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Ergänzungen und fachliche Aktualisierungen zum Fischschutz- und Vermeidungskonzept
Anlage 1: The Fishprotector – An integral fish protection system

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ELECTRIFIED FLEXIBLE FISH FENCES

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ABSTRACT

The flexible fish fence consists of horizontally clamped steel ropes. It is placed in front of the intakes to the turbines of hydropower plants and arranged in a way that it directs the fish towards a downstream fish passage facility. The electrified flexible fish fence is a significant advancement to the original prototype, as the steel ropes are used as electrodes to create an electrical field. The electrified version of the flexible fish fence is functioning as a guiding system to prevent fish from entering turbines and to guide downstream migrating fish towards a downstream passage facility. Therefore, it combines both, a mechanical as well as a behavioral barrier and guiding system.

Keywords: Ecohydraulics, Hydropower, Fish Protection, Ethohydraulic Experiments, Fish Migration

1 INTRODUCTION

The climate targets formulated by the European Union support future investments in hydropower. This might compromise the environmental objectives of the EU Water Framework Directive (WFD). The WFD postulates the safe migration of fish. This implies that up- and downstream migrating fish must be able to bypass hydropower plants in both directions. In regards to downstream migration so far only structural barriers (e.g. intake screens) have been utilized to achieve a satisfactory rate of fish protection. Intake screens protect the turbine blades from damages caused by floating debris and, at the same time, can act as a mechanical barrier to prevent the fish from swimming into the turbine intakes during their downstream migration (Aufleger et al., 2015; Böttcher et al., 2015). Depending on turbine type and fish size, many organisms are injured or killed if they enter the turbine. The smaller the gaps between the bars of the screens, the better the fish are held back.

Only the usage of very fine racks prevents small fish from passing through the turbines. The required small spacing between screen bars, however, leads to substantial energy losses and high costs in construction and operation. Hence, they are often only an option for small hydro power plants. Typically, the bars of the screens are arranged in an upright position at the turbine intakes, i.e. in front view the bars extend vertically. Considering the typical body shape of fish, screens with horizontally extending bars are expected to better halt fish from entering the turbines. These are increasingly being used in new hydroelectric power plants but give rise to by no means negligible investment and maintenance costs.

2 FLEXIBLE FISH FENCES (NON–ELECTRIFIED)

2.1 Concept

The flexible fish fence differs from the fish protection screen in its fundamental construction and mode of operation (Brinkmeier et al., 2013; Böttcher et al., 2014). The mechanical fish protection barrier is constructed through multiple steel cables or steel ropes which are mounted parallel to each other. Typically, the cables are braced horizontally below the water surface between two or more abutments. In this way, large span widths can be achieved inexpensively. Each individual cable can be braced at one or more abutments, and also cast off from them, independently of the other cables. Therefore, a steering/tension device for each cable is attached to at least one of the abutments for repeatedly stretching tights and relaxing the corresponding cable. The device can be made by multiple winches or hydraulic cylinders.

The flexible fish fence can easily be completely opened by relaxing individual cables. This can be particularly important during high flows or floods to avoid log jams and harmful interactions with the bed material. Further, the flexible fish fence is cleaned by partially or completely relaxing some or all cables and stretching them tight afterwards. Flexible fish fences are no turbine protection systems. This task must be undertaken by different measures. Within the scope of an ecological upgrade of a hydro power plant the turbine protection and the debris removal can be further ensured through the existing much coarser intake trash rack and the corresponding automatic cleaning systems.

2.2 Preliminary results of ethohydraulic experiments

Within the scope of a research project, financially supported by the Austrian Research Promotion Agency (FFG), a comprehensive series of ethohydraulic experiments was carried out in a 2.0 m wide test flume in an outdoor research area of the University of Natural Resources and Life Sciences (BOKU, Vienna) in Lunz am See (Lower Austria). The tests were performed with three fish species (grayling, chub and brown trout) which were caught in adjacent rivers. Each fish was marked by pit tagging. The layout of the testing facility is presented in Figure 1. Each experiment was conducted with about 25 fish and lasted for 60 minutes. Before the start fish were acclimatized for 45 minutes in the upstream section of the flume. Flow velocity was 0.5 m/s. At the start of the experiment the corresponding barrier was removed. Fish were free to remain upstream of the flexible fish fence (blue color in Fig. 1 and Fig. 2) or to use the bypass intended to provide safe downstream migration (green color). The number of fish swimming through the flexible fish fence in direction of the virtual intake of the hydro power plant (red color) are considered as an important indicator for the efficiency of the specific layout of the fence.

