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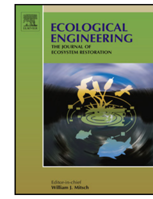

Linking the restoration of rivers and riparian zones/wetlands in Europe: Sharing knowledge through case studies

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ABSTRACT

Floodplains in Europe are heavily impacted by human intervention and often disconnected from the main river channel. Restoring lateral hydraulic connectivity between wetlands, fringe habitats and riparian land with the adjacent river channel is extremely important to maintain natural functioning of floodplain wetlands. However, there is no simple solution to restoring and rehabilitating rivers and their floodplains, particularly in terms of long-term sustainability. Floodplains are often the most fertile and productive part of the landscape, in terms of both agricultural production and natural ecosystems. Restoration projects must be able to balance conflicting needs and interests. Flood management is one of the most powerful drivers of developing strategies for floodplain restoration. Appropriate restoration management of floodplains is vital for the conservation of unique bio-diverse systems and for sustainable agricultural productivity. By developing strategies that better incorporate floodplain restoration in the context of the basin scale, it will become more feasible to develop the most effective restoration actions for a specific river type and location. Within this context we must not forget that successful natural resource management is much more than developing good science; it requires working with landowners, meeting deadlines, securing funding, supervising staff, and cooperating with politicians. Furthermore, the benefits of floodplain restoration must be equally demonstrated for multiple purposes including a range of ecosystem services. This paper explores the various interactions associated with floodplain dynamics. Through case studies it explores the various approaches that have been taken across Europe to forward the restoration of these fragile and important ecosystems and embeds these in the context of current European environmental policy and directives.

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1. Introduction

Riverine systems and, most specifically, their associated wetlands have been significantly altered and degraded in Europe with perhaps 50% of the European population living on former areas of wetland (Hughes, 2003). Across Europe 50% of wetlands and more than 95% of riverine floodplains have been converted to urban and agricultural lands. For some river systems such as the River Seine in France, these figures are nearer to 99%. In addition to land use change, other causes of disconnection between the river and its floodplain are the deepening of rivers through dredging and confinement of rivers to an unnaturally narrow channel; such alterations are widespread in Europe but especially in Italy and France, where incision of the bed as a result of such river confinement can reach up to 10–12 m (Rinaldi et al., 2011; Surian et al., 2009; Surian and Rinaldi, 2003). As a consequence, in most fluvial ecosystems in Europe, the hydrological connectivity between rivers and their floodplains has been restricted to groundwater flow pathways, while geomorphological dynamics that reshape rivers and floodplains are mostly absent (Heiler et al., 1995; Hohensinner et al., 2008; Tockner et al., 2010), resulting in the decline of natural wetlands (Bruijse et al., 2002; Tockner et al., 2009). Moreover, even in situations where floodplains have not been claimed for agricultural or urban use, natural riparian wetland vegetation has often been removed to give way to larger areas of dryer forestland. Such forest encroachment due to land use changes and water abstraction will

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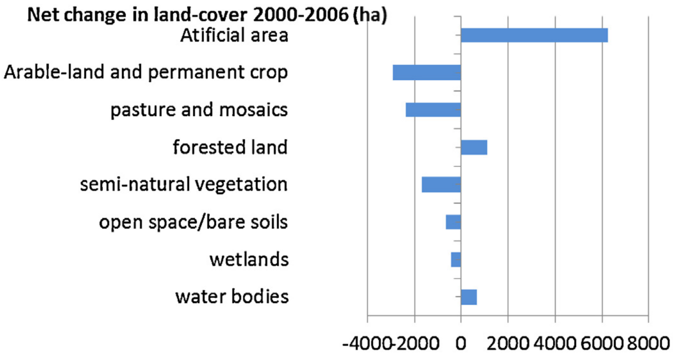

Fig. 1. Total area, in hectares, of net land-cover changes in Europe between 2000 and 2006
Source: EEA/ETC-LUSI, 2010.

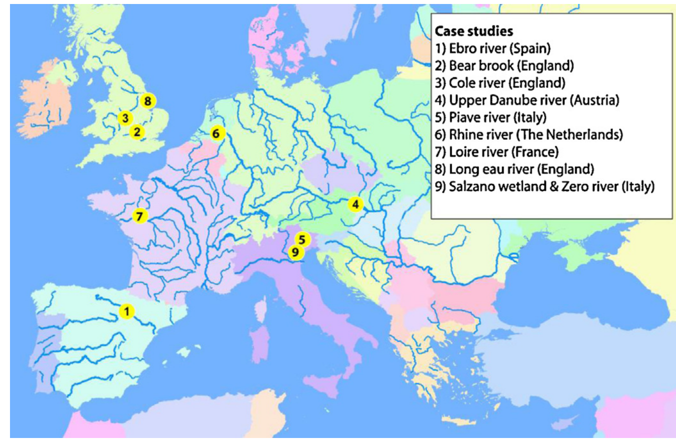

Fig. 2. Map of Europe with the location of all case studies described in the paper.

result in a significant reduction in floodplain dynamics and narrowing/loss of the riparian margins functionality (Keesstra et al., 2005; Keesstra, 2007; Piégay et al., 2004).

Between 1990 and 2000 woodland creation and natural afforestation resulted in a total of 68.3% of wetland habitat consumption (EC, 2007a). During the same decade urbanization expanded considerably encroaching on nearly 8000 km^2 of land, representing a 5.4% increase in urban land cover during that period. Urbanized land, forest cover, and artificial open water surfaces increased whereas agricultural lands and wetlands have declined significantly. To further demonstrate the fragility of these floodplain ecosystems, even semi-natural wetland areas continued a downward trend from 1990 to 2000 (Romanowizc et al., 2006). Increasing needs for access to water-resources will continue to impact on society's willingness to undertake wetland conservation efforts. Society must remain mindful of the abundant resources associated with these biodiversity-rich natural and semi-natural wetlands, even in the face of expected continued declines, albeit more slowly as indicated through documented trends recorded between 2000 and 2006 (Fig. 1). Water surface areas have increased as a result of the development of new detention basins, artificial lakes and reservoirs, which have little natural functionality to support ecosystems or provide habitat connectivity (EEA, 2010).

1.1. *Integrating societal needs with river, wetland and floodplain functioning*

The use of floodplain areas for economic gain has always brought further river and floodplain habitat degradation. This reflects not only the choices we make as a society but also the fact that, until recently, the contribution these ecological systems make in terms of climate regulation, air and water purification, flood protection, soil formation and nutrient cycling has not been sufficiently recognized (Brander et al., 2006). More recently, the concept of ecosystem services has begun to consider these elements and provides a mechanism to evaluate these benefits alongside costs. A key question to arise in Europe during the last decade however, has been: "Can river systems be designed to support both commercial activity and ecosystem functions? Across Europe this is now starting to be addressed through changes in policy as discussed in DEFRA (2007, 2010) where, for example, floodplains are recognized as an important part of the functioning river system and that to achieve the greatest benefit for social and economic well-being reconnection to the associated wetland and floodplain is an essential consideration within spatial planning.

In the context of societal needs and understanding the synergies between river and wetland functioning it is suggested that a paradigm shift is required away from current land use planning and rivers management. In essence only long-term well supported cost/benefit analysis in conjunction with stakeholder consultation and understanding of the dichotomy of issues will enable this to occur. One such activity funded through the European Community Life+ "information and communication initiative", is the RESTORE project (see www.restorerivers.eu). This initiative provides a delivery mechanism to promote the importance of rivers and their floodplains across Europe that is the topic of this paper.

1.2. *Aim of paper*

This paper uses a set of case studies that discuss the current issues surrounding wetland/floodplain restoration and connectivity with rivers in the context of balancing conservation, agricultural, economic and societal needs.

