

UNDERLYING MECHANISMS OF MOVEMENT PATTERNS IN CYPRINIDS AFFECTED BY HYDROPEAKING

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The overexploitation of water resources has disrupted the natural flow variability and induced drastic changes in the ecological processes of riverine ecosystems. Hydropower production results in daily energy peaks (hydropeaking) with the release of artificial downstream discharge peaks, with subsequent negative effects on the abiotic components and the biological communities of the river system. Despite the growing awareness of hydropeaking impacts on fish biota, it is still largely unknown how fish react and behave under peak events. Moreover, hydropeaking studies have been dominated by fast-swimming salmonids, and very few information is available on the behavior of cyprinid species. Cyprinids are also an important biological component of fish assemblages with some species being at risk due to human-induced impacts. In this work, the movement behavior of cyprinids was tested when exposed in an artificial flume (8 m long, 0.7 m wide, 0.8 m high) to different cycles of pulsed peak flows. Fish organism level responses and movement behavior were assessed for different conditions of flow ratio, rate of water level change and frequency of peak flows. Results indicate that fish movements are triggered by discharge fluctuations. This work improves the knowledge and understanding of fish behavior under hydropeaking conditions and associated environmental causes that will contribute to a more sustainable hydropower management.

1 INTRODUCTION

Natural flow regime is a key driver of the river ecosystem and together with physical habitat, biotic interactions, energy sources and water quality determines the ecological integrity of the river ecosystem [1]. The growth of hydropower production as a reliable, cost-effective and renewable source of energy results in highly modified streams with direct and indirect consequences for fish communities [2].

The production of hydroelectricity results in the release of artificial discharge peaks downstream the hydropower plant, phenomenon known as hydropeaking. Although the impacts of artificial flow regimes in downstream fish communities are well documented, the effects of pulsed peak flows on the movement behavior of fish remain unclear [2]. Potential negative impacts of pulsed flows include downstream displacement [2], stranding [3], search for velocity refuges [4], alteration of migration patterns [5] and decreased growth [6]. Whether or not fish move laterally or longitudinally to find velocity refuges and return to the initial habitat after the rapid flow fluctuations remains unknown [7].

There is a considerable amount of research describing the effects of hydropeaking in fish, but very few evaluate fish movement behaviour under cycles of rapid peak flows over time [5,8]. Furthermore, only a handful of studies propose mitigation measures based on hydrodynamic models [9] and very few evaluate fish responses according to structural mitigation measures [10]. Additionally, most of the research on the impacts of hydropeaking focuses on salmonids and other species of commercial interest. With lower swimming ability, cyprinids are subjected to higher energetic costs making them more vulnerable to severe flow changes. Cyprinids

are an important community in fish assemblages, but knowledge on their movement behavior and habitat preferences remains scarce, particularly in combination with hydrological parameters (but see [10]).

The main objective of this work was to investigate the effects of rapid flow fluctuations on the movement behavior of the Iberian cyprinid, *Luciobarbus bocagei*. PVC flashboards mimicking natural stream deflectors were installed in an experimental flume and different series of peak cycles were tested. Movement behavior was analyzed using behavior recording methods and physiological tools.

2 METHODOLOGY

2.1 Flume experimental setup

The experiments were conducted in an indoor artificial flume located at the hydraulic laboratory of Instituto Superior Técnico, University of Lisbon. The flume (8m long x 0.7m wide x 0.8m high) has a steel frame and glass viewing panels on both sides (Figure 1A). Flows are controlled by an upstream plane gate and a downstream flap gate allowing rapid variations in flow. PVC flashboards were installed in the false bottom of the flume to simulate deflectors mimicking fish shelters in the river (Figure 1B).

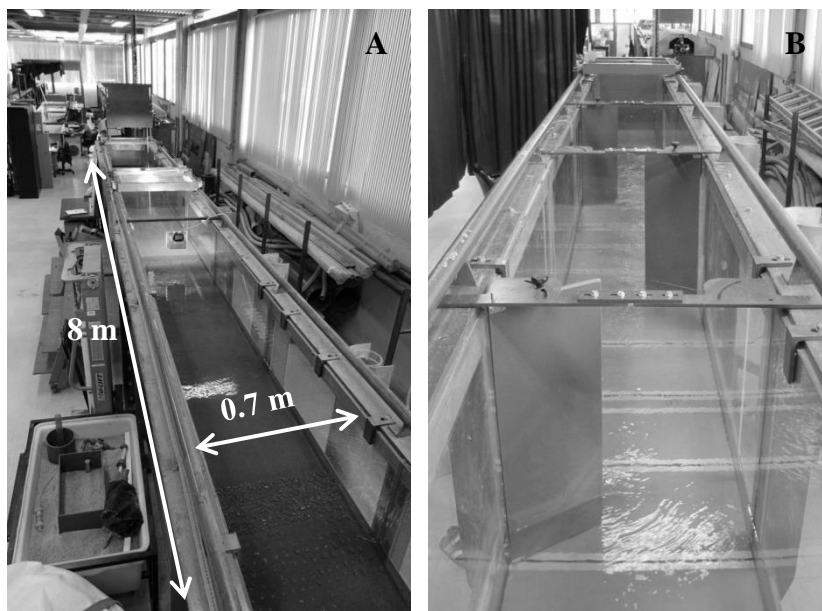


Figure 1. Experimental flume facilities. A – Flume dimensions; B - Flume with PVC flashboards mimicking natural shelters.