Within several months of research numerous experimental runs were performed. Multiple experimental setups were conducted where parameters like flow velocity, downstream slope of the fence, and the open vertical widths between the cables were varied.

Figure 2 illustrates an important result: The efficiency of a fish protection system based on a flexible fish fence depends on the vertical width between the steel ropes. At a spacing of 20 mm a higher number of fish swam through the fence compared to a vertical width of 10 mm. The smaller vertical width setup prevented all movements through the fence. The preliminary results indicate that the influence of the horizontally braced flexible fish fence on downstream fish migration has to be considered as a mechanical barrier only. The 20 mm vertical width of the ropes did not restrict chub and trout movements as much as it did for grayling.

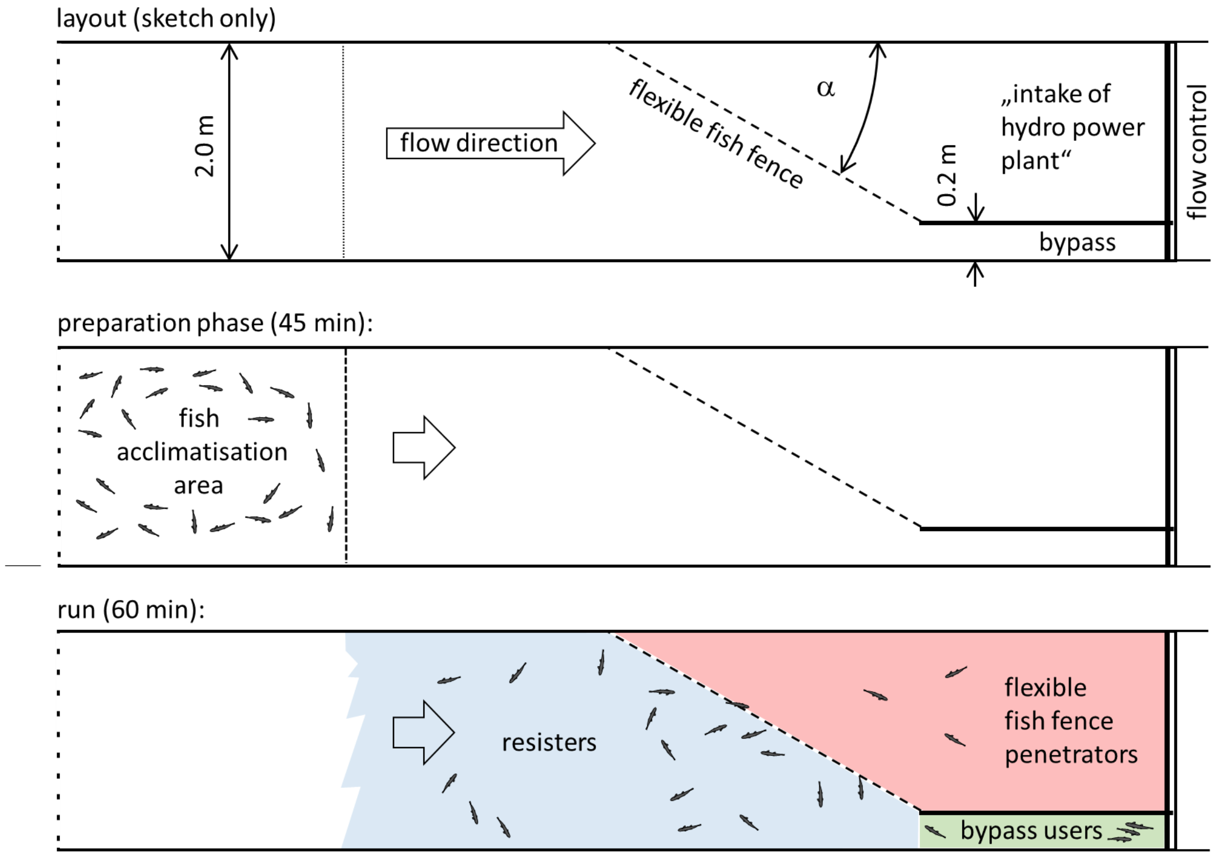

Figure 1. Ethohydraulic experiments – layout and testing method (test phases, colors refer to the illustration of the results in Figure 2)