The aim is to demonstrate how different suites of local circumstances have resulted in various approaches being implemented depending, to some extent, on the specific range of social and economic needs of the floodplain but also in the context of top down policy drivers. A short discussion of these key policy elements is followed by examples in which key topics are examined and discussed in more detail. The importance of understanding not only the concepts of natural dynamics and process but how these elements are instrumental in driving and delivering floodplain restoration for a range of environmental and economic goods and services are considered which has rarely been addressed. The location of each case study can be found in (Fig. 2) and key elements of these in terms of drivers and benefits are summarized in Table 1.

2. European policies in context

It can be argued, that policy initiatives in response to the decline in riverine and wetland ecosystems began when the international Ramsar agreement was signed in 1971, under which more than 950 European wetlands of international importance totaling a surface area of more than 25 million hectares are now listed. However, in many European Member States, responsibility for water and associated wetland management is often either split between different parts of the same organizations or indeed between entirely different organizations. This often results in a conflict of interests and missed opportunities that could enable more strategic thinking about wetland and river multi-functional use for flood risk, habitat enhancement and public amenity. Even in France, for example, where the Law on Water was introduced in 1992 followed by a National Action Plan for Wetlands in 1995, actual implementation

Table 1
Summary of the main features that characterize the case studies described.

Name	Country	project area/length km^2	Main actions	Completion date	Major restoration drivers	Coherence with European policies	Stakeholder involvement and approach	Key benefits
Ebro River	Spain	1.13 km^2	Removal of embankment	2009	Flood risk	Habitat, WFD, Flood risk	Informal participatory process	Enhance habitat diversity, refuges for protected species
Bear Brook	United Kingdom	1 km	Creating a meandering river, with riffles and pools, and reconnection to the floodplain	1993	Flood risk, habitat creation and access for people	WFD, Flood risk	Primarily top down but with public meetings.	Appraisal in 2006 demonstrated flood benefit was significant. ecological improvement for fish and macrophytes
River Cole	United Kingdom	2 km	Creating a new meandering river with pools and riffles, change of land use	1997	Habitat creation, flood risk benefit and access for people	WFD, Flood Risk, and habitat directive	Stakeholder meetings and questionnaires to evaluate local community concerns and requirements	Reconnection to the floodplain benefit for flood risk. Improve habitat although fish passage is still limited.
Danube River	Austria	5.5 km^2	Lowering of embankment and check dams to approach pre-regulation condition	2001	Improve water quality (surface water exchange)	coherent with river basin management plan (ICPDR), National park management plan and WFD	Top down	Basic floodplain properties Improve habitat availability
Piave River	Italy	Area: 9.2 River: 2.6	River: new embankments and groyings to protect the adjacent wetland Wetland: specific actions aimed to improve habitats	2009	Improve biodiversity of the wetland complex	Non coherent with WFD Dilemma about the coherence with NATURA 2000	Top down Expert pannel	Increase/improvement of wet habitats and related species
Rhein river	Netherland	Spread area	Natural grazing processes	Still active	Flood risk	Flood risk	Farmers by PPP	Sustainable agricultural activities
Loire Grandeur Nature Plan	France	Spread area	Improve habitats River functional corridor Sustainable management	Still active	Flood risk, biodiversity Conservation of water resources	Flood Risk	Multi-actor planning process Participatory process	Sustainable agricultural activities
Long Eau	United Kingdom	Spread area		Still active	Flood Benefit and biodiversity improvement	Flood risk but in-channel WFD benefits limited due to continued maintenance in the short time. Now changes to this but too early to demonstrate clear benefit.	Discussion with local land owner and agreement that current approach was not successful. Stakeholder engagement however, limited.	Success in terms of floodplain reconnection and benefits for flooding downstream. The success within the channel is more limited.
Venice lagoon watershed	Italy	Spread area	Restore query to wetland Newly afforested, sub-irrigated riparian buffer	2009	Improve water quality in Venice Lagoon	WFD, Flood Risk, Habitat Directive	Diversified and informal engagement of Stakeholders	Flood risk and better ecological status

was initially slow due to lack of strategic powers and associated funding. Eighty seven wetlands of national importance have now been identified by the Ministry for the Environment in France (Moss and Monstadt, 2008) and similar initiatives to restore and protect floodplain areas across many European countries have been prioritized in an effort to protect endangered species. This required the development of trans-boundary consortiums to create action plans for threatened species. This has often been completed with the support of European funds (such as the LIFE program which supports environmental and nature conservation projects). Many of these plans have focused on Natura 2000 sites (EC, 2007a) as identified under the Habitats Directive (1992). These Natura 2000 sites comprise Europe's network of more than 26,400 protected natural areas, with a total area of 986,000 km^2 (70% of the European protected areas), covering almost 18% of the European landmass (EEA, 2012). These protected habitats provide an important refuge for many of Europe's endangered species of which, for example, 151 invertebrate species are identified in annexes II and IV of the Habitats Directive. More recently some key policy documents have been driving water and wetland development and have aimed to incorporate ecological improvements in the context of other societal drivers. These are outlined below.

2.1. The Water Framework Directive (WFD 2000/60/EC)

This key European Directive focuses on preventing the deterioration of water bodies (EC, 2000, 2007b) and critically has provided a new framework for integrated river and wetland basin management, protection and restoration, with links to various other EU nature conservation policies (EC, 2011) including the Habitats (92/43/EEC) and Birds directives (79/409/EEC). It does not explicitly set environmental objectives for wetlands, but those features that either recharge groundwater aquifers, form part of a surface water body, or are designated as protected habitats (sites of community importance) will benefit from WFD-mandated efforts to protect and restore the water bodies (Art. 4). For some water bodies, the structure and condition of wetlands in the riparian, shore or intertidal zones will contribute to the achievement of targets for biological quality. In addition, to having GES (Good Ecological Status) as a focus, this European directive has put emphasis on engaging the public in the process of achieving this water body status (Art. 5). One of the main challenges however, is to consider the water resource management within long-term strategic planning processes, based on management actions, cost/benefits analysis and new governance arrangements at different spatial scales. To achieve this aim, the WFD encourages scientists and managers to work more closely and to involve stakeholders throughout the decision-making process. This is a significant challenge since Europe's integrative science is adopted differently between Member States, although public participation is now being recognized as key driver to enhance this interaction (Piégay et al., 2008a).

An example of a participatory tool used in European countries and within trans-boundary River Management collaboration is the "River Contract". River contracts are participative management structures aimed at bringing together everyone working in the same water basin, whether they come from a political, administrative, financial, associative or scientific background, in order to define and sign a program for restoring watercourses and their surrounding areas in a collaborative way. In France, the SDAGE (*the schéma directeur d'aménagement et de gestion des eaux*) is the organization of the development and management of water resources and is based on a watershed unit. The scheme was drawn up together by national, regional and departmental governments and whilst managed by the water agency, they incorporate the views of and consult with a range of stakeholders to deliver plans for the management of the basin over specific time frames. One such example can be found at the L'eau en Loire-Bretagne website (www.eau-loire-bretagne.fr/Sage) where current plans are identified for a 6 year period from 2010 to 2015 to coincide with the WFD delivery timescales.

2.2. The Flood Risk Management Directive (2007/60/EC)

Another European Directive that could have significant implications for wetland and floodplains restoration is the adopted Flood Risk Management Directive. This directive requires member states to assess the flood risk in the context of assets, cultural heritage and human health and take adequate and coordinated measures to reduce associated risk. The directive states the need to co-ordinate these goals with those of the WFD, yet to date, the development of strategies to achieve this are still under discussion. Furthermore, whilst the favorable conservation status associated with natural wetlands as a buffer zone to pollutants (Mant, 2002; Pinay et al., 2006), and to provide biodiversity hotspots is increasingly recognized, they are not always considered as an effective way of achieving sustainable flood risk measures through water retention. Unfortunately there are still significantly different approaches to flood risk management across Europe. In several countries especially the Netherlands and Denmark, there are examples of technical solutions to cope with flood risk through the design of retention-based floodplain areas, the inclusion of secondary channels to alleviate flood risk and most specifically reconnection of the floodplains to the main channel (Vivash et al., 1998). On the other hand, like in Italy, artificial heavily engineered structures (e.g. retention basins) are still generally considered the best or even the only solution to cope with flood risk. This directive should have some significant benefits in term of flood retention, but unless formally linked to WFD it does not directly encourage the use of natural flood management processes for the benefits it offers compared to engineered concrete structures (see for further discussion http://www.environment-agency.gov.uk/research/planning/136425.aspx).

