Ecological impacts on fish of a controlled sediment flushing from a large dam on the French-Swiss Upper-Rhône River.

Impacts écologiques sur les poissons d'une opération de chasse contrôlée des sédiments d'un grand barrage sur le haut-Rhône franco-suisse.

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RÉSUMÉ

Les chasses hydrauliques sont des opérations couramment pratiquées pour évacuer les sédiments fins accumulés dans les retenues de barrage, mais peu d'études ont évalué quantitativement les impacts écologiques associés, et moins encore ont comparé les impacts de différentes stratégies de gestion. Ici, nous avons : 1) analysé les impacts sur les poissons de l'Abaissement PArtiel de la retenue de VERbois (APAVER ; Rhône genevois) de mai 2021 à large échelle spatiale, en incluant les effets potentiels sur les trois retenues successives du Haut-Rhône en aval (Chancy-Pougny, Génissiat, Seyssel) ; 2) comparé les impacts observés en 2021 à ceux de l'APAVER de 2016 et de la vidange complète de 2012. Les données, en cours d'analyse, permettront de tester si l'APAVER a entrainé une variation de l'abondance/biomasse du peuplement piscicole dans les quatre retenues, mais également d'évaluer les comportements (déplacements journaliers) d'individus marqués avant, pendant, et après la perturbation. Un modèle de survie (type Cormack-Jolly-Seber) évaluera les effets de l'opération plus finement pour trois espèces. Enfin, la méthodologie étant en grande partie commune aux suivis réalisés lors des opérations de vidange complète de 2012 et d'APAVER 2016, et les métriques évaluées étant identiques, une comparaison pourra être réalisée.

ABSTRACT

Fine sediment flushings from reservoirs are common management practices worldwide, but few studies report quantitative evaluations of their ecological impacts, and even fewer compared impacts of different sediment management strategies. Here, we 1) analysed impacts on fish of the controlled flushing of the Verbois reservoir of May 2021 (called APAVER ; Geneva Rhône River) at a large spatial scale, including potential effects on the three successive reservoirs located downstream (Chancy-Pougny, Génissiat, Seyssel) ; 2) compared the impacts observed in 2021 to those from the APAVER 2016 and the full drawdown flushing of 2012. Data, which are currently being analysed, will allow to test if the APAVER operation led to a change in abundance/biomass of fish within the four reservoirs, and to assess the behaviour (daily movements) of marked individuals before, during, and after the disturbance. A survival model (Cormack-Jolly-Seber) will be applied on three species. Finally, because the methodology is common to that applied to monitor impacts of the full drawdown flushing of 2012 and of the APAVER 2016, and the evaluated metrics are the same, a comparison could be done.

MOTS CLES

Gestion sédimentaire, hydroacoustique, impacts piscicoles, retenue hydroélectrique, télémétrie

1   INTRODUCTION

Sediment flushings of hydropower reservoirs are commonly performed worldwide to maintain water resource uses and ecosystem services (Kondolf *et al*. 2014). However, these operations may have strong ecological impacts, especially on fish populations. Despite the worldwide scope of this issue, very few studies report quantitative *in situ* evaluations of sediment flushing from dams, and even fewer compared impacts of different sediment management strategies.

On the Swiss Rhône River, the Verbois reservoir (vol. 13 Mm^3) traps massive amounts of fine sediment carried by the Arve River, whose confluence is 8 km upstream to the dam. The sediment deposition in the reservoir was historically managed by full drawdown flushing every three years from 1968 to 2003, and then again in 2012. In 2016, following a close cooperation process between French and Swiss dam operators and authorities, the sediment management strategy changed and now mainly relies on a controlled reservoir flushing (called APAVER, for '*Abaissement PArtiel de VERbois*'). In this context, the water level is partially lowered in the reservoir and the suspended sediment concentrations (SSC) are controlled below the dam.

Ecological impacts on fish were shown to be severe both in the reservoir and downstream following the 2012 flushing (Grimardias et al. 2017), while the shift to a controlled flushing in 2016 significantly reduced impairments (Cattanéo et al. 2021), with most impacts being behavioural rather than lethal. However, the sensitivity of individuals to the flushing seemed to be species-specific, with roach appearing little tolerant to SSC.

In this study, we analysed *in situ* impacts on fish of the APAVER of May 2021 and compared results with those of the APAVER 2016 and the full drawdown flushing of 2012.

2   MATERIAL AND METHODS

2.1   Study sites

We analysed impacts on a *ca.* 60 km cross-border reach of the French-Swiss Upper-Rhône River, including the four hydroelectric schemes (dam + reservoir) of Verbois, Chancy-Pougny, Génissiat, and Seyssel, and the lotic reaches of the Rhône River below Verbois and Chancy-Pougny dams.