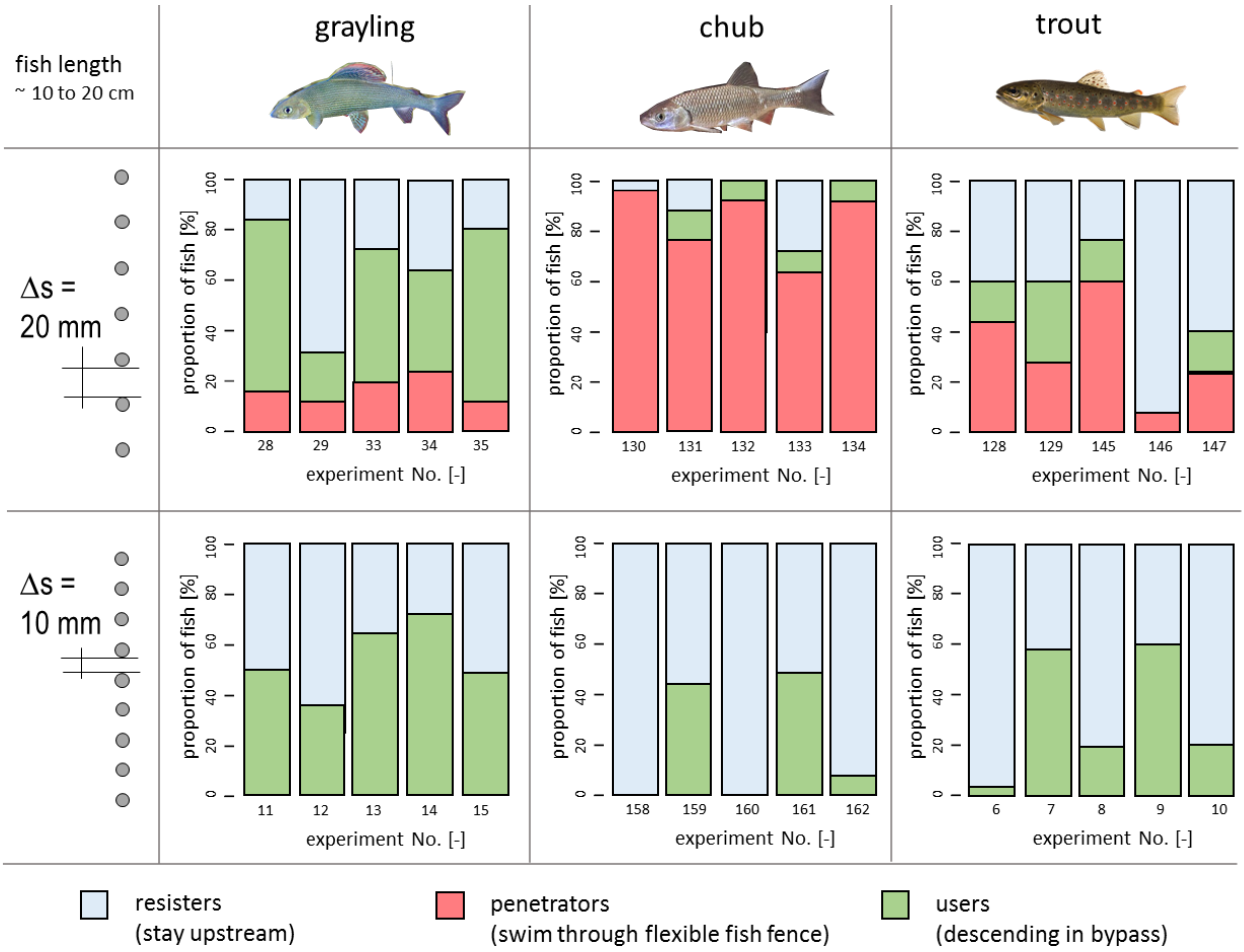

Figure 2. Ethohydraulic experiments – results for flexible fish fences (non–electrified) with vertical open widths between the steel ropes of 20 mm and 10 mm (flow velocity: 0.5 m/s)

These results underline that a cost-effective fish screen of horizontally braced steel ropes fulfills the requirements of a fish protection system at least within the meaning of a mechanical barrier (with 10 mm spacing). Due to the lower investment costs and their important system advantages (e.g. their robustness, relatively low hydraulic losses, and the possibility of lowering the cables to the riverbed in the case of high flows) flexible fish fences can be considered as an attractive alternative to large horizontal steel racks which require a lot of efforts concerning the related traditional bearing structure typically consisting of rigid concrete and steel elements.