2.3. Common agricultural policy

The WFD and the Flood Risk Management Directives are valuable policy tools that aim to tackle some the most difficult water-related challenges. However, there are other policies that can and/or could help to make the much needed links between rivers and wetland areas. Perhaps, one policy that is potentially able to do this is the European Common Agricultural Policy (CAP). The EU spends around 55 Billion Euros per year on agricultural subsidies (http://farmsubsidy.org) and currently there is a debate about how to introduce a green payments into the next CAP reform period (from 2014 to 2020). These discussions are based on integrating existing environmental obligations including: (i) a baseline link with WFD requirements, (ii) the obligations for farmers to ensure that at least 5–7% of their eligible hectares, excluding areas under permanent pasture, are ecologically focused; and (iii) erosion control through crop rotations that can contribute to the provision of public goods related to water quality and quantity protection. The ecological areas should functionally integrate wetlands, riparian zones and buffers into the agricultural landscape, providing benefits for water quality, biodiversity and climate change mitigation and adaption (Matthews, 2012). It is a real opportunity for governments, with the new CAP, to develop environmental standards in agriculture, which would significantly enhance sustainable farming of floodplains (WWF, 2000).

3. Restoring connectivity between rivers and floodplains

Hydrology is the most important determinant of wetland conditions and dynamics, therefore water management is most often the key-driver to wetland restoration. Anthropogenic changes on floodplains affect hydrologic connectivity and in turn alter flow dynamics often preventing the flood flows spilling onto floodplains which are essential for ecological functioning of river systems in terms sediment redistribution and replenishment of habitat features. To restore, or allow for, a more naturally functioning floodplain dynamics it is essential to work with the current hydro-geomorphic regime and understand how this interacts with biological processes (Palmer et al., 2005; Rinaldi and Gumiero, 2008; Piégay et al., 2008a; Rinaldi et al., 2009). Thus, it is known that improving the ecological status of many of Europe's main river systems would be achieved by increasing the hydraulic connectivity between the dredged and canalized river sections and reconnection of their long abandoned floodplain and oxbow lakes (Kondolf et al., 2006; Perotto-Baldivieso et al., 2011). On the other hand still social and economic pressures often dictate that floods are controlled or diverted and this outweighs concerns for habitat and the maintenance of natural river and floodplain dynamics (Acreman et al., 2007).

In order to encourage the reconnection between the canal and its river corridor and provide the necessary space for water to move across the riparian corridor some strategies have been developed and applied within European Water Management Plans such as the "functional 'mobility' corridor" (Malavoi et al., 1998), the 'Erodibile Corridor Concept' (ECC Piégay et al., 2005) and the 'room for rivers' (Alberts, 2009; EA, 2009). There are indeed many reports and government initiatives that recognize that natural processes are necessary to enable riverine ecosystems to provide sustainable management of flood risks; e.g. European Commission (2003) and DEFRA (2004). In addition, the return of lateral connectivity to convey flood pulses and transport/store sediment can reduce unpredictable bank erosion which ironically was one of the reasons for initially constraining and confining our rivers (Piégay et al., 2008a; Rinaldi et al., 2009). Indeed, where a river is connected a floodplain area it will respond to external climatic and human-induced changes, and find a new equilibrium state that in turn will support a mosaic of self-perpetuating habitats and geomorphologic forms and processes. Recognizing that these systems are naturally dynamic and working with natural processes wherever feasible could significantly reduce maintenance needs (Kondolf and Piégay, 2003; EA, 2010) and sometime the cost of the project as demonstrated in the Ebro river, the first in a series of case studies described below.

3.1. Establishing a functional 'mobility' corridor along the Ebro River

One example of this approach to riparian reconnection is demonstrated on northern Spain's River Ebro. The middle reaches of the Ebro River have seen massive hydraulic alterations to control flooding. Large reservoirs and embankments were constructed along the river to protect agricultural lands, but these defenses have not provided the expected level of protection. Floods still occur and are now potentially more destructive than before construction. The retention of sediment in reservoirs resulted in channel downcutting below them as the flowing waters sought to regain their natural sediment loadings. As a result, secondary channels that previously conveyed some flood waters became disconnected and ground water levels declined (Ollero et al., 2007).

Solutions for this issue included the naturalization of flow regimes and riparian-zone rehabilitation, in at least some floodplains that were disconnected from the main channel, with sustainable solutions to flood risk as the main driver. One restoration project was carried out in Soto Tetones, along 113 ha of floodplain located 3 km upstream from the town of Tudela. In 1970, this area was owned by the local municipality and was cultivated by local tenant farmers. Irrigated rice crops were very profitable and the mosaic of floodplain habitats was leveled to facilitate expanded rice cultivation resulting in the loss of riparian wetlands. However, over time it became apparent that this intensive agriculture approach was not sustainable. Fifty centimeters of fine sediment built up in rice-paddy fields resulting in reduced permeability of riparian soils. This resultant impermeable layer impeded the vertical movements of water and prevented groundwater recharge. Furthermore, a soil and riparian vegetation survey (showing the encroachment of salt-tolerant plants) indicated that the changes in hydrological condition had exacerbated salinity concentrations. These alterations together with river embankments, the construction of roads and concreted waterway for irrigation only served to further negatively affect the natural hydrologic flows of the riparian zone and significantly began to reduce rice crop yields (Ollero, 2007).

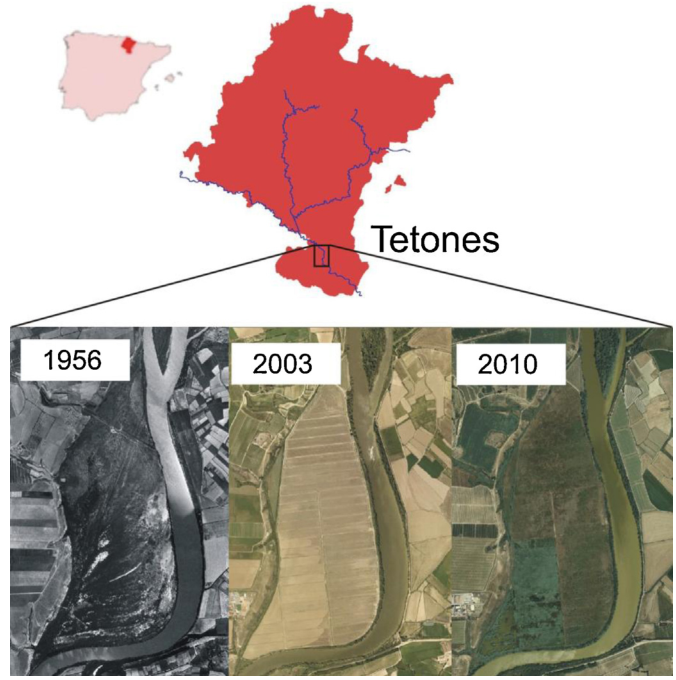

Fig. 3. Aerial view of Soto Tetones: before (1956) during (1980) and after (2006) rice crop.

