Stream Response to Experimental Floods

Can artificial flooding restore the ecological integrity of rivers downstream of reservoirs? Experimental flood releases from a large reservoir just outside the Swiss National Park markedly altered the ecology of the receiving river. The response of aquatic flora and fauna to flood disturbance reflected species-specific life histories and the cumulative effects of earlier floods. Results indicate that artificial flooding has great potential as a restoration strategy for regulated rivers.

Large dams (>15 m high) are prominent features of most rivers [1]. Worldwide, about 40,000 large dams are used for power production, irrigation, navigation, water supply, recreation, and just recently, for ecological purposes [2]. Large dams in the Alps are used primarily for power production; streams below these dams have greatly reduced or no flow due to water diversion and therefore become physically altered, e.g., temperature increase and clogging of the streambed by fine sediments [3, 4]. The biota also change in response to the altered habitat, usually showing substantial increases in those organisms favored by more constant environments, concomitant with decreases of organisms adapted to natural flow patterns [5].

The removal of small dams has become increasingly common, especially in North America where around 180 dams have been removed in the last decade [6]. However, most large dams will remain in place for a variety of management purposes, with around 260 new large dams becoming operational each year [7]. Consequently, there is a strong need to restore the natural flow regime of regulated rivers to enhance their ecological integrity [1, 2]. Therefore, we were interested by the possibility to use artificial flooding as a management tool to improve river health below large dams.

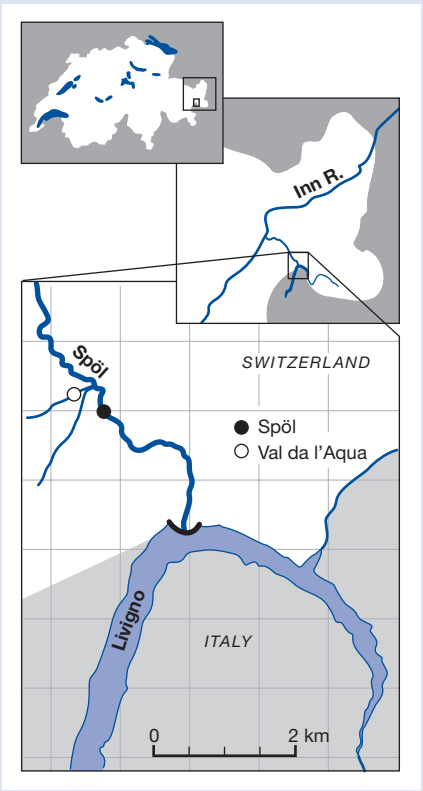

Fig. 1: Location of the Spöl study site in Switzerland.

The Spöl Project: A First in Flood Management

Only one other study examined the effects of an artificial flood on a river below a large dam, this being the Glen Canyon Dam in the USA [3]. Our study was conducted on the River Spöl, flowing below a large dam (Punt da Gall) on the border between Switzerland and Italy through the Swiss National Park (Fig. 1). Operation of the dam since 1974 has resulted in a constant discharge of less than 2.5 m^3/s. The reduced flows have caused clogging of the streambed by fine sediments and allowed side-slope debris fans to form in the main channel. A reference stream, Val da l'Aqua, was located nearby to document ecological patterns in an unregulated system. Park authorities and the power company agreed to test whether artificial flooding can restore more natural conditions to the river. It is a multi-disciplinary project involving the Swiss National Park, Engadiner Kraftwerk, University of Berne, Hydra, Graubunden Fish and Game, and EAWAG, each focussing on different components of the system. In this article, we concentrate on the response of algae and zoobenthos, two important groups for assessing biological change, to artificial floods.

The Experimental Flood Regime

Figure 2 shows the discharge regime of the River Spöl during:

- three typical years (1960–1962) before dam construction (full operation in 1974),
- a typical year after dam construction (1999),
- the first year of experimental flooding (2000).

A reduction in residual flow following September 1999 provided enough water for the floods to be a cost neutral experiment. The artificial floods, one each in June, July and August, were comparable to those before dam construction, although being of shorter duration. The fourth flood in October resulted from heavy rain that filled the reservoir, allowing the release of excess water.