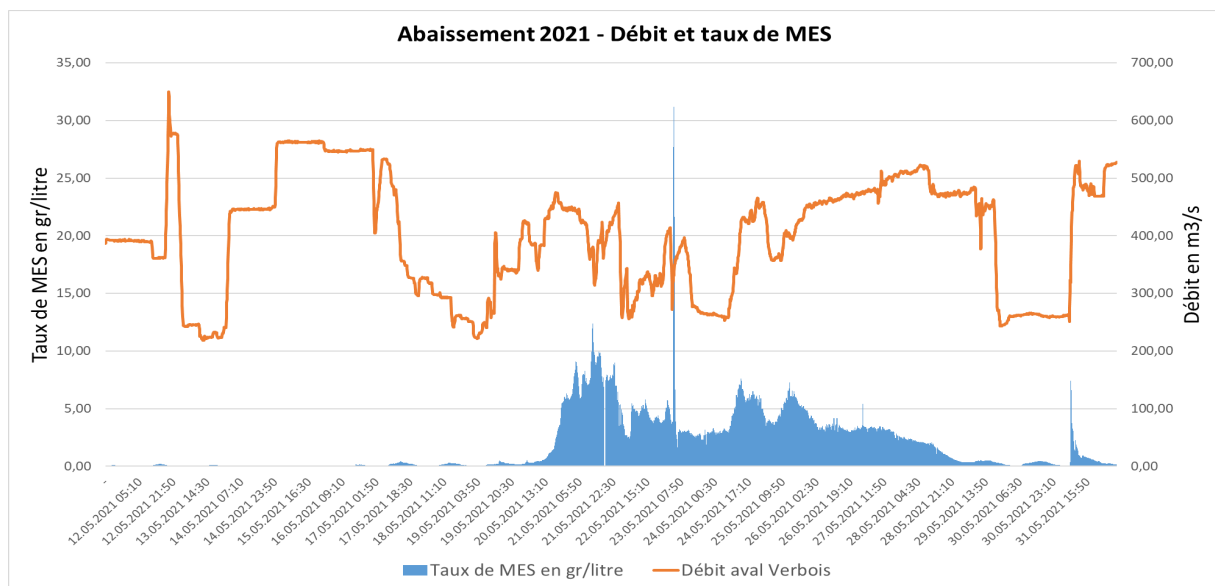## 2.2   The controlled flushing operation of May 2016 (APAVER)

Figure 1: Suspended Sediment Concentration (in g.L^{-1}) and Rhône River flow (in m^3.s^{-1}) from 11 May to 1 June 2021 (data from SIG). APAVER occurred from 19 May to 30 May.

The flushing of the Verbois reservoir occurred between 19 May to 30 May 2021 (*Fig. 1*), and an estimated volume of 1.2 Mt of fine sediment was released downstream (SIG). Except a short peak on 22 May (32 g.L^{-1}), the SSC did not exceed 10 g.L^{-1} all along the event.

2.3   Impact monitoring on fish

Impacts were evaluated at the community scale within the four reservoirs, and at the scale of individuals on the behaviour and apparent survival below the Verbois dam.

A series of hydroacoustic surveys conducted just before and after the flushing allowed to assess fish density changes within the four reservoirs, as well as the size distribution of fish. Differences between surveys were tested by non-parametric Krukall-Wallis tests. Hydroacoustics surveys were also performed during years without flushing to analyse the seasonal variability in fish density, independent of sediment management operations, to compare post-APAVER observed densities to what could be expected without sediment management operation.

The behaviour of individual fish (movement distances) and apparent survival rates for representative species (*Barbus barbus*, BAF; *Squalius cephalus*, CHE; *and Rutilus rutilus*, GAR) were analysed by means of a capture-mark-recapture approach using radio and acoustic telemetry. Tracking sessions were performed before, during, and after each flushing event. The overall apparent survival rate *Φ* was calculated as the proportion of marked fish that remained alive in the study area at the end of the flushing. A Cormack-Jolly-Seber (CJS) mark-recapture model was used to assess daily apparent survival rates and to test for potential effects of species, flushing event, and their interaction.

3   RESULTS AND DISCUSSION

A total of N = 98 individual was marked during four dewatering the Verbois dam fishpass, from which N = 70 were radio-marked (22 BAF, 17 CHE, 31 GAR) and 28 additional GAR were marked with acoustic transmitters. Data are currently being analysed and complete results will be presented during IS RIVERS 2022.

At first sight, it seems that impacts were mainly behavioural rather than lethal. Barbel and chub were displaced downstream following the increase in SSC below the dam, over distances comparable to that observed in 2016. In accordance to observations during the APAVER 2016, the roach appeared to be especially sensitive to the flushing, as only 3% of marked individuals were detected at the end of the flushing (prospections from Verbois to Chancy-Pougny). However, further prospections revealed that some individuals found shelter in the Génissiat reservoir (*ca.* 25 km downstream from their point of release), and one individual was even captured (alive) by a professional fisherman at Belley (*ca.* 67 km downstream from their point of release).

The implementation of the new management strategy, including the controlled flushing, allowed mitigating ecological impacts on fish. However, impacts are still significant, though mainly behavioural on adult fish. Impacts on younger stages are unknown. Some species (e.g. roach) clearly appeared to be more sensitive to SSC, and were displaced over long distances. Impacts regarding the population dynamics and the recolonization of the Rhône River are also unknown.

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