The restoration began in 2006 with the removal of all man-made structures in this 113 ha area. Embankments were removed to increase flooding frequency and reactivate the floodplain's natural dynamics (Fig. 3). In addition, all 113 ha were deep-ploughed to improve soil permeability and allow groundwater recharge (Ollero and Elso, 2007). No planting was done as it was expected that floods would bring seeds and natural sediment on which vegetation would develop. Natural sedimentation processes were also encouraged to enhance habitat diversity. Subsequently, flood frequency has increased, riverside vegetation has become naturally established, and grassland areas located further away have flourished. White poplar (*Populus alba*) forests were the first communities colonizing the southernmost area of the floodplain and slowly other typical species from Mediterranean river forests such as French Tamarisk (*Tamarix gallica*), Black Poplar (*Populus nigra*) and Common Ash (*Fraxinus angustifolia*) established. The phreatic level also allowed formation of wetlands where aquatic vegetation such as Broadleaf Cattail (*Typha* sp), Prairie Rush (*Scirpus maritimus*) and Common Reed (*Phragmites australis*) developed, together with species that need salty environments (Alkali Seepweed *Suaeda vera* and Glasswort *Salicornia patula* or Saltmarsh Alkaligrass *Puccinellia fasciculata*) along the borders of the wetlands. In areas were the phreatic level is lower, grasslands dominated by Thinleaf False Brome (*Brachypodium phoenicoides*) and Couchgrass (*Elytrigia campestris*) are becoming established with Bulrush (*Scirpus holoschoenus*). The restored riparian areas now provide habitat heterogeneity for several important species. Among the aquatic birds, the presence of breeding couples of Purple Heron (*Ardea purpurea*), Eurasian Bittern (*Botaurus stellaris*) and Little Grebe (*Tachybaptus ruficollis*) have been observed, whilst the presence of European Pond Turtle (*Emys orbicularis*) has been detected and European protected species such as Otter (*Lutra lutra*) and European mink (*Mustela lutreola*) have now found refuge in Soto Tetones (Ollero et al., 2007).

The success of this example, in terms of return to more natural flood dynamics, has demonstrated that flood flows are essential for the ecological functioning of riverine communities. They play a crucial role in the geomorphological dynamics of river systems by transport and redistribution of sediment, formation of sand and gravel banks, changing the channel morphology, the development of new channels and wetlands, rejuvenation of riparian vegetation, replenishment of nutrients, recharging of groundwater (Ollero and Elso, 2007). With the advent of river basin management planning, there is now a viable opportunity to build on current examples of success such as this example, to learn how hydrogeomorphic assessment at the basin scale, can become an integral step in the process of wetland creation and floodplain reconnection. It is important to note the first agreement between the municipality and the Regional Government of Navarra to improve floodplain management at Soto Tetones was signed in the mid-1980s, with a target that restoration be completed by 2003. This level of forward thinking demonstrated that, with stakeholder agreement, ecological benefit can be restored and, given sufficient time, the local community can adjust to the need to change in land use for better management of water and biological resources (Ollero, 2007; Ollero et al., 2007; Ollero and Elso, 2007). The final cost of these restoration works was only 145.184€ to recover all 113 ha of the Tetones floodplain. In today's context the project demonstrated that it could integrate at least three EU policy directives (i.e. Habitat, WFD and Flood Risk) and open new opportunity for the new CAP 2014-2020.

3.2. When natural regeneration is more difficult

The role of natural processes in river restoration efforts is dependent on the type of river system. For example, in low energy riverine systems it may be necessary to consider a much greater intervention to achieve morphological reconstruction of the river and its connecting floodplain environment, because natural channel recovery (Brookes, 1988) may not provide the range of habitats needed for ecosystem functioning. A river can only re-adjust naturally if the balance between stream energy bed and banks sediment cohesion, and the frequency of channel-altering floods will determine how a system responds (Wasson et al., 1998).

The Bear Brook is a small clay catchment river system situated in Alyesbury, England that provides an example for restoration of a low-gradient stream. As part of a flood alleviation scheme in 1993 where flood risk was the key driver, a section of the Brook was re-meandered for 1 km with low berms constructed and banks reshaped to gently slope to the water's edge. The bed depth was reduced by cutting a new channel at a higher elevation, allowing water to spread onto surrounding parkland during flood events (Fig. 4B). The re-meandered channel was smaller than the previous water course but nonetheless was actually still over-sized for the site's flow regime. This enabled silt to deposit within the channel and the river began to naturally narrow. By 2006, this low energy brook had narrowed by more than a meter in places. The brook acted as a sink for material that helped shape an appropriate form for the hydrological regime. If the bed had been dug too narrowly in the original design, it would not have had the opportunity to adjust in this way. This specific issue was previously observed on another lowland restoration project on the river Cole at Coleshill, England where habitat gain and flood risk benefit was the primary focus. In the case of the river Cole, where cohesive clay dominated in the catchment, the river has had no opportunity to adjust in size since it was designed strictly to take low flows (Fig. 4D). Ten years of repeat fixed-point photography carried out by the UK's River Restoration Centre has indicated that there has been no resultant change in channel cross-section size at this site. Nevertheless, both projects have shown significant benefits in terms of habitat improvement and reduced flood-risk and these are discussed along with the specific issues associated with restoring lowland streams in Biggs et al. (2001) for the river Cole.

A series of possible strategies, based on recent experiences with incised rivers (Habersack and Piégay, 2008; Rinaldi and Gumiero, 2008), have demonstrated that channel widening or recreation of an active floodplain by lowering the terrace surface and/or secondary (side) channels can allow a river system's natural geomorphic dynamics to be kick started. In such cases, naturally occurring sediment is re-mobilized through the lowering of the terrace (Rinaldi et al., 2011). Floodplain lowering is also becoming promoted as a win–win perspective where gravel extraction companies can participate with collaborative actions. Such opportunities, however, need careful monitoring and decision making to understand how the sediment-derived features will develop over time in conjunction with the specific flow regime. The sediment extraction can be managed to restore floodplain processes through flood dynamics aimed to develop natural morphological features. One example is currently being designed and implemented in Milton Keynes, England with the aim of creating a wetland forest area with multi-habitats and local amenity value (http://www.therrc.co.uk/rrc_case_studies1.php?csid=64). Because of its links with a gravel removal company there has been considerable efforts made to ensure that all local stakeholders are well informed of the process with public meetings and updates on progress and ideas regularly disseminated through local community web-based newsletters.

3.3. Effects of changed hydrological connectivity on nutrient cycling of floodplains

Floodplains are also an essential component to control nutrient cycling within river systems with the emphasis on improving water quality. Biogeochemical hot spots in nitrogen cycling (sensu McClain et al., 2003) are closely linked to hydrological exchange conditions between uplands and wetland systems. Similar effects of increased nitrogen cycling controlled by lateral exchange can also be observed between floodplains and river channels (James, 2010; Welti et al., 2012). The Upper Danube River Basin is an example of a river that has been subject to extensive hydro-morphological alterations (regulation, channelization, dam constructions) (Sommerwerk et al., 2009). This has resulted in wide habitat destruction and disrupted habitat continuity with few remnants of native wetlands sections still functionally intact (Hohensinner et al., 2008). Assessments for the Water Framework Directive (ICPDR, 2009) resulted in moderate ecological status or

Fig. 4. (A) Aerial view of the Bear Brook and flood storage/overspill area. (B) Four years after the scheme and vegetation is shaping the low flow channel, establishing in the deposited silty margins. (C) In 2006 narrowing as a result of silt deposition and marginal plant growth. The open channel section has a clean bed. (D) The river at Coleshill 10 years after restoration showing little development from its dug dimensions; no deposition occurs due to the 'accurate' sizing of the channel for its flow regime and hence no marginal vegetation.

potential in heavily modified river sections for most of the Upper Danube stretches. In Austria, one of the two remaining free-flowing reaches with a better ecological status along the Upper Danube River is a 48 km floodplain section downstream from Vienna, toward the Slovakian border. Even here there has been a loss of riverine landscape, and improvement of the river floodplain connectivity is now being undertaken. The area is public and part of the National park "Donau-Auen", established in 1996. As part of the national park management plan, one aim is the re-establishment of the former continuous upstream connection, by restoring its natural branching system, with several floodplain segments to partly re-gain the original mobility of the channel. The effects of these efforts have been considerable, including a floodplain area of around 5.5 km^2 on the Orth floodplain that was reconnected with the Danube's channel by different measures (Fig. 5). Surface water connectivity increased from less than 30 days to more than 220 days per year leading to lotic conditions and an enhanced sediment dynamics during more than 50% of the year (Hein et al., 2004). To achieve this goal have been carried out many restoration activities like: (i) removal of riverside embankments (former tow path) at three former floodplain channels, (ii) removing a check dam, and (iii) building one culvert in a check dam within the floodplain system. The increase in surface water exchange has also led to greater nutrient loading from the river being transported into wetland areas as shown for nitrate concentrations of a connected side arm versus water retention time (Fig. 6) (Hein et al., 2004). The

