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Fish Ecological Monitoring at Innovative and Conventional Hydropower Stations in Bavaria, Germany

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Abstract

The use of hydropower is ambivalent, providing a contribution to decarbonisation of energy supply on the one hand, and impacting aquatic habitats and their connectivity with consequences for fish and biodiversity on the other hand. The aims of this project were to compare different types of innovative and conventional hydropower technology in terms of direct and delayed fish mortality, external and internal fish injuries as well as the impacts on habitat quality and aquatic biodiversity up- and downstream of the hydropower dams. The main findings suggest considerable species- and site-specific mortality and injury patterns that are strongly governed by local fish communities as well as construction aspects (such as screen properties, turbine type, hydraulic head) and operational modes. In contrast to the expectation, innovative technologies were not generally less harmful to fish than conventional ones equipped with specific fish protection screens. Even within one type of technology, site-specific differences strongly governed the observed impacts. The main impact on habitat quality and aquatic community structures was a result of the dam construction, irrespective of the installation of hydropower turbines. The observed seasonal and diurnal patterns of downstream fish movement along different corridors as well as the findings on fish mortalities and injuries can be used for an objective discussion on reducing adverse ecological effects of hydropower utilisation including its operational management.

Introduction

The contribution of hydropower utilisation to energy decarbonisation on the one hand, and its ecological impacts on river ecosystems, fish and aquatic biodiversity on the other hand, all contribute to the controversy on whether hydropower utilisation should be considered a “green” or “red” energy (Geist 2021). Minimising the ecological impacts of hydropower utilisation has become a target of conservationists and hydropower producers alike, requiring information on the impacts of different types of hydropower plants on fish mortality and injury patterns as well as the impacts on physicochemical habitat quality and biota other than fish. A systematic and comparative analysis based on field experimentation was conducted in the course of the project “Fish Ecological Monitoring at Innovative and Conventional Hydropower Plants” at the Chair of Aquatic Systems Biology of Technical University of Munich, Germany, funded and supported by the Bavarian State Ministry of the Environment and Consumer Protection and the Bavarian

