Impact of the Verbois reservoir flushing in 2012: how did fish survive 'the apocalypse'?

Impact de la vidange de la retenue de Verbois en 2012 : comment les poissons ont-ils survécu à « l'apocalypse » ?

David Grimardias [1] ; Jean Guillard [2] ; Carole Nawratil De Bono [3] ; Seydina Diouf [3] ; Jean-Luc Zanasco [3] ; Franck Cattanéo [1]

[1] Haute école du paysage, d'ingénierie et d'architecture de Genève (hepia), Institut Terre-Nature-Environnement, Route de Presinge 150, CH-1254 Jussy, Switzerland (corresponding author : david.grimardias@hesge.ch). [2] UMR Carrtel, INRA Université de Savoie, Institut national de la recherche agronomique (INRA), 75 avenue de Corzent, BP 511 74203 Thonon les Bains, France. [3] Services Industriels de Genève (SIG), Case postale 2777, CH-1211 GENEVE 2, Suisse.

RÉSUMÉ

Les opérations de chasse des sédiments sur les grands réservoirs hydroélectriques sont couramment réalisées pour maintenir le volume de la retenue et, parfois, minimiser les risques d'inondations. En Juin 2012, la vidange du réservoir de Verbois (Rhône, Suisse) a été réalisée, et les impacts du relargage des sédiments ont été mesurés sur le peuplement piscicole présent à la fois dans le réservoir (suivi hydroacoustique de 18 mois) et en aval (survie et comportement à court terme par utilisation de la radio-télémétrie). Globalement, l'étude a montré que ce type d'opération de gestion des sédiments impacte sévèrement la communauté piscicole du Rhône, que ce soit en amont comme en aval du barrage. Une baisse majeure de la densité de poissonsa été détectée dans le réservoir, et celle-ci est restée à un niveau très bas durant les 16 mois suivants. La survie moyenne globale des poissons radio-marqués a été estimée à 74 % immédiatement après la vidange. Le délai depuis la dernière vidange, et donc la quantité de sédiments relargués, ainsi que le mode de gestion réalisé semblent constituer une perturbation très forte pour un peuplement piscicole à faible résilience. Un mode de gestion différent, moins dommageable, doit être envisagé pour relarguer les sédiments fins accumulés.

ABSTRACT

Sediment sluicing operations of large hydroelectric reservoirs are commonly performed to maintain power production and to ensure safety concerns. By June 2012, the emptying of the Verbois reservoir (Rhône River, Switzerland) was performed, and subsequent impacts of sediment release on fish assemblages present both in the reservoir (18-months hydroacoustic survey) and downstream (short-term movement and survival using radiotelemetry) were assessed. Overall, the study showed that such sediment management operations severely impacted the fish community of the Rhône River, both downstream and upstream the dam. Major loss of fish density with slow recolonization process was detected in the reservoir, while the overall mean survival of marked fish after the flushing was estimated to 74%. The flushing delay and strength seem by far too constraining for such a low-resilience fish community, claiming an alternative, less harmful way of releasing accumulated fine sediments.

KEYWORDS

Fish assemblage, impact assessment, reservoir flushing, sediment management, telemetry

1 INTRODUCTION

Hydraulic sediment flushing is a commonly used operation to clean reservoirs with high sedimentation rate (Owens et al. 2005). Nevertheless, despite the worldwide scope of this issue, effects of reservoir sluicing on fish communities have been poorly documented, and even fewer for large dams. Most investigations focused on the physico-chemical impacts of sediment flushing (suspended solid, oxygen or toxic concentrations. These impacts on fish may be direct (e.g. physiological damages, behavioural disorders, mortality) or indirect (e.g. habitat modification), and largely depend on the species and affected life stages. Similar to many large rivers of the world, the Rhône River has been heavily modified with a strong focus on hydroelectricity production. Downstream Lake Geneva, the Verbois Dam and its reservoir (22 m height, 13.106 m^3 storage capacity) constitutes a major sediment trap, and sediment management was based on periodic emptying and hydraulic flushing every three years until 2003. At the onset of the 2012 flushing operations (the first since 2003 event), an estimated volume of 5.6 million m^3 of sediment was trapped (SIG, SFMCP 2012), reducing the water storage capacity and increasing risk of flooding in Geneva city. Finally, 2.69 million m^3 of deposited sediment has been swept away during this sluicing event.

We aimed at analyzing the short- and long-term impacts (up to 16 months) of this major 2012 sluicing operation on the Rhône River fish assemblage, both upstream and downstream the dam, using an original combination of radio-telemetry and hydro-acoustic approaches. We focused our attention on analyzing the temporal changes of fish density in the reservoir to assess the impact of the operation and the recolonization process, as well as on the survival and behavioural responses of target species representative of the Rhône River ichtyofauna.

2 METHODS

Echosounding was realized on the lentic part of the Verbois reservoir, by performing a zig-zag sampling design from one bank to the other. Eleven night hydroacoustic surveys have been carried out: two were performed before the reservoir emptying (late May 2012), and nine were realized at different time-steps in 2012 and 2013 after the reservoir filling (from five days to sixteen months).

Additionally, 42 fish were sampled and radio-tracked during the sluicing operations and after (to August 29th). The fish were representative of the local Rhône River ichtyofauna: barbel (*Barbus barbus*, Cyprinidae; N = 23), chub (*Squalius cephalus*, Cyprinidae; N = 16), and brown trout (*Salmo trutta*, Salmonidae; N = 10). Fish were tagged with an external mount radio-transmitter (F1970 model, Advanced Telemetry Systems Inc., Isanti, Minnesota, USA), in agreement with the 2 % tag to body weight ratio.