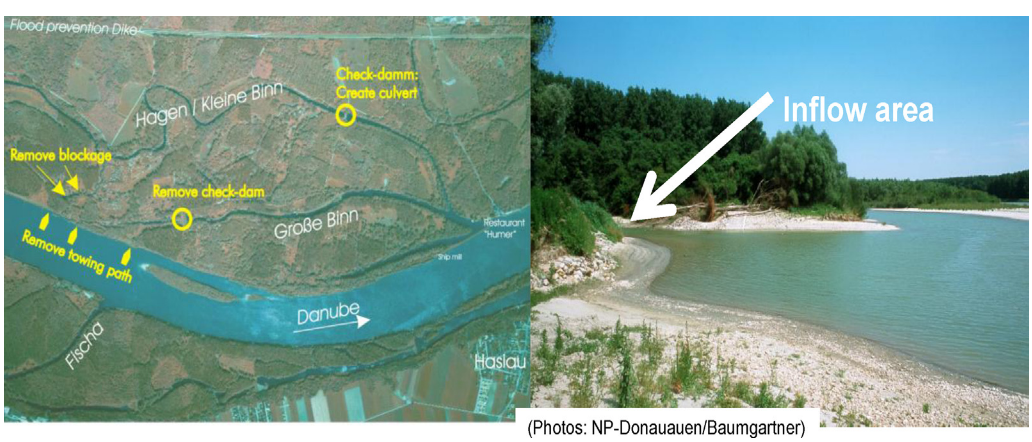

Fig. 5. Left picture: Satellite image of the restoration measures in the floodplain area of Orth. The "birds eye view" clearly shows some old anabranches and meanders and the measures implemented.– © NationalparkDonau-Auen and OeBF group. Right: Photograph of the inflow area in Orth. Right side of the photograph the river main channel can be seen.– © NationalparkDonau-Auen/Baumgartner.

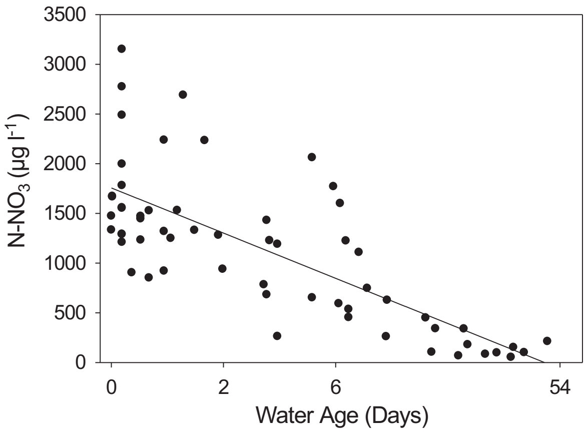

Fig. 6. Water age in the floodplain versus nitrate concentration in the floodplain ($n = 52$). Water age is a measure of water retention time in the floodplains depending on surface water river input (low water age implies high river water input, see Hein et al., 2004). Nitrate concentrations at a water age of zero resemble the concentration in the river channel. Measurements of water between 2006 and 2009 in the restored system Orth.

Fig. 7. Partial view of the portion of Piave river bordering the Nature reserve; in the upper part it is possible to see a portion of the impressive system of groynes and bank protections built to protect the reserve. The wetlands, not visible, are located inside the riparian forest.

productivity of the riparian system became stimulated by these riverine inputs leading to enhanced nutrient cycling and retention and more export of aquatic produced organic matter to the river channel (Hein et al., 2005).

The restoration of floodplains has also induced increased microbial activity in the system with greater inputs of nitrate and organic matter. Decreased oxygen concentration in the sediment stimulated efficient nitrate turnover especially during higher flows. Welti et al. (2012) assessed the importance of restored sites compared to degraded sites as biogeochemical hot spots at the landscape scale and found inundated areas in the restored floodplain had the greatest potential for de-nitrification and a lower potential for nitrous oxide emission. This exemplifies that restored areas experiencing frequent pulses of nitrate input are activated in terms of nitrate cycling and can be of significance for the overall retention especially during flow and flood pulses in a particular river section. Clearly, increased hydrological connectivity can activate floodplain areas to become important biogeochemical transformation sites and improve the ecosystem capacities to retain and process nutrients delivered from upslope catchments and also improve water quality, an important goal for river restoration.

3.4. Conflicts between wetlands biodiversity and river-floodplain reconnection

An example of conflicts between species protection and natural dynamics come from a system of wetlands namely, Vincheto di Celarda Nature Reserve (protected by The Ramsar Convention on Wetlands) located in the floodplain of the Piave River, in northeastern Italy. This wetland complex is surrounded by perennial water courses. There is an abundance of channels, supplied by springs, and bodies of water within the area. This has given rise to the presence of a very interesting range of flora and fauna, with the presence of rare and endangered vegetation types and of valuable communities of birds. The riparian forests and the wetlands system were recently restored by a LIFE Nature Project. Three main actions were planned and realized after consultation with a restricted panel of experts since the land was public and little consultation was required: artificial formations dominated by spruce were cut to enhance the restoration of riparian forests; dead wood was released to promote the settlement of the saproxylic fauna; a network of small canals was restored (widening and diversification of sections) and the surface area of wetland habitats has been increased. This last action led to an improvement of the habitats for the native river crawfish (*Austropotamobius pallipes*) as well as for all those species of invertebrates, amphibians, fishes and birds which depend on wetland habitats for food and reproduction. Rare and interesting vascular plants from the water crowfoot species such as *Ranunculus tricophyllus* and *Ranunculus fluitans* increased their populations which in turn create habitat structure for other species.

The Piave River rises at an elevation of 2037 m a.s.l. and has a length of 222 km. It flows from its source in the Dolomites, via the Venetian Pre-Alps, to the Venetian Plain. In its middle course, where the river is very wide and characterized by a braided channel pattern, significant channel changes have occurred during the last century due to hydroelectric dams, flow diversions, gravel mining and bank stabilization structures. The channel has decreased in average width to 35% of its initial value, while the braiding index proposed by Ashmore (1991) has decreased from about 3–1.5. In several reaches the planform pattern has changed from braided to meandering. These observed trends have been deemed likely to continue in the immediate future (Surian, 1999).

At this unique and protected wetland site, the Piave river is still potentially active (Surian et al., 2009) in terms of lateral movement, but the riparian wetlands are not directly connected to the river because of embankments and other structures, some specifically placed to protect the wetland reserve (Fig. 7). A dilemma here, as discussed by Newson (2010), is how to balance needs to conserve specific species with the need to restore natural processes at sites where new species have appeared and/or has been managed for a specific species. If one considers that the EU Water Framework Directive identifies the importance of natural geomorphological dynamics in rivers and on associated floodplains then in some cases this might be in direct opposition to the protection and the conservation of wet ecosystems that have developed overtime. In such situations decisions need to be made about whether or not it is in the best interest of habitats to continue to constrain some of the natural river geomorphological dynamics or, recognize that conservation actions must be planned working with natural process to achieve habitat heterogeneity appropriate to the hydrological range (i.e. what it can naturally support). Although it is not an easy problem to solve what arise from this example is that an integrated restoration projects need consultation beyond expertise in species conservation. In another example discussed by Acreman et al. (2007) on the Tisza River is emphasized that, although increasing the interaction between a river and its floodplain wetlands should benefit river ecology, the current ecological conditions and local vulnerabilities need to be considered based on their function and the environmental services they provide.