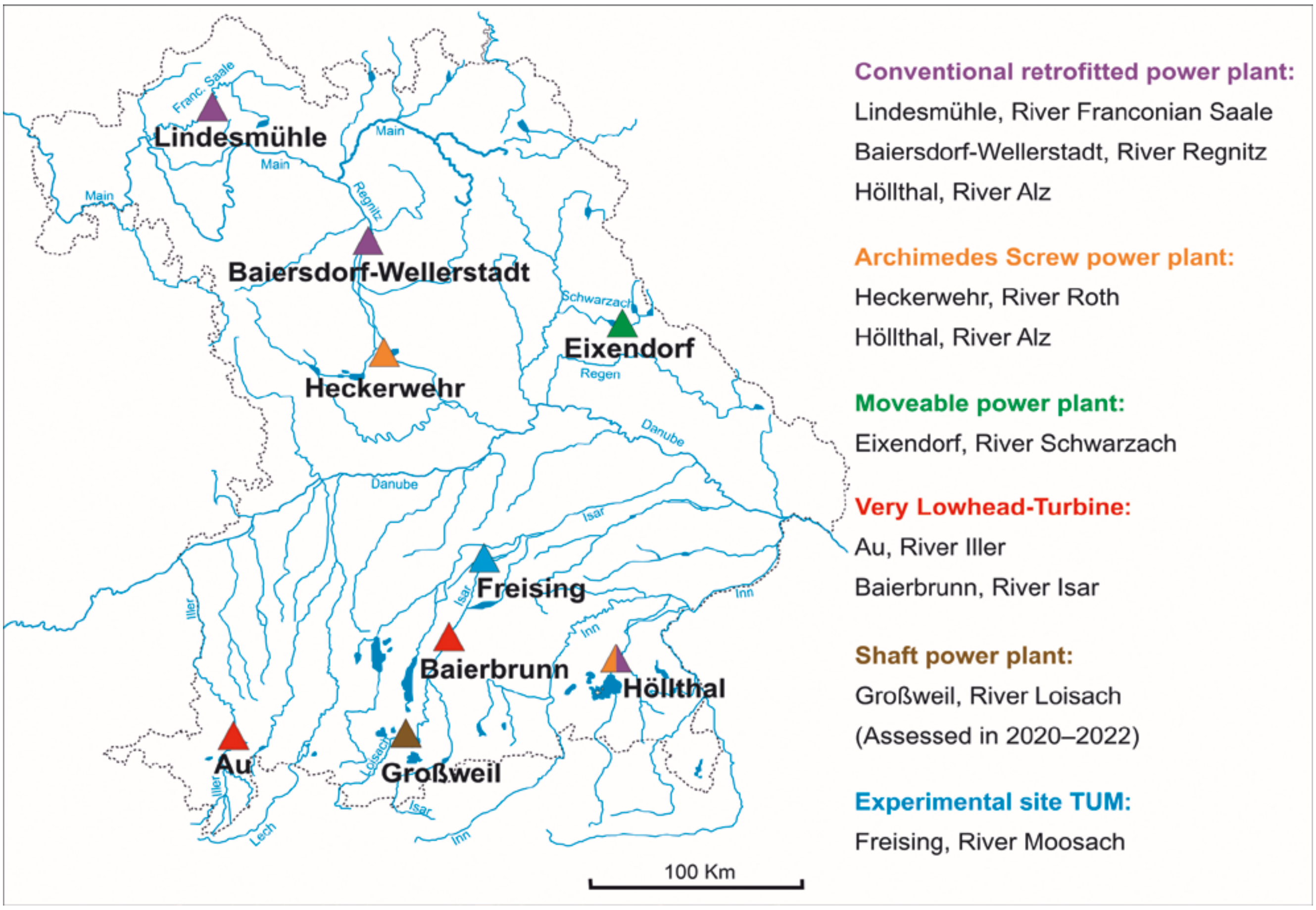

Figure 1: Study sites of the project on innovative and conventional hydropower production in Bavaria, Germany, comprising eight hydropower stations and one experimental site for pre-testing

Environment Agency. This project combines investigations into direct and delayed effects of downstream passage on fishes with characterisations of observed habitat changes. It commenced in 2014 and is currently in its final phase.

Methods

The study was conducted at eight different hydropower sites and one experimental site for pre-testing in Bavaria, Germany *(fig. 1).* The project established several meth-

Figure 2: Setting up catch nets for investigating mortalities and fish injury patterns downstream of a hydropower plant. Photo credit: Martin Erd

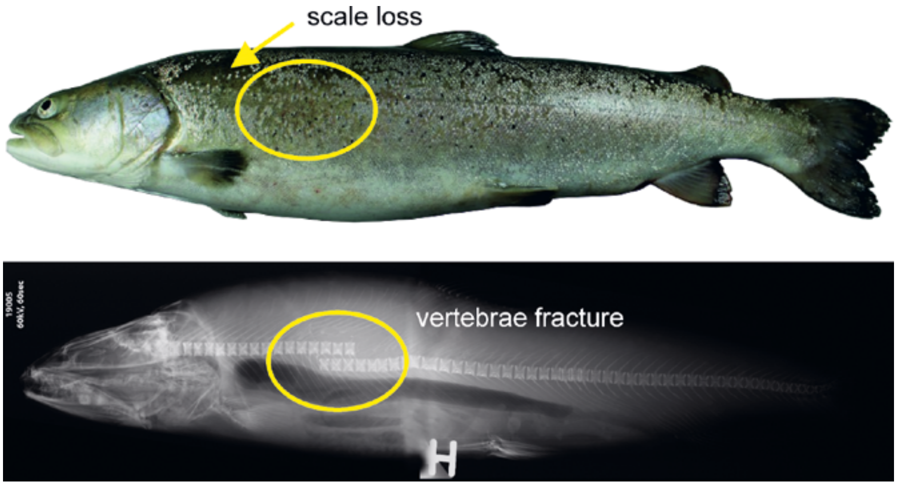

Figure 3: External (scale loss, upper picture) and internal (backbone fracture, lower picture) injuries of the same Danube salmon (Hucho hucho) following downstream passage of a hydropower facility

