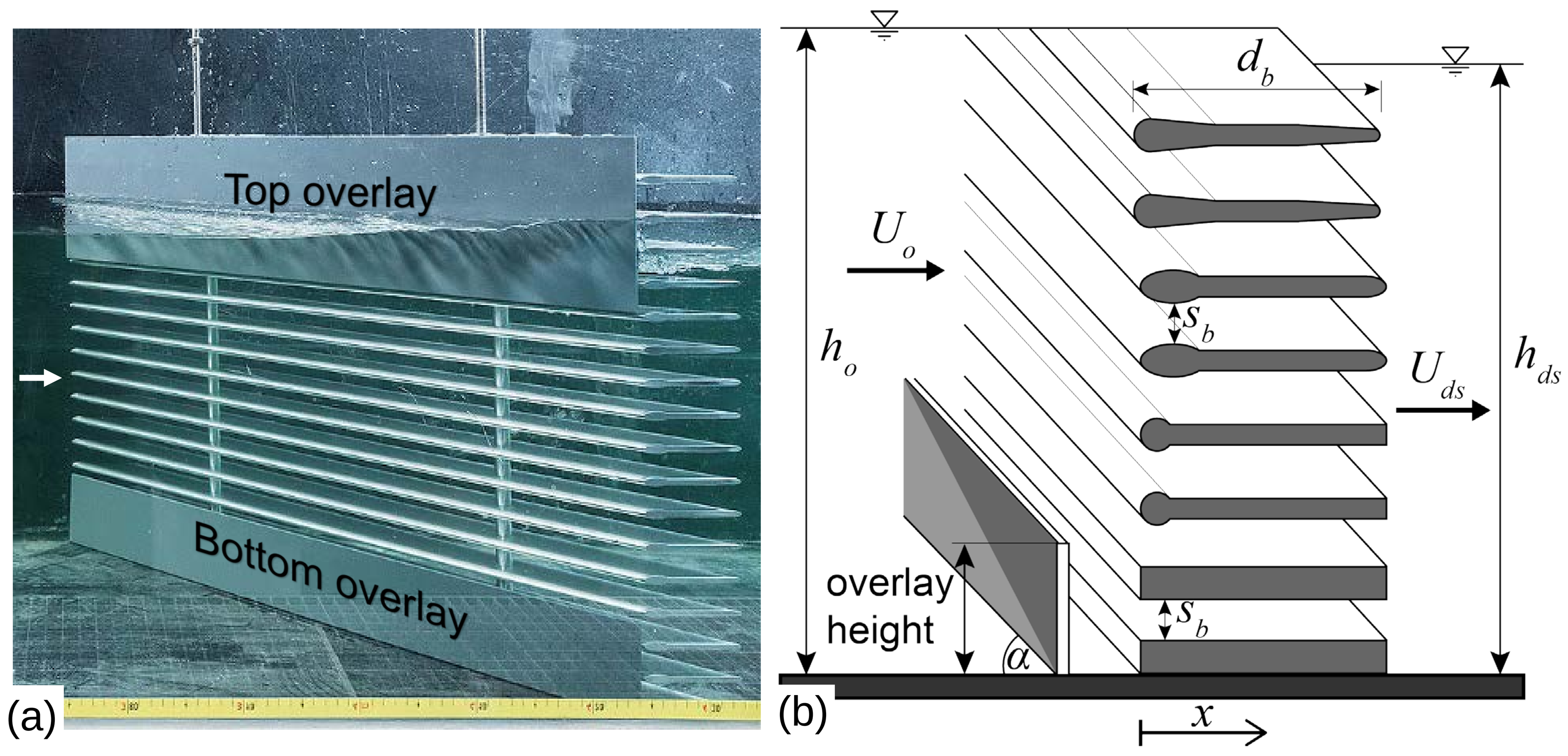

Fig. 2: (a) Laboratory experiment on a HBR with bottom and top overlays
(b) Definition sketch for governing HBR parameters

4. First results

Fig. 3 shows the velocity fields of HBRs (a) without overlays and (b) with a 40% overlay blocking (20% bottom and top overlay each) at mid water depth for an approach flow velocity U_o = 0.5 m/s.