4. Participatory processes and tools, experience from Danube Basin

As a regulated river system that is used primarily for navigation purposes the Danube River of the estimated original 26,000 km^2 of floodplain area, 20,000 km^2 have become "functionally" lost (Tockner et al., 2009). The International Commission for the Protection of the Danube River (ICPDR) provides an example of how using wider scale planning instruments and developing new ecosystem service concept-derived tools can help to inform future policy and delivery of more effective integrated management.

The ICPDR is responsible for balancing all the stakeholder requirements of the basin including those associated with environmental and water quality, and navigation issues (ICPDR, 2007a). This is being achieved through a joint statement with the agreed basis of ensuring integration through good sustainable waterway planning practice through developing theoretical ideas into practice (ICPDR, 2007b). As part of this initiative, the aim is to facilitate the exchange of best practice cases to allow for much better integration between waterway planning in Western and Eastern Europe (the PLATINA project http://www.icpdr.org/main/publications/project-east-vienna-public-participation-situ-tests). The key task of this program is to preserve a sustainable functioning "Danube-River-Cultural-Landscape" ensuring the range of associated ecosystem-driven services will continue to be available and functioning for to future generations (Junghwirth, 2012). For this reason one of the priorities within a cost/benefit analysis framework is valuing the water-related environmental goods and services that are not traded on markets to establish the willingness to pay for river restoration (Bliem and Getzner, 2012). To achieve this, the ecosystem services deriving from the reconnection of Danube floodplain were analyzed through the European project "Aquamoney" (www.aquamoney.org) which brought together research teams from more than ten European Countries to test the assessment of environmental and resource costs and benefits of river restoration (Brouwer et al., 2009). The outputs from this project provided the impetus for two important policy-forming papers namely; the Millennium Ecosystem Assessment (MA) (http://www.unep.org/maweb/en/index.aspx) and the Economics of Ecosystems and Biodiversity (TEEB) (http://teebweb.org) where the importance of river and wetland connections are clearly stated to allow for the delivery of a range of importance natural services for the benefit of society.

In essence, the program clearly identified that in order to develop and identify strong acceptable economic and social restoration opportunities for rivers and their floodplains, it was significant to adopt a bottom-up approach through participative processes. To achieve this it was essential to identify and/or develop good and appropriate scientific SSD (Support Systems for Decision making) tools, that are able to implement multi-criteria analysis (MCA), to explain the complex and multi-variant stakeholder points of view and then, in turn, be in a position to assign satisfaction levels for each decision process (Corsair et al., 2009; Turner et al., 2000). The program, however, identified that even though some examples could be found where such a MCA approach had been taken (see for example http://www.share-alpinerivers.eu), tools that lead to a better understanding of the dichotomy between preserving river ecosystems and the development of hydropower schemes as a service, for example, are not yet commonly used. This is in part because of the lack of knowledge about how to implement the tools, but also because current systems are not always readily adaptable to specific local situations. Despite this current under development of tools to explain stakeholder perception, most European directives state stakeholder participatory processes as an essential element to achieving long-term sustainable results.

5. Agriculture and heritage management in rehabilitated floodplains

5.1. Public–private partnership within the floodplains

When implementing a riparian restoration project if land acquisition in not being pursued, then a contract with private partners will be necessary (i.e. a public–private partnership PPP). In this case, rights to implement planned measures must be documented as part of the agreements (Rijkswaterstaat, 2009). This type of PPP partnership approach is being pursued in floodplains throughout northern Europe. Here we evaluate this type of management through three case studies that involve agricultural activities in the Rhine and Loire two of the largest rivers in Europe and in one small river in England.

The Rhine River has been extensively transformed to provide safe navigation conditions. Moreover, agriculture expanded after WWII and floodplain areas were converted for pasture and cultivation of maize. Between 2003 and 2008, German and Dutch organizations worked together on the sustainable development of floodplains (SDF project) along the River Rhine. This effort comprised restoration on former and existing floodplains in twelve pilot projects in which measures such as dike relocation (river widening), floodplain lowering, excavation of secondary channels, and natural rehabilitation measures were implemented and evaluated (Nijland and Menke, 2006; Menke and Nijland, 2008; Rijkswaterstaat, 2009). Within the rehabilitated floodplain areas, flooding events are more frequent and this often precludes intensive agricultural uses. In some areas where floods are rarer, where for example, a summer-dike is present or in naturally higher areas such as levees or river dunes, managed low-intensity cattle grazing can allow for conservation goals and provide local recreation opportunities. In the Netherlands, natural grazing processes have been used to foster natural floodplain dynamics since the 1980s. Composition of herds and seasonal grazing needs to be managed carefully to balance between habitat and farming needs. Another major goal to introduce cattle in the rehabilitated floodplains was and still is safety from floods. The cattle can reduce the fast growing vegetation in those new floodplains quite well if the density of grazers (animals per unit area) is appropriate (Rijkswaterstaat, 2009).

In 1994, the French Government initiated the Loire Grandeur Nature Plan, a PPP with aims toward integrated management of the Loire, and meeting the requirements to protect people and property, encourage economic development, and conserve natural heritage. A second phase started officially in 2002 (LGNP, 2011) and enlarged the plan to include tributaries, headwaters and small streams to help achieve integral management of the catchment basin. This plan has three main objectives: protection of biodiversity; maintaining river dynamics and flood expansion zones through a functional mobility corridor and; conservation of water resources. To conserve the biological heritage of this basin, restoration actions have been undertaken for grasslands, floodable meadows, alluvial forests, oxbow lakes, peat bogs, heathlands, etc., and efforts to control invasive species are also underway. Improving management has included diverse practices in meadow and grassland ecosystems though collaboration with farmers to refine grazing or haying systems, implement pastoral works such as fencing, and converting crop fields and poplar plantations into natural meadows. Other actions have included felling conifers to restore

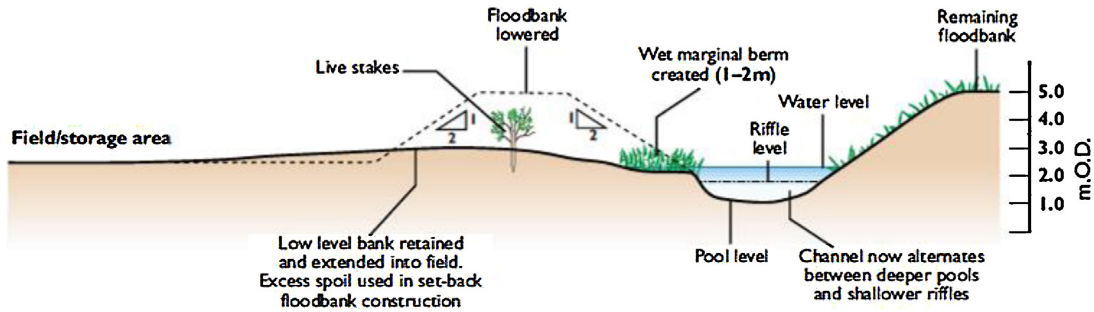

Fig. 8. Cross section of the restoration principles on the Long Eau (RRC 2002).

fragile environments, planting hedges, limiting vehicle access, conservation of islets where terns nest, and removing woody invasive species (LGNP, 2011). Local farmers are partners of the Loire Nature program and since 2006 more than 2000 hectares have been made available to 112 farmers for grazing and hay harvest. Partnership with farmers, which take heritage management objectives and farming constrains into account, are drawn up in various contexts: leases, grazing agreement, availability via the SAFER (society for land development and rural installation) to manage meadows or heathland. These sites can be made available for grazing and also cutting. For example, in the low Angevin valleys farmers follow particular specifications involving the non-use of fertilizer, a limited number of animals per hectare, late cutting using a conservation technique for certain birds such as the corncrake (*Crex crex*) that nest in long grass. The sustainable farming contract is used to allow farmers to obtain agri-environmental subsidies as well. These systems encourage agricultural practices which meet the requirements for maintaining natural environments, and certain rustic livestock breeds such as the Sologne and the Limousine sheep. This example cooperation could be very informative for the new coming CAP 2014–2020.