odological procedures, which are already detailed in other publications. This comprises investigations into an improved understanding of the effects of net-based catching techniques on observed mortality and injury patterns (Pander et al. 2018), including the behaviour of fish inside catch nets (Smialek et al. 2021), as well as establishing protocols for external (Mueller et al. 2017) and internal (Mueller et al. 2020) fish injury patterns that were also linked to the physical and hydraulic forces of turbine passage using technical sensor fish (Boys et al. 2018). The field experiments required the installation of big catch nets at each of the possible downstream migration corridors *(fig. 2)* to study corridor choice as well as corridor-specific mortalities and injury patterns *(fig. 3)*. An ARIS sonar was used to study the behaviour of fish, in particular (silver) eels approaching hydropower facilities on their downstream migration *(fig. 4)* as recommended in Egg et al. (2018). To investigate the impacts of hydropower facilities on habitat quality and aquatic biodiversity, habitat changes and aquatic community structure up- and downstream the facilities were compared *(fig. 5).*

Results and Discussion

The results of the study provided several new insights into the effects of hydropower at the investigated sites. Fish mortalities and fish injury patterns strongly differed depending on the local fish community, the site-specific construction effects (e.g., turbine types, hydraulic head) as well as the operational modes. All results are available via the official project website under www.lfu.bayern.de/wasser/fischschutz_fischabstieg/ergebnisse and https://www.fisch.wzw.tum.de/aktuelles.html. In contrast to the initial hypothesis, innovative hydropower solutions, which are often presented as being particularly "fish friendly", did not always result in lower species-specific mortalities than conventional ones equipped with fish protection screens. Rather, under certain conditions (e.g., low hydraulic head, slow rotational speed) conventional turbines caused fish mortalities comparable to or even lower than those of the examined innovative turbine types. Even the same technologies used at different sites revealed differences in species-specific effects related to differences in discharge, hydraulic head, available corridors for downstream migration and the species inventory.

Another key finding was that the lengths of the majority of fish specimens caught from natural downstream movement was < 15 cm and thus not effectively protected from entrainment by most screen types. Moreover, at most sites the majority of downstream moving fish used the turbine corridor, despite the installation of different bypass systems (e.g., crest cut-out in movable power plant, see Knott et al. 2019). Only at one site, where a 40 m wide rock ramp

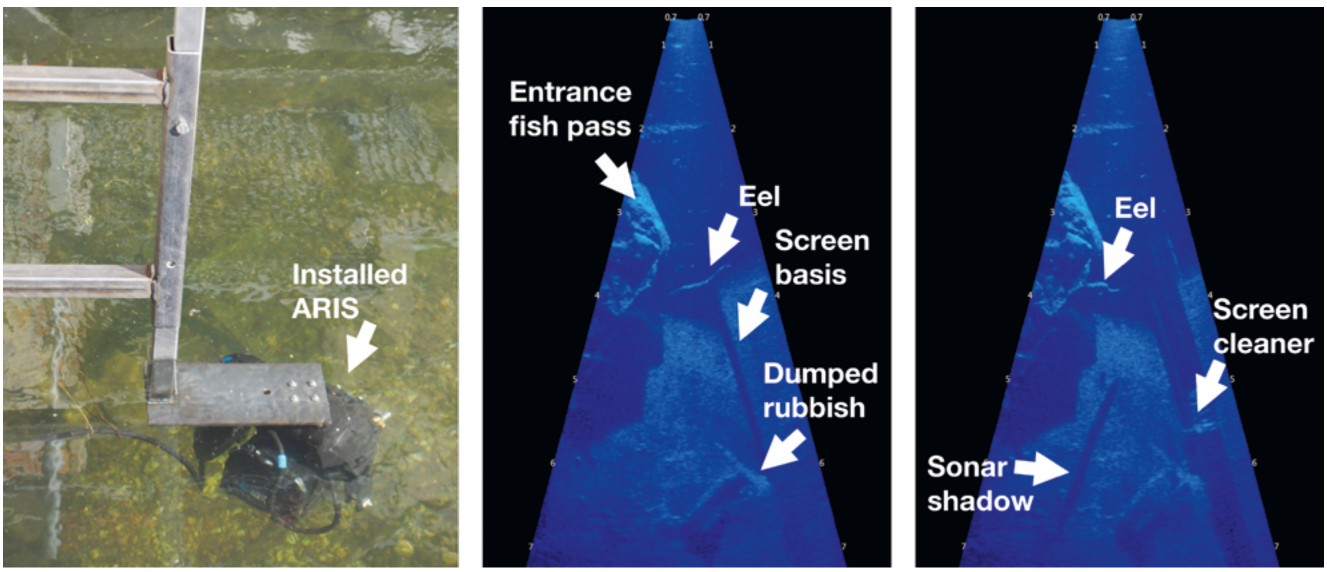

Figure 4: Investigation of fish behaviour is also important in understanding corridor choice. In the project, an ARIS sonar was used