There remains a clear dependency between the required vertical width between the steel cables and the efforts which must be made for transferring the resulting horizontal loads to the ground and for keeping the fence free from debris for trouble-free operation of the hydro power plant. The bigger the required spacing between the horizontally braced ropes is the greater the advantages of the flexible fish fences compared to other systems will be.

3 ELECTRIFIED FLEXIBLE FISH FENCES

3.1 Basic idea of the electrified flexible fish fence

Since the very beginning of the research related to the flexible fish fences additional external stimulations like vibrations, light or electrical currents were considered as additional effects, which might enhance the efficiency of the fish protection system. As steel cables themselves are electrical conductors it was suggested that they could serve as elements of an electrified version of the flexible fish fence.

3.2 Fish protection using electrical fields

Electric guidance and barrier systems are used to change fish behavior. While guidance systems are supposed to attract fish to specific locations (e.g. bypass), the objective of an electric barrier is to block fish movement completely. These systems create an electric field by placing a conductive anode and cathode in the water and passing a current between the conductors (Little, 2015), which causes a physiological reaction in the aquatic species. The cathode usually has an avoiding effect while the anode has an attractive effect on fish. Very close to the anode and cathode galvanic anesthesia may occur, an effect which is used in electrofishing, but should be avoided in the case of electric guidance or barrier systems. The effect of such electric systems depends not only on the conductivity of the water but also on the fish size and fish species. Recent applications of fish barriers use direct current (DC) or pulsed DC (Svoboda and Hutcherson, 2014). To avoid habituation effects in fish behavior, the pulse rates can be randomly controlled (Schmalz, 2010). Furthermore, peak voltage, peak current, pulse width and frequency have to be considered to trigger the desired fish response (Svoboda and Hutcherson, 2014). Since electric fields show a radial propagation, a straight fish guiding to a bypass is often difficult. In addition, diadromous species often react moderately to behavioral barriers, especially when the bypass is not easy to find. Best practice examples for hydroelectric power plants are largely missing. Only Pugh et al. (1971) were able to achieve a rejection rate of 69-84% of salmon smolts.

3.3 Preliminary ethohydraulic tests with electrical flexible fish fences

Within the scope of the ethohydraulic experiments for the flexible fish fences, an alternative approach of the system was investigated, where the horizontally braced steel ropes were electrified. An electrical switch (provided from expert companies in Germany and Poland) was used as energy source. This switch was developed to deliver targeted power surges which are adjustable in terms of the maximal voltage, to scare fish away from turbine intakes. The flexible fish fence presented in Chapter 2 was adopted in a way that allowed to change the order of the positive (+) and negative (-) charges of the steel cables. 30 preliminary experiments were carried out. Numerous parameters were changed. Beside using different fish species and increasing the maximal voltage a systematic variation of the settings of positively (+) and negatively (-) charged cables was performed (Figure 3). A vertical open width between the horizontally braced cables of 30 mm was chosen for all preliminary experiments.

The results in Figure 3 indicate that the electrical field influences fish behavior. The percentage of fish swimming through the flexible fish fence decreases significantly if an electrical current is present. Even though the type of impact of the electrical field on the fish is still not known in detail the preliminary results indicate that the electric field has a repellent effect on fish. Video sequences of the experiments showed that most of the fish do not approach the ropes as soon as electricity is applied to the system.

