

## Floodplain and channel restoration challenges in the Middle Ebro River

### Défis de la restauration du lit et de la plaine inondable de l'Ebre moyen

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## RÉSUMÉ

L'Ebre est un grand fleuve ibérique qui, dans son cours moyen, développe une vaste plaine inondable avec des crues et des processus d'inondation fréquents. La dynamique fluviale a été stabilisée par la régulation et les défenses. Actuellement, le paradigme de gestion des inondations a été modifié et certaines solutions basées sur la nature sont mises en œuvre dans le cadre de la stratégie et du projet LIFE+ Ebro Resilience. Issu d'une large équipe scientifique interdisciplinaire, le projet SEDEXCHARE évalue ce changement dans la gestion des crues dans une perspective hydromorphologique et de restauration des rivières. Les réalisations jusqu'à présent sont peu nombreuses en matière de restauration, mais importantes en matière de gestion des risques. On explique dans quelles directions il convient d'intensifier les actions de récupération de la dynamique fluviale, en proposant un espace de liberté pour le fleuve. Des pistes d'apprentissage sont également définies à partir du diagnostic actuel dans un contexte d'urgence climatique et de multiplication des événements extrêmes. La santé retrouvée du fleuve assurera la résilience territoriale de la zone inondable, qui comprend les centres de population, les utilisations agricoles et les espaces naturels.

## ABSTRACT

The Ebro River is a large Iberian watercourse that develops an extensive floodplain in its middle reach with frequent floods and flooding processes. Fluvial dynamics have been stabilised by regulation and defence works. The flood risk management paradigm has now been changed and some nature-based solutions are being implemented within the framework of the LIFE+ Ebro Resilience strategy and project. With a large interdisciplinary scientific team, the SEDEXCHARE Project evaluates this change in flood risk management from a hydromorphological and river restoration perspective. The achievements so far are scarce in restoration, but important in risk management. It is explained in which line actions should be increased to recover the river dynamics, proposing a territory of freedom for the river. Learning lines are also defined from the current diagnosis for a context of climate emergency and increase in extreme events. The recovered health of the river will provide territorial resilience to the floodable space, which includes population centres, agricultural uses and natural spaces.

## KEYWORDS

floods, fluvial geomorphology, meandering channel, resilience strategies, risk management

crues, dynamique du méandrage, géomorphologie fluviale, gestion du risque, stratégies de résilience

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## 1 THE MIDDLE EBRO RIVER AND SEDEXCHARE PROJECT

The middle reach of the Ebro River is a free meandering channel in an extensive floodplain along 340 km, in the NE of the Iberian Peninsula. It is one of the largest and most valuable free rivers in Southern Europe, standing out for its remarkable channel dynamics in the past, generally meandering, although with periods in which it responded to a wandering fluvial style, as in the first half of the 20th century. But since 1950 it has witnessed intense hydrological regulation and a stabilization of its channel (Ollero, 1992, 2010; Najes et al., 2019), so that only some gravel bars retain active dynamics (Viñas, 2021). Floods are frequent, inundating a large part of the floodplain, with damage to crops and livestock and risk for some urban centres (Ollero et al., 2021). Risk management in the past has been unsuccessful, and after the 2015 flood a change of model was initiated, that has worked adequately in the floods of 2018 and 2021. This new model aims at river and territorial resilience by proposing nature-based solutions. These are river rehabilitation measures applied to flood management.

From the research project SEDEXCHARE (*Sediment, hydrological extremes, historic-environmental changes and river resilience: the Ebro River*), funded by the Spanish Ministry of Science and Innovation, and composed of three coordinated interdisciplinary subprojects (1. *Management of risk and environmental changes in the Middle Ebro River: fluvial restoration and territorial resilience*; 2. *The Ebro Sediment Observatory (OSE): hydro-geomorphological adjustments in response to human-induced impacts. Implications for flooding risks and sediment management*; 3. *History of a navigable fluvial landscape: the Ebro River*), we are evaluating the new management measures and observing their benefits compared to the old model. We are also analysing hydromorphological indicators, such as the evolution of sediment bars and channel morphology and bathymetry, to check the local effects of the new measures (Ollero et al., 2024).

## 2 RESTORATION AND RISK MANAGEMENT CHALLENGES

Management of the risk of bank erosion and flooding prior to the 20th century was very scarce, with some precarious local actions that could not prevent the very active river dynamics. In 1945 the first large headwater reservoir came into operation, and in 1960 the Yesa reservoir, the one with the greatest regulation capacity in the basin. After the 1959-1961 floods, continuous earthen dikes were built to protect against flooding, and the concave banks of the meanders were defended with riprap, so that there were no more cut-offs or migrations registered. This traditional defence system was completed after the 1977-1981 floods, converting the Ebro riverbed into a stabilised meandering channel. However, exposure in the flood zone increased, the damage was significant and the floods of 2003 and 2015 demonstrated that the management system was not useful. Since 1990, the scientific community has been calling for a change in risk management and proposing river restoration measures, in particular returning space to the river, creating a free space or river territory (Ollero, 2010). However, these ideas were not adopted by the water administration (Ebro Basin Authority) until 2015.