combined with a technical fish pass was positioned directly next to the turbine inlet covering 31% of the discharge, the majority of downstream moving fish (70%) used the ramp, and an additional 10% the technical fish pass. Further, a zig-zag tube system efficient for facilitating silver eel downstream passage in laboratory experiments (Hassinger & Hübner 2009) was found to be not efficient in the field setting. Instead, downstream migrating eels strongly responded to the opening of an undershot sluice gate, which thus provided an efficient corridor for downstream passage (Egg et al., 2017). For future planning, considering optimal positioning and sufficient water dotation for alternative corridors than the turbine pathway is key to impact reduction.

Typical injuries included amputations, scale loss as well as internal injuries such as swim bladder rupture (Mueller et al. 2017, 2020), which could be explained by the physical and hydraulic forces experienced during turbine passage (Boys et al. 2018). The observed strong seasonal and diurnal differences in downstream movement patterns (Knott et al. 2020) suggest that adjustment of operational modes according to the main movement times may be suitable to substantially reduce the negative impacts of the facilities on fish. Concerning the impacts of hydropower utilisation on physicochemical habitat quality, in most cases only marginal differences in the abiotic habitat properties and the biological community structures were observed comparing time points before and after installation of the innovative hydropower technologies. This strongly indicates that the main effect on serial discontinuity was already introduced by the dams and weirs (Mueller at al. 2011), irrespective of the installation of hydropower turbines.

The findings of the study provide a natural-scientific background for decision-making, which now also needs to include other aspects and disciplines such as engineering and socio-economic considerations (Geist 2021). Furthermore, the findings of this project provide a basis for comparison with future technological developments, which all deserve a chance, but need to be objectively evaluated with respect to their impact.

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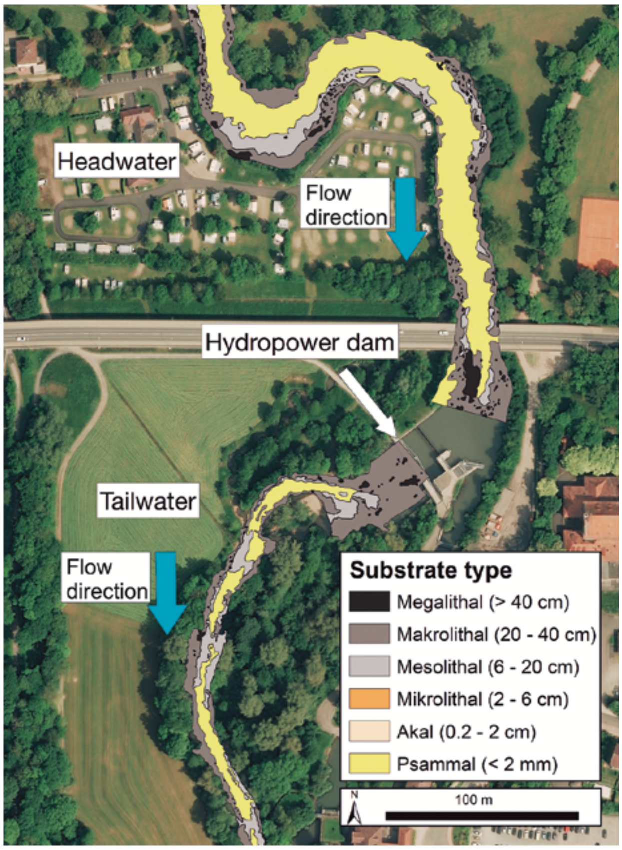

Figure 5: Substrate mapping in up- and downstream areas of hydropower sites conducted as part of the habitat effect assessment

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