The third example of a public–private partnerships scheme for river system restoration is the Long Eau, a small river in eastern England. It drains a catchment of about 22.3 km^2 which is predominately agricultural land consisting primarily cereals such as wheat and barley. Until the mid-20th Century a natural floodplain dominated with lapwing, snipe, plover, redshank and other wetland birds present. In the 1940s the river was first channelized and dredged, with levees also constructed long the channel for water conveyance purposes and to enable agricultural development and engineered flood control. Today the Long Eau is a highly regulated river which is kept dredged with shaped and mown banks. Major levees were constructed in the 1980s and water abstractions increased at that time. Despite these flood control efforts, the banks were still regularly overtopped causing damage to crops. The river, although it had reasonably good water quality, had very poor aquatic habitat because of these alterations.

By the early 1990s it became obvious that further dredging and raisings of banks could never completely protect crops and was detrimental to wildlife. The Environment Agency for England and Wales stated that "restoration of the floodplain storage area to enhance flood protection and improve wildlife habitat in the river channel, banks and floodplain" had become a key objective for section of the Long Eau. By setting back or removing sections of the flood bank and allowing periodic flooding of the formerly protected land, it was anticipated that this project would improve flood protection (by sacrificing smaller areas of land) and at the same time benefit wildlife (Fig. 8). The success of this project was primarily a result of key government-funded organizations working together with the local stakeholders and landowners, to not only forward the project, but also develop a 10-year management plan and identify funding opportunities to implement a Stewardship Scheme. These steps began in the early 1990s and by 1995, 10 ha of floodplain were re-opened. Interestingly, an adjacent farmer recognized the value of this scheme and offered additional opportunities. While being attracted by stewardship payments, and the advantage of "sacrificing" less fertile land to the floodplain to better protect productive farmland was obvious (Fig. 9). A second section of banks were subsequently set back. Reconnection of the floodplain was completed in tandem with attempts to introduce better river management practices including management practices to encourage production of aquatic vegetation and natural sediment conveyance (EA, 2011). This scheme is small, but nonetheless clearly demonstrates the issues associated with linking floodplain restoration to the river to maximize habitat benefit. Setting back the levees in this case, has created flood storage of around 600,000 m^3 which has increased

Fig. 9. Left an example of the large levees on the Long Eau prevent connection to the surrounding floodplain. On the right after restoration.

the standard of flood protection on that reach from 1 to a 100 year flood risk at a relatively modest cost of around £70 K based on mid 1990s costing (Moss and Monstadt, 2008). Floodplain habitat improvements have been identified with a more natural flooding regime resulting in wet grassland that now supports over wintering and migrating birds. There remains a lack of natural woody in- and near-channel vegetation which means habitat heterogeneity is not at full potential, but in time local stakeholders might accept implementation of diverse practices to further enhance habitat.

5.2. Reclamation consortia: working with local stakeholders

Although the drainage of wetlands has become common practice in Europe for centuries, the extent of this human intervention has increased significantly in the past century, and especially in the last 100 years. Roman settlers, more than 2000 years ago, were the first to attempt the reclamation of wetlands, making the plains more suitable for agriculture. Originally, Italy had almost 3 million of hectares of wetland; today most of these lands (95%) have been reclaimed or drained for agricultural uses. The Reclamation Consortia (also called drainage consortia) are an important and unique institution established by the Venice Republic in 16th century and still exist. Their role has changed from the early years when protection and management of public reclamation and irrigation works was their focus. Since the 1960s this expanded to include a new role for prevention of flooding. With the urbanization of recent decades, this drainage consortia has dealt with cultivated lands, urban settlements and other issues as well. For few of them protection of natural resources became part of their work in the 1990s, as well as issues pertaining to water-use rights and licenses. Thus the traditional role of the Consortia is changing in a wider social framework of environmental protection of habitats that could be strongly influenced by human activities and do to ensure suitable water for irrigation, and reduce water pollution. In order to carry out these new functions, some of the Consortia begin to take part in urban and territorial planning and in water resources management targeting to environmental sustainability.

5.2.1. Restoration measurements within the Venice Lagoon watershed to improve water quality

A notable and rare Italian example of environmental restoration activities carried out by a Consortia has been completed within the drainage basin of the Venice Lagoon by the Consortium "Acque Risorgive". In order to reduce eutrophication problems that severely impair the quality of the lagoon waters, the local government (the Veneto Region Authority), more than a decade ago, established a series of targets for the the reduction of nutrients that flow into the lagoon. For two of the main rivers managed by the Consortium, (the Dese River and its tributary Zero River) nutrient loads reduction were established in 150 tons/year for total Nitrogen and 40 tons/year for total Phosphorous. This represents a reduction of 12% and 17% respectively of their total loads. To achieve these results, the Consortium planned many river restoration projects throughout the territory. So in addition to improving water quality other relevant goals could be achieved such as: (i) reducing flooding risk, through widening river sections and the use of riverine wetlands for water retention; (ii) restored natural habitats, particularly wetland ecosystems; and (iii) diversification of land use and visual and esthetic qualities of the landscape (Gumiero et al., 2009).

As a detailed example, The "Salzano wetland" restoration was completed by the consortium which was, until the mid-1980s, subject to mining of clay. Since this period this 60 ha site has gradually been restored. Today this site is characterized by a mosaic of habitats of different spatial extent (Fig. 10). The main actions of the project were:

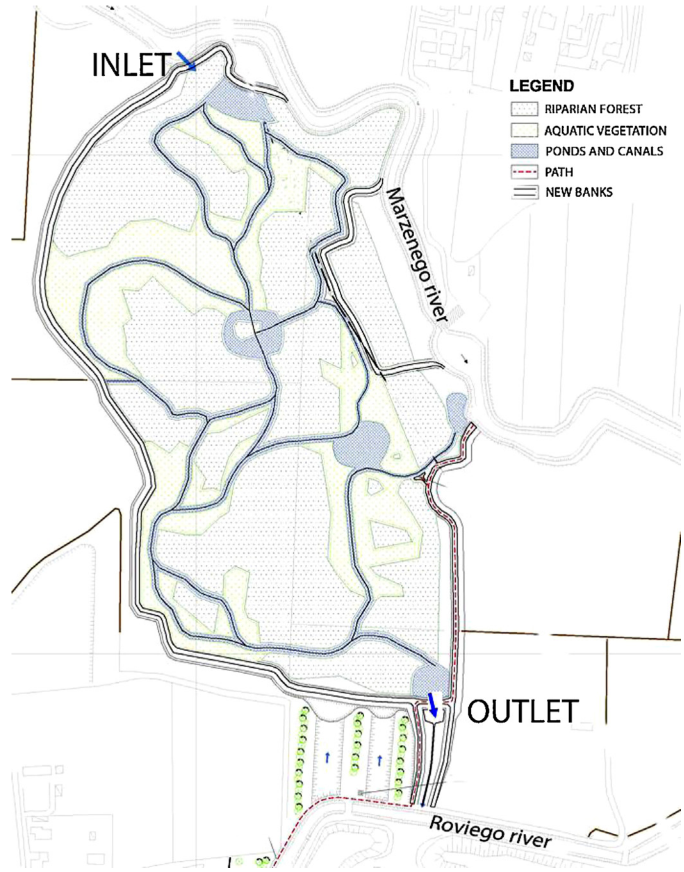

Fig. 10. Map of the Salzano wetland with the indications of the restoration actions.

- to create a system of new banks around a dry and with low ecological value portion (20 ha wide) of the extent wetland, and later to connect this area with the adjacent watercourse using gates to manage flows;
- reshaping the net of canals, ponds and pools inside this area to find the optimal residual time of the water to assure an efficient nutrient reduction;
- re-establish rare and endangered aquatic vegetation types (*Carex elata*, *Cladium mariscus*, *Allium angulosum*, *Cirsium canum*, *Senecio paludosus*, *Typha laxmannii*, *Iris pseudacorus* and *Nuphar luteum*) and monitor their development;
- create a new net of small channels to connect this restored wetland to the other portions;
- create a net of path and observation structures accessible to the public for recreation, educational and technical-scientific purposes.