Meanwhile, no river restoration project or strategy has been developed in the Middle Ebro River, despite the rise of the National River Restoration Strategy (since 2006). In the urban space of Zaragoza, no restoration initiative was carried out within the framework of the 2008 International Exposition. The only context in which we can speak of an incipient river restoration in the Middle Ebro River is that of the Ebro Resilience strategy, promoted by the Ministry of Ecological Transition through the Ebro River Basin Authority. This strategy, which carried out its first actions in 2015-2016, has state and European funding and its priority objective is the implementation of the Flood Risk Management Plan (PGRI) required by Directive 2007/60/EC. Later, the strategy became the LIFE+ Ebro Resilience project from 2021, continuing along the same lines.

In the SEDEXCHARE project we are verifying, classifying, mapping and evaluating all the actions of Ebro Resilience: security perimeters and closures of urban centres, elimination, setback and lowering of dikes, controlled flooding zones, relief channels, opening of small channels in meander lobes (initially called 'curages'), permeabilization of infrastructures and removal of obstacles, etc. These are actions that are developed as a mosaic, in different sections, already exceeding 150 actions (García Lagranja, 2024). Officially they are not considered restoration or river rehabilitation. But they represent a certain environmental improvement for both the riverbed and the floodplain, so they can be considered in a line of recovery of the complex ecosystem of the Middle Ebro River. The great challenge is to extend and develop them much further, since up to now they are very scarce if the aim is to restore the natural functioning of the river, although they are acceptable and have good results for the purpose of reducing the danger of flooding. Ebro Resilience has become a model of action for other rivers in Spain. Its strength is very positive, although its continuity will depend on political changes. This strength also

conditions a negative aspect: no other river restoration initiatives can be proposed for the Middle Ebro River that cannot be included in the Ebro Resilience program. In this sense, if we want to address a true river restoration, much more ambitious and global measures must be proposed and implemented for the entire river section, far beyond the mosaic of small actions of Ebro Resilience. The great challenge would be to achieve a free and protected river territory for the middle Ebro, in which the channel can recover all its freedom, and the floodplain as a whole can function as a large lamination space. This challenge may be considered in the future, but right now it is far from being viable in the coming decades.

There are two actions integrated into Ebro Resilience that have already been evaluated by SEDEXCHARE: relief channels (Ollero et al., 2024) and permeable corridors or small secondary channels in meander lobes (Cuartero et al., 2022). Both typologies began to be applied in 2016 and there are already several years of observations for their diagnosis and evaluation.

The relief channels have been developed in three cases. Two of them (Alfaro and Cabañas) have been occupied by the river during floods, but they have not worked completely effectively, with a low flow running through them and the river not taking them as secondary channels, so they dry up and are being colonized. The Alcalá relief channel, with a more suitable morphology, curved and cutting the entire lobe of the meander, has been functional even in low waters and has shown in a bankfull flood that 64% of the flow circulates through it, so it has been consolidated as a secondary channel and may tend to become a main channel.

Small corridors open in meander lobes are the most common action, with more than a hundred corridors developing in around twenty different areas. Not all of them become functional and some have become sediment traps, but in general they function in floods. The most interesting and valuable are those that reproduce old flood channels of the old wandering or braided layout of the first half of the 20th century.

### 3 KEY LESSONS LEARNED

From the learning of the evolution of the river and the effects on river dynamics of the different actions, looking to the future, and thinking in a context of climate emergency and increase of extreme events, we can establish the following key ideas:

- 1) Floods and inundations of the Middle Ebro River must be valued and protected as natural processes necessary for the river's functioning and to provide health to the planet and people; it is necessary that, from environmental education and risk culture, the riverside populations understand and accept this principle.
- 2) Traditional risk management was unsuccessful, and current management is still short in time and scarce in results; it is necessary to allocate more measures and economic resources to river restoration, both as a mechanism for ecological improvement and as a set of nature-based solutions for flood management.
- 3) Recent extreme events in different rivers (e.g. DANA of October 2024 in Valencia) are reactivating proposals to recover old hard engineering actions, which would be very negative in the case of the Ebro River, leading to the mistakes of the past; in the face of this, it is necessary and urgent to consolidate a new model based on adaptation, caution and nature-based solutions.
- 4) The best restoration and management measures that are being implemented in the Middle Ebro River are the setting back of banks, the creation of controlled flooding areas flooded from downstream, relief channels and permeabilization corridors that recover secondary channels. The observations and measurements carried out demonstrate the good functioning of these measures.
- 5) However, defences have not been removed on the concave banks of the meanders, which prevents the recovery of channel dynamics and the contribution of more sediment to the processes; it would be highly advisable to address these actions as well.
- 6) In the urban areas affected by floods, there is a lack of emergency protocols that are known to all inhabitants; especially in the larger areas (Zaragoza city), this deficit must be overcome.
- 7) The SEDEXCHARE project is working on the creation and application of a river resilience index that can evaluate the different restoration and management procedures, in order to establish a diagnosis that can be used to propose the most appropriate measures on a global and local scale.

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