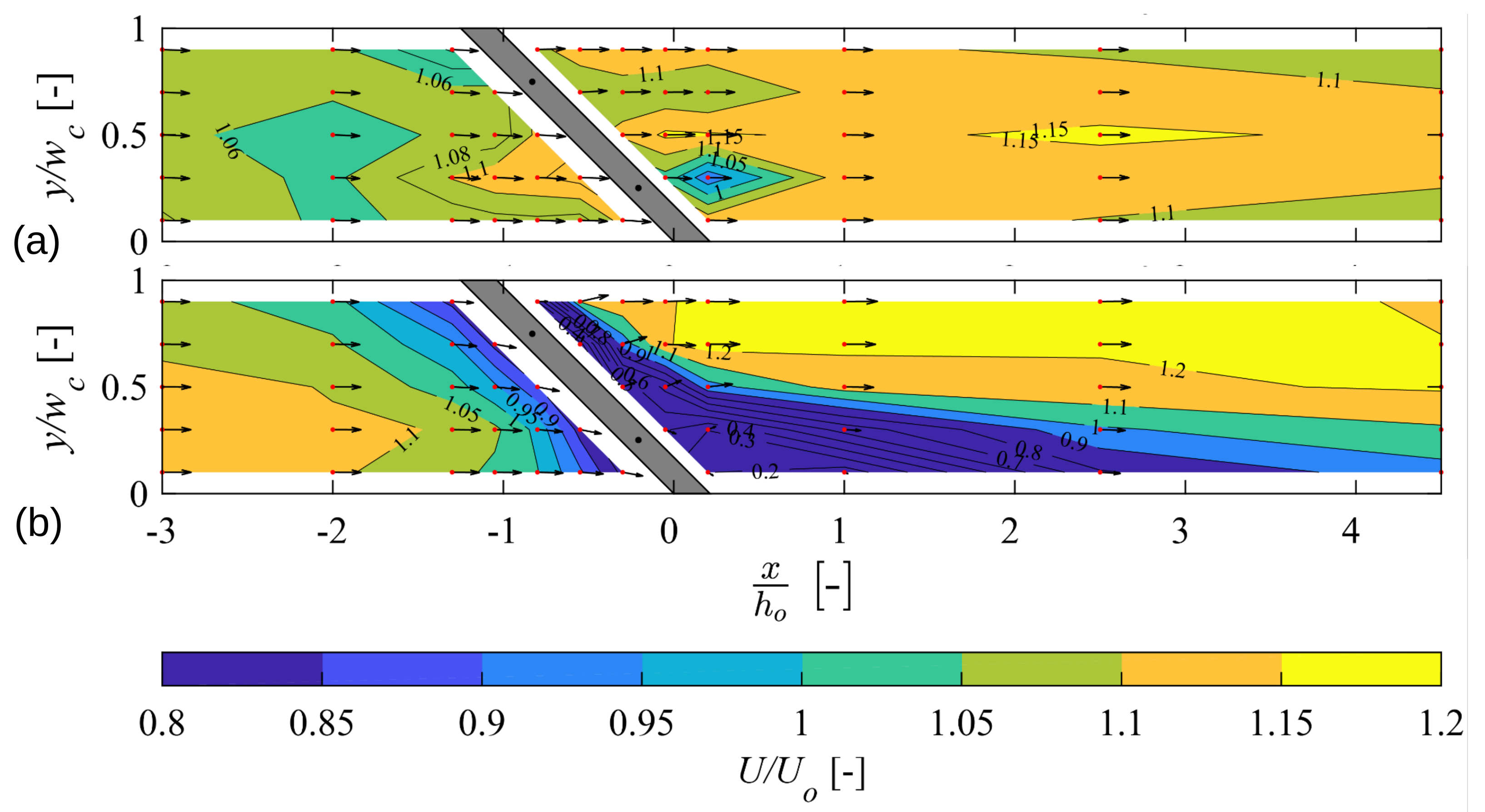

Fig. 3: Velocity fields of HBR with foil-shaped bars, α = 45°, s_b = 20 mm (a) without and (b) with 20% overlay blocking by bottom and top overlays each

The flow field at the rack without overlays is almost unaffected with a homogeneous velocity distribution (Fig. 3a). In contrast, for a configuration with overlays the approach flow is decelerated and a rack-parallel velocity component establishes (Fig. 3b), thereby increasing the guiding efficiency for fish, bed load material and floating debris. Disadvantages of overlays include the larger hydraulic losses and the asymmetrical downstream velocity field, leading to uneven turbine admission and therefore reduced turbine efficiency.

5. Conclusion and outlook

HBR-BSs are considered as state-of-the-art fish downstream passage facilities in Europe. Despite the successful operation at prototype HPPs, several research questions remain. First laboratory experiments demonstrate small hydraulic losses and minor effects on the velocity field of configurations without overlays, indicating a great potential for further applications. Future experiments will focus on operational aspects of HBR-BSs and the fish guiding efficiency.

6. References

Ebel, G. (2016). Fish Protection and Downstream Passage at Hydro Power Stations — Handbook of Bar Rack and Bypass Systems. Bioengineering Principles, Modelling and Prediction, Dimensioning and Design. ISBN 9783540437130. 2nd edn. Büro für Gewässerökologie und Fischereibiologie Dr. Ebel, Halle (Saale), Germany [in German]