Finally, to compare the effects of the 2012 reservoir sluicing operations with previous events (from 1987 to 2003), the Newcombe and Jensen (1996) 'severity of ill effect' model was estimated, considering the exposure duration (in hours) and the mean concentration of suspended sediments (in mg.L-1). Suspended sediment concentrations were measured at La Plaine station by the Services Industriels de Genève.

3 RESULTS AND DISCUSSION

The sluicing operation severely affected the fish assemblage within the reservoir, with a higher magnitude in the downstream zone near the dam. The acoustic fish density drastically dropped after the sluicing operations, with a decrease of 57.0 % (Figure 1). The decline in fish density differed among the reservoir zones: it dropped by 66.76 % in the downstream zone, while the fish density decreased by 43.34 % in the upstream zone. Afterwards, the acoustic fish density in the reservoir remained low and stable (Figure 1). Results showed that the resilience of the fish assemblage of the reservoir is weak, as no increase in the density was observed 16 months after the sluicing.

By the end on the reservoir sluicing (June 20th), a global survival rate of 74 % was detected downstream to the dam. Per species, survival rates were 77 % for barbel, 80 % for chub, and 40 % for trout. A decrease in the daily survival rate was observed only during the first three days of the sluicing (emptying and flushing operations, respectively 0.992 ± 0.039, 0.923 ± 0.060 and 0.957 ± 0.043) for chub and barbel. The daily survival rate returned to 1.000 and remained constant thereafter.

A global downstream movement was observed for both Cyprinidae species from the onset of the sluicing operation, with a peak on 4th day for barbel and 5th day for chub (end of flushing events). Barbel went down on average by 1041 m (mean distance to the dam: 1996 ± 949 m), while chub

moved downstream on average by 1451 m (mean distance to the dam: 3322 ± 1673 m). Both species showed the strongest drifting movement on 11 June 2012 (drifting speed: 814 ± 710 m/day for barbel, 789 ± 873 m for chub), corresponding to the peak of SSC. Tracking also revealed that several fish stayed either inside or in the immediate vicinity of the Allondon stream (Rhône River tributary) all along the flushing operations.

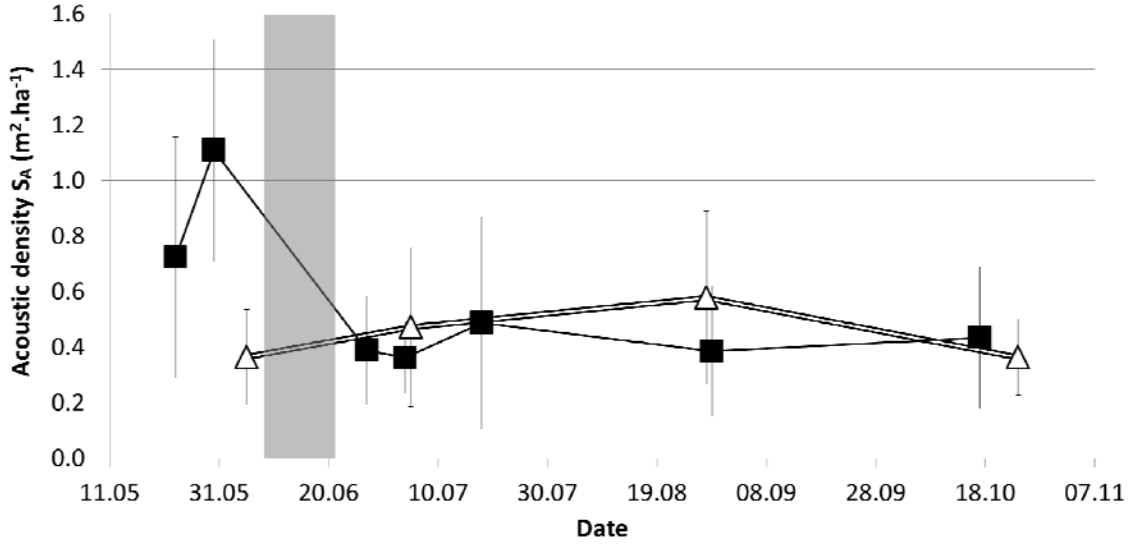

Figure 1. Evolution of SA (mean ± SD) on the whole Verbois reservoir for 2012 and 2013 surveys. 2012 data are represented by black squares and single line. 2013 data are represented by white triangles and double-line.

Finally, 'severity-of-ill effect' models estimated values of 11.0 and 10.2 for trout and barbel/chub, respectively, for the 2012 reservoir sluicing event (exposure duration: 114 hours, mean SSC: 14.9 $g.L^{-1}$). SEV of 10 and 11 respectively predict first lethal effect (0-20 % of mortality) with pronounced habitat degradation, and 20-40 % of mortality (Newcombe and Jensen 1996). By comparison, SEV values were estimated between 4.5 and 5.1 for trout, and between 7.0 and 7.5 for chub/barbel for previous reservoir sluicing events, predicting sublethal effects, such as behavioural changes, habitat degradation and physiological stress.

4 CONCLUSION

The original use of combined telemetric methods showed that such sluicing (with total emptying) of a reservoir on the Rhône River resulted in a drastic decline in fish densities in the reservoir and induced ~26 % (range 20-60 %, depending on the species) overall mortality of adult individuals with noticeable behavioural responses (drift). The high degree of fragmentation of the Rhone River continuum appeared to be an aggravating factor, which may explain the low resilience of the assemblage. The present study strongly suggests that defining a less harmful, more sustainable fine sediment management strategy is necessary for the Rhône River.

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