General Ecological Affects of the Floods

The First Flood: The first flood was patchy in its effects on stream algae and zoobenthos. Some areas of the stream bed were

Photographs: U. Uehlinger, EAWAG

The Spöl at baseflow and …

highly changed due to scouring and bed movement, resulting in a reduction in algae and zoobenthos, whereas other areas of the stream bed, such as boulders, were less affected and accumulated organisms. These less disturbed areas probably enhanced recovery by providing colonists or propagules, as occurs in unregulated systems. Some stones still had prolific growths of mosses that probably retained and also provided refugia to organisms. Algae and zoobenthos recovered rapidly after the first flood (Figs. 3 and 4), although remaining highly patchy. In Val da l'Aqua, the reference stream, algae and zoobenthos showed little change over the study period.

The Second Flood: The second flood was the largest (Fig. 2) and mobilized most areas of the stream bed. It caused major reductions in algae and zoobenthos (Figs. 3 and 4). Some pools were even filled with deposited sediment. Stones, including boulders, were bare after this flood and little moss cover was found in the channel. Recovery after this flood was delayed and neither algae nor the zoobenthos achieved preflood levels before the next flood. This lack of recovery probably can be explained by the larger impact of the flood, the unfavorable seasonal timing of the flood in respect to the life cycles of the biota, and a change in the composition of the biotic communities (Fig. 5).

The Third Flood: The scouring and disturbance potential of the third flood was markedly reduced because the second large flood had a major "cleaning" effect, transporting many fine sediments downstream. Nevertheless, the third flood also reduced zoobenthos abundances, but had little affect on algae. Although the third flood was similar in size to the first flood, recovery by algae and zoobenthos was more pronounced after the first than after the third flood (Figs. 3 and 4).

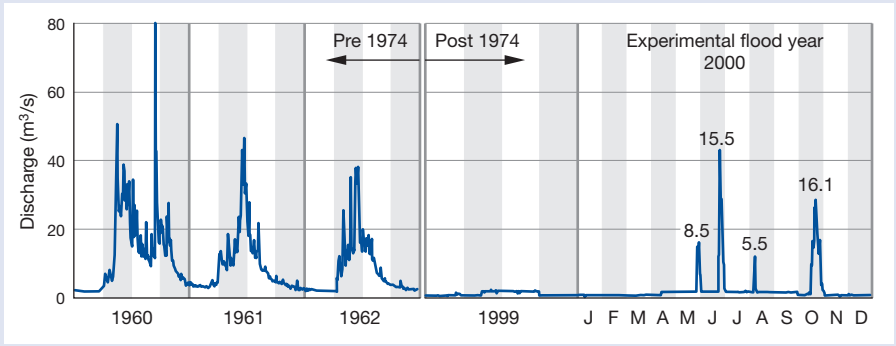

Fig. 2: Typical flow regime of the River Spöl before dam construction (years 1960 to 1962), after dam construction (1999), and during the experimental flood year (2000). The flow in 1999 represents the residual flow maintained below the dam with excess water being diverted for power production. The numbers above the flow peaks in 2000 are the average daily flows in m^3/s.

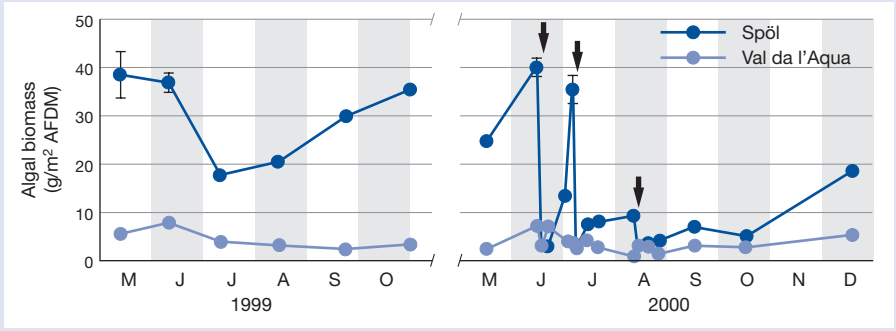

Fig. 3: Mean (±1 SD) algal biomass expressed as mg ash-free dry mass (AFDM) per m^2 in the rivers Spöl and Val da l'Aqua in the years 1999 and 2000. Arrows indicate the three experimental floods during 2000.