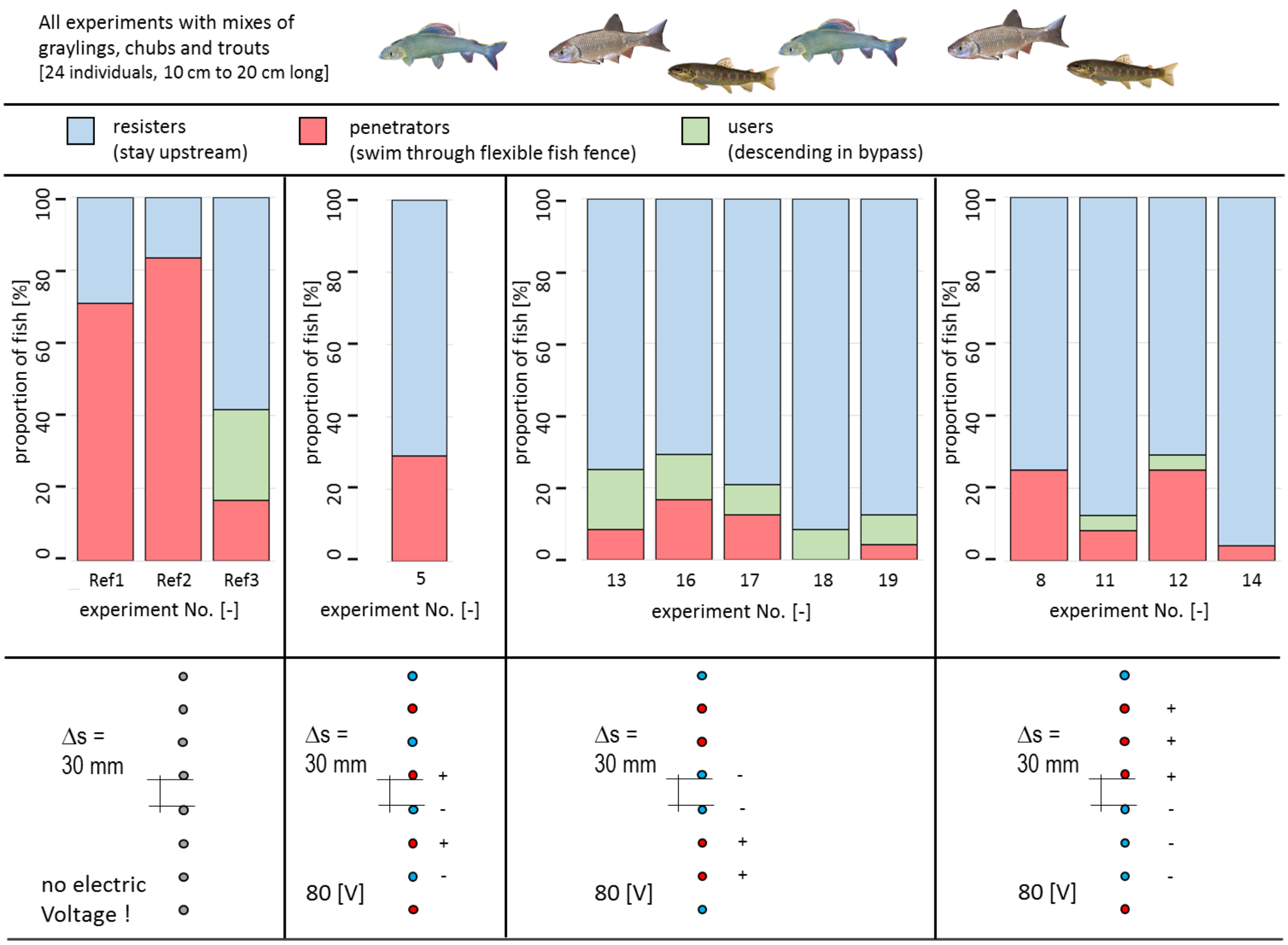

Figure 3. Ethohydraulic experiments – first results for electrified flexible fish fences with vertical open widths of 30 mm, flow velocity of 0.5 m/s, and different electrical settings (left column: reference tests without electrical voltage);

4 CONCLUSIONS AND OUTLOOK

Currently the development of an electrified version of the flexible fish fence is in progress. First results of ethohydraulic experiments prove the fundamental efficiency of the system to prevent fishes from swimming through a plane in space created by a combination of a mechanical barrier and an electrical field. Electrified flexible fish fences have the potential to efficiently and directly create an electrical field in the water column with unprecedented spatial coverage, to reach a so far not possible homogeneity and coverage in its scaring effect, to allow larger vertical distances between individual rack elements (ropes) compared to a non-electrified version of the flexible fish fences (which reduces construction cost and operational cost) and to serve as the basis for the establishment of a cost-effective and potent fish protection and fish-guiding system that is suitable for small, medium and large run-of-river plants. Further ethohydraulic experiments are planned to investigate and improve the effects of the electrified flexible fish fence.

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