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How are the water velocity and depth used by young Atlantic salmons to cross a hydropower plant?

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ABSTRACT
The influence of the river discharge on the passage of young Atlantic salmons (smolts) through hydropower infrastructures during their downstream migration is often noted in studies but remains unexplained in hydraulics. In this study, we investigate two of its main components: the velocity and the water depth to understand their use by smolts at hydroelectric facilities. Six releases of 6 smolts each were monitored using 2Dradio telemetry and the flow characteristics they encountered were numerically modelled in 2D. The comparison of the water velocities and the water depths (water columns) used by the smolts with the availability of these 2 variables in the flow shows that: smolts prefer high velocities and they mainly use the most available water depth while avoiding extreme values (lowest and highest depths). These results pave the way for an in-depth exploration of these two variables on the downstream migration routes equipping hydropower facilities.
Keywords: Atlantic salmon, Hydropower, Telemetry, Hydrodynamic

INTRODUCTION
The difficult passage of fish at hydropower dams is presented as the most important negative impact of hydroelectricity on the environment (Silva et al., 2018). This phenomenon is often fatal to young salmons (smolts) migrating from rivers to the sea because of the inefficiency of the proposed migration routes. A challenge linked to the poor knowledge of hydrodynamic variables used by smolts to orient themselves despite numerous scientific observations of the river discharge influence on the success of downstream migrations (Renardy et al., 2021). This is most likely because the discharge is an aggregate variable of other flow characteristics. Therefore, this study uses 2D telemetry to generate smolt trajectories near a hydroelectric dam and 2D numerical hydraulic models to investigate two discharge components (velocity and water depth) used by smolts when attempting to cross the dam.

MATERIALS AND METHODS
The case study is Mery, a hydropower plant on the Ourthe river, a tributary of the Belgian Meuse River. The site comprises 4 migration routes, namely: 2 hydroelectric turbines, the bypass, the weir, and an Archimedean screw. Thirty-six smolts, each equipped with a radio transmitter placed according to animal ethic requirements (Renardy et al., 2021) and subdivided into 6 releases of 6 individuals, were monitored by 2D radio telemetry over the period going from April 8th to May 6th, 2021. This tracking allowed the generation of their successive positions (Figure 1 a) with an average time spacing of 6.8 minutes between 2 smolt positions. Using Wolf2D software (Erpicum et al., 2010), the hydrodynamic conditions encountered by each smolt were numerically modelled under 4 discharge configurations with an overall error of 4.3%. The model inputs were obtained from the recorded hydraulic operations at the site and from the Sauheid hydrological station 9km downstream. The bathymetry used covers 230.9m of linear distance upstream of the turbines with a horizontal resolution of 0.5m and a vertical accuracy of 15cm for 52831 computation cells as depicted on Figure 1 b. The spatial superposition of smolt positions with the flow characteristics in the model allowed the extraction and comparison of the velocities and water depth utilizations by smolts during each release to their availability in the flow.

Figure 1: a) One of the 36 fish trajectories generated with radio telemetry at Mery HPP. b) Velocity distributions (heatmap: absolute velocity; arrows: velocity vector) in the numerical model (18.4m^3/s).

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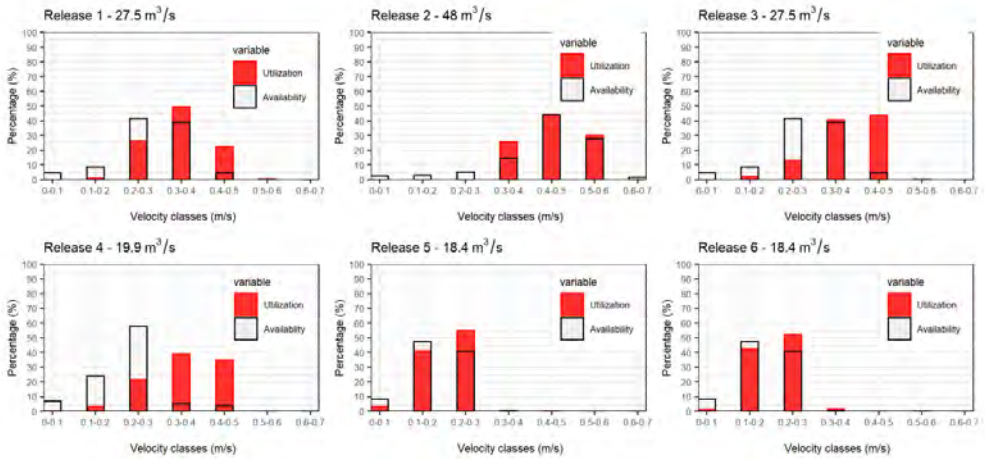
RESULTS AND DISCUSSION

a.



b.

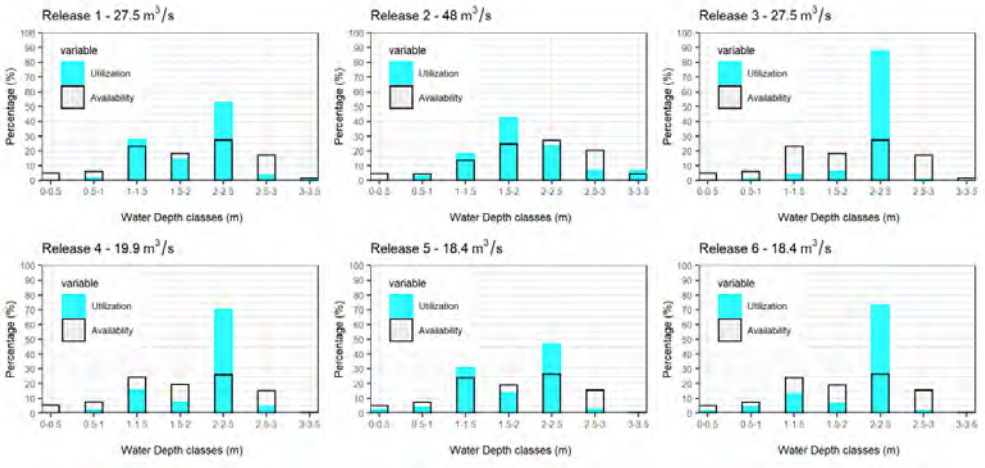


Figure 2 : Comparison between: a. Velocity utilization by smolts and its availability in the models, b. Water depth utilization by smolts and its availability in the model.

For all six releases, smolts preferred the highest velocities available at the site as depicted in Figure 2a. The velocity utilizations always corresponding to the highest classes of the availability. For water depths, a strong use of the most available class on the site was noted (2 to 2.5m) as well as a weak utilization of the extreme classes (0-0.5m and 3-3.5m) as depicted on figure 2b. In conclusion, these results show a preference of smolts for the same configurations of velocities and water depth available in the flow despite the variations of the discharge. This is a promising avenue to explore further to identify the influence of these 2 variables on the attractiveness of existing downstream migration routes at hydropower plants.

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