Dammed Rivers: The case of the Ebro

Rivières barrées : Le cas de l'Ebre

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RÉSUMÉ

Les barrages sur tout le bassin de l'Ebre, et en particulier sur son cours inférieur, modifient les débits et les régimes sédimentaires du fleuve, ce qui affecte son fonctionnement physique et écologique. Les données obtenues sur l'hydrologie, le transport des sédiments et la dynamique du chenal (c'est-à-dire la mobilité des particules et la structure du lit) ont participé à la conception et la mise en œuvre des chasses depuis 2002. Les principaux objectifs de ces chasses étaient le contrôle de la croissance de la végétation aquatique (macrophytes) et le maintien d'un transit sédimentaire dans le chenal en aval du complexe de barrages Mequinenza-Ribarroja-Flix. La recherche met en évidence le déséquilibre sédimentaire du fleuve, avec une charge sédimentaire actuelle équivalant à 1 % de celle estimée au début du 20e siècle en l'absence de barrages et sous différents usages des sols. Les changements de forme du canal montrent que le chenal s'est stabilisé depuis que les barrages ont été fermés et qu'une réduction significative de la disponibilité des sédiments a eu lieu, renforçant le déséquilibre sédimentaire de la rivière.

ABSTRACT

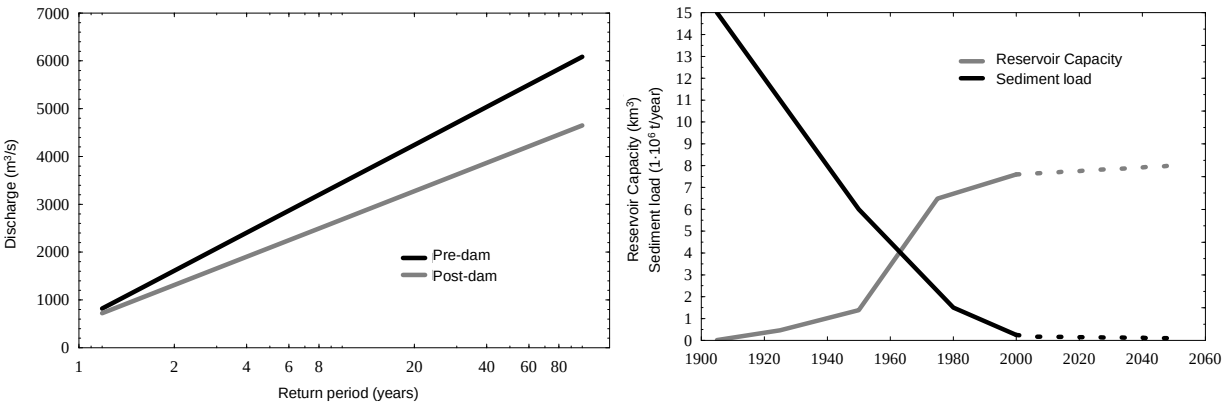
Dams in the whole Ebro basin and, in particular, in the lower section of the river alter the river's flow and sedimentary regimes, thus affecting its physical and ecological functioning. Data obtained on hydrology, sediment transport and river channel dynamics (i.e. particle mobility, bed structure) have aided the design and implementation of flushing flows since 2002; the main objectives of these artificial releases were the control of excess growth of aquatic vegetation (i.e. macrophytes) and the maintenance of certain sedimentary activity in the channel downstream from the Mequinenza-Ribarroja-Flix Dam complex. Research highlight the sedimentary disequilibrium of the river, with the current sediment load equating to 1% of that estimated at the beginning of the 20th century in the absence of dams and under different land uses. Channel planform changes show that the channel has become more stable since dams were closed and a significant reduction of sediment availability has occurred, together reinforcing the sedimentary disequilibrium of the river.

KEYWORDS

Dams, flood frequency and magnitude, sediment load, flushing flows, macrophyte, River Ebro

1. FLOW AND SEDIMENT TRANSPORT

Flow and sedimentary regimes of the River Ebro are profoundly marked by the human activity. Reservoirs and land use changes have systematically altered the pattern of water and sediment yield, and the associated river processes (i.e. channel morphodynamics) along the twentieth century. Data indicate that runoff and especially magnitude of frequent floods have been reduced all over the basin; moreover, sediment supply has diminished due to extensive afforestation of catchment mountainous headwaters, while dams trap most of sediment that still circulating in the drainage network. Overall, sediment yield in the Ebro basin is estimated to be less than 2% of the original load at the beginning of the twentieth century. An average of 0.45×10^6 tons of sediment per year (60% in suspension and 40% as bedload) have been measured during the intensive monitoring period 2002–2004 at the control section of Móra d'Ebre (in the lowermost part of the basin downstream from dams), and further corroborated by data obtained between 2005 and 2008. Sediment deficit is mostly evident in the lower reaches of the river mainstem but also in some of its main tributaries. However, the channel is still active from the sedimentary point of view showing a net export of sediment during competent floods, a fact that produces channel deepening and incision; at the same time, though, riverbed armouring occurs, a fact that progressively stabilizes the channel facilitating, for instance, a massive colonisation of the riverbed by aquatic vegetation (macrophytes).



(Left) Reduction of flood frequency and magnitude in the Lower Ebro downstream from large dams; (Right) Reduction of the Ebro's sediment load during the 20th century in relation to the increment in reservoir capacity

2. FLUSHING FLOWS

Within this context Flushing Flows (i.e. $Q_{1.5\text{-}2}$) are regularly carried out to remove the excess macrophytes in the lower River Ebro. They are designed to mobilize surface gravels hence plants anchored onto them. These artificial releases exhibited higher transport capacity in comparison to natural floods regardless their considerably lower magnitude and duration. Effectiveness of flushing flows (i.e. rate of macrophyte removal) may attain 95%, but decreases substantially downstream. Large quantities of aquatic vegetation are removed in the first hours of the floods. Fine to medium gravels are mobilized but bedload rates are typically low and given the short duration of the floods causes no river bed incision, but river-bed armouring. Despite constrains Flushing Flows have shown their potential for sediment transport; data is useful to inform measures to enhance fish habitat and supply sediment to the delta. Flushing flows designed with environmental criteria have financial costs due to losses in water storage and operational costs; however, FFs can be overall considered financially sound and they are an efficient strategy to improve hydromorphological functioning of the river; with direct benefits to third parties (public health, irrigation communities, etc.). Sediment transport and flood hydrology data obtained during Flushing Flows helps informing restoration actions in the lower Ebro and may be of use for restoration programmes in large regulated rivers, especially in the Mediterranean region.

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