Changes in Community Structure from the Floods

Over the flood year, the stream bottom changed from being covered by moss *(Fontinalis* sp.) to being covered by diatoms and filamentous algae, especially *Hydrurus foetidus,* a common filamentous alga of alpine streams in winter. Zoobenthos typical of streams with more constant flows decreased during the flood year, including the turbellarian *Crenobia alpina* and the amphipod *Gammarus fossarum* (Fig. 5). The turbellarian was greatly reduced after the first flood, whereas the amphipod increased in density following this flood but showed lower numbers after the second larger flood. The difference probably is because gammarids are strong swimmers, whereas turbellarians must crawl to refugia. Zoobenthos more typical of unregulated rivers showed a positive response or recovered

quickly to the floods, and included the midges (Chironomidae), mayflies (Baetidae) (Fig. 5) and black flies (Simuliidae, not shown).

Conclusions

The flow regime is an integral component of rivers and the modification of discharge patterns, including the elimination of floods, is an important disturbance to riverine organisms and can markedly alter biological communities. Our results show that artificial floods can change the abundances of algae and zoobenthos, reducing species favored by river regulation. Additional studies are required to determine the long-term effects of artificial flooding, especially regarding their timing and magnitude, as our results suggest that floods of similar magnitude may have different effects depending on flood history and seasonal changes in population abundances.

... during the large July flood.

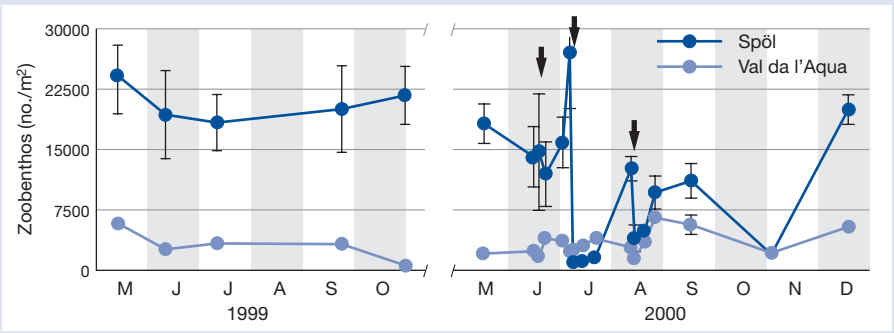

Fig. 4. Mean (+1 SD) zoobenthos density expressed as individual numbers per m² in the rivers Spöl and Val da l'Aqua in the years 1999 and 2000. Arrows indicate the three experimental floods during 2000.

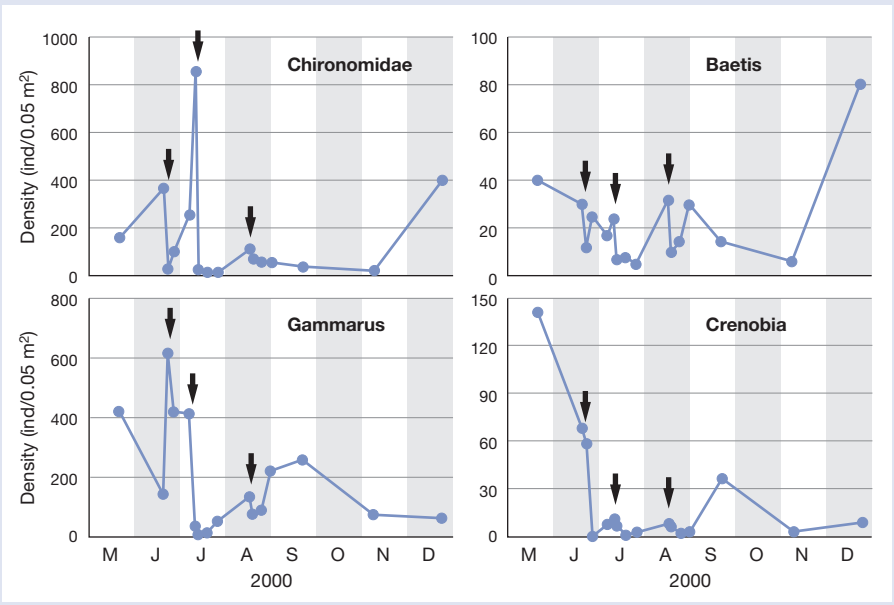

Fig. 5. Mean density (individual numbers per 0.05 m²) of 4 selected macroinvertebrate taxa representing the different response patterns to the experimental floods (arrows). Error bars not shown.

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