Different series of peak flow cycles were tested to simulate sub-daily hydropeaking conditions. The tested flow cycles (Figure 2) fluctuated according to magnitude, frequency and duration to test whether or not the amount of water and the rapid changes over time would determine the fish movement behaviour.

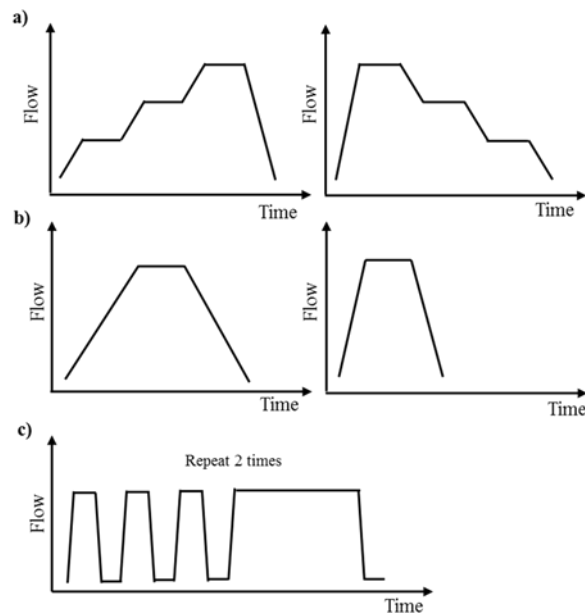


Figure 2. Tested cycles of peak flows. a) Step up and down ramping rates; b) Single up and down ramping with different degrees of abruptness; c) Repetition of cycles of peak flows versus base flows with alternating frequencies.

Water quality parameters, were controlled in a daily basis using multiparametric probes (temperature, pH, dissolved oxygen and conductivity) and in a weekly basis using photometry (nitrites, ammonia, ammonium and chlorine).

2.2 Biological survey

The selected fish species was the Iberian barbel (*Luciobarbus bocagei*). This potamodromous species performs upstream migrations during spawning season choosing faster water currents. During the rest of the year this species prefers low flow habitats.

Fish sampling took place at River Lizandro where no hydropeaking conditions occur. Fish were sampled using low-voltage electrofishing and transported in constantly aerated large containers to the laboratory. Fish were transferred to two 900 L acclimation covered tanks with ambient temperature and natural photoperiod for 3 days. Water was permanently aerated, filtered and monitored using multiparametric probe and photometry. Before each experiment, fish were acclimated in the flume for 20 minutes under base-flow regimes. Fish were fed only after the acclimation period and at night. After the experiment period biometric data was recorded. In the end of the experiment a total of 210 fish were sampled and tested.

2.3 Fish movement behavior

Movement behaviour was classified according to swimming activity and shelter approach. Individual behavioral differences were assessed as each group included individuals with different age, sex and size. Each cycle of flow tested comprised a group of five individuals and was repeated three times. Three control experiments were performed.

To quantify the movement behaviour of fish, video recordings complemented with direct observations were used. The retrieved data was analyzed according to shelter approach using behavior frequency and duration measures.

To complement the visual observations of behavior we used physiological tools to assess whether or not the peak flow cycles would present a stressor to fish. Tightly connected to locomotion and as a result of exhaustive exercise, blood lactate likely presents an organism level response to rapid and pulsed peak flows. Thus, as unpredictable peak flow events will likely trigger burst swimming activity, blood lactate was measured. Additionally, external stimuli that cause exhaustive exercise produce other organism level responses, namely an increase of blood glucose. Therefore, blood glucose and lactate were used as stress indicators. Blood samples were collected via caudal puncture within a period no longer than 3 minutes after capturing each fish. Blood

lactate and glucose values were measured using portable meters that have been confirmed to provide valid results [11].

3 PRELIMINARY RESULTS

The effects of pulsed peak flows on the movement behaviour of the Iberian barbel (*Luciobarbus bocagei*) were assessed. The combined usage of physiological and visual observation tools evidenced that cyprinids are affected by the degree of unpredictable flow changes. Our results suggest that the Iberian barbel selects velocity shelters to avoid exhaustion. Blood parameters were different between basal and peaking flows.

Results from this study will contribute to the design of more adequate habitat mitigation measures and provide a valuable insight on the importance of organism level responses for the environmental flow science particularly in hydropowering rivers.

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