During the first year the residential time was lower than expected (5.7 dd) nevertheless the monitoring of nutrient removals rates was 76% of $NO_3{}^-N$, 57% for $PO_4{}^-P$ and 66% for suspended solids (Palmieri et al., 2011). Positive results were achieved for the other goals as well.

Another innovative wetland typology developed in this area is a newly afforested, sub-irrigated riparian buffer (30 ha wide) which integrated hydraulic works (drains, pumping system) within a natural riparian forest. Ridges and furrows facilitate sub-surface water flow throughout the field from the inlet point, represented by irrigation ditches where the water of the adjacent Zero river is pumped through, to the parallel drainage ditches located at lower elevation. The particular hydraulic structure of this area, and the presence of an experimental site (0.7 ha wide) for long-term monitoring, enable direct control of some parameters, such as water inflow and outflow, which in natural riparian systems cannot generally be managed. After one year the arable land was converted to a wooded wetland, the experimental buffer system started to efficiently remove nitrogen loads flowing through, reaching 80–85% of nitrate removal; a rate deemed to be sustainable (for more details see Gumiero et al., 2011).

Considering the fragile (reclaimed area) and complex territory (highly urbanized and intensive agricultural activities, protected areas), to promote this new multitasking approach, has not been possible to implement sophisticated tools but was taken a step by step approach in which the consortium has played a crucial role working together with trade associations and stakeholders. A large and significant dissemination strategy was led to local communities were kept informed by various dissemination activities (public meetings, newsletters, information boards, etc.) on project ideas and their subsequent development. What has been most successful in the cultural transformation of the people was to note the positive results obtained in many actions taken by the consortium and work side by side on field.

6. Discussion

Hydro-geomorphic dynamics of rivers are increasingly seen as vital for creating and maintaining habitats and aquatic and riparian ecosystems. Flood pulses and intervening flow variability, sediment transport, bank erosion and associated channel mobility represent key physical processes and their understanding is of crucial importance for defining river restoration and management strategies. Similarly, the ability of a river to develop a mosaic of habitats is related to both longitudinal and lateral connectivity. Restoring floodplains and recognizing the need to provide more space for rivers, has now become a priority strategic objective for some central European governments as European policies demand.

These objectives however, have implications not only for environmental gain but also for the economic benefits that these measures can provide. There has been a gradual acceptance by policy makers and governments that “hard engineering” attempts to control rivers for flood alleviation are not necessarily either sustainable or desirable. Examples of this new approach versus the traditional engineering concepts are the various “Room for the River”, “Making Space for Water”, “Living Rivers”, and “Environmental River Enhancement” which are all European country-led initiatives that recognize the importance of floodplains. Equally, the Fluvial Territory concept as a possible solution to restore river geomorphological processes and to mitigate flood risk, preventing further deterioration of the river ecosystem due to “maintenance works” has been shown as an efficient tool along the Ebro river and other European rivers (Blackwell and Maltby, 2006; Hughes, 2003; Nijland, 2005; Swanenvleugel and Laninga-Busch, 2007). As shown in the case study of the Venice Lagoon watershed land management has built on a policy with the aiming of reducing maintenance costs as much as possible and at the same time building a more sustainable landscape that can provide the many services required by society. The gradual implementation of the actions that span agricultural, social and economic needs has enabled people to appreciate the changes and become valuable allies of the benefits of a new management regime that can lead to ecological gain.

In essence any floodplain restoration and water management has to interface with a wide range of social and landscape conditions that range from low to densely populated areas, heavily modified to more dynamic rivers and from upstream high energy streams to low energy systems situated in the lowland plain areas which result in widely differing approaches across Europe. On the one hand there remains an argument for robust, traditional and expensive flood control structures in relation to the protection of local assets but conversely, “environmentally friendly”, low-cost structures have been encouraged as a way forward in some instances, particularly where the rivers are still partially natural and free-flowing as demonstrated on the river Ebro. Attitudes toward how to develop and/or preserve European floodplains vary between member states and are often dependent on economic and social interests. In the Netherlands for example, flood defenses is a priority due to the high population density. As a result forest development within the floodplain is limited to 10% of the total area whilst in the Germanic upper catchment of the Rhine River areas, natural flood retention by floodplain forest, plays an important role for water managers (Rijkswaterstaat, 2009).

Biodiversity in riverine wetlands ecosystems is recognized to be highly dependent on geomorphological processes and therefore, enhancement actions need wherever feasible to work with natural processes to achieve habitat diversity. Yet, the floodplains of Europe have been disturbed for centuries. Therefore, limited disturbances such as moderate grazing (see Rhine and Loire case studies) can increase species richness and deter invasive species or monoculture from becoming dominant. Because of extensive past disturbances, providing space for river movement and the development of natural processes does not always lead to biodiversity improvements (Acreman et al., 2007) due to the influence of a range of complicating factors. There are circumstances where floodplains have become isolated from the river system but nonetheless have fostered the development of habitats that are important for rare or endangered species such as demonstrated on the river Piave. However often these controversial results are due to the lack of a broad and integrated vision because of small group of expert and, even more, to the lack of a long-term strategy. A major effort to develop a wider participatory process can be of a great benefit.

Looking at Rhein, Loire, Gran Eau rivers and Venice Lagoon watershed case studies river and floodplain restoration can also provide opportunities for the promotion of sustainable land and water management through the introduction of river and floodplain restoration options especially in locations where land has previously been drained for agricultural and other uses. In highly modified riverine ecosystems the most appropriate approach may be to restore the ecological characteristics of the wetland through appropriate and artificial water management that focus on a range of issues including water control, topography, flood storage, controlled wetland connection with rivers and sustainability of water supply under climate change. At a basin scale restoration management measures should be used in conjunction with other measures addressing the adjacent land use activities and, in some cases, water activities as well. The spatial distribution of riparian forests and wetlands relative to agricultural fields is likely to affect their functioning and sustainability in controlling nitrogen fluxes. Equally the connectivity between these riparian buffer and landscape sources of nitrogen fundamentally influences their efficiency at the landscape level. Indeed, farming systems constitute the key driving force in undermining or enhancing both spatial distribution and connectivity of riparian wetland within agricultural landscape. Hence, the spatial and functional sustainability of floodplain under varying farming practices needs to be evaluated in order to propose the most efficient landscape design to reduce nitrogen fluxes under a given climatic and farming constraints. In Europe is in progress the implementation of the new CAP 2014–2020 (Common Agricultural Policy) where one of the main challenges is to promote greener farming practices.

Many of the case studies reported in this paper however, demonstrate that flood management is one of the most powerful drivers in determining the future functioning of floodplain areas.

Currently, the confidence in designing floodplain options that consider environmental needs and meet the non-environmental objectives is still limited because of the lack of a robust evidence base and detailed case studies. Some of case studies like Ebro river and Bear Brook demonstrate what type of restoration is appropriate for different river systems and suite of ecosystem services that must be maintained. Understanding what action is appropriate and why it is crucial to success are difficult lessons to learn. Adverse consequences can be significant, as exemplified on the River Cherwell in England where flood peaks were increased by 150% by embanking the river, compared to if the floodplain had been used to store flood water (Acreman et al., 2007). The case study of Orth floodplain (upper Danube) shows that another important driver for wetlands restoration is improve water quality by restoring its natural branching system. What is more challenging is to develop, starting from a more powerful driver, a multitasking strategies like showed in several case studies of this paper.

Scientific and technical tools in participatory processes are not very often use yet, not only because of lack of knowledge but also because they are not always readily to adaptable to specific local situations. On the other hand almost all European directives consider the participatory process a key tool essential for achieve long-term sustainable results; for this reason the instruments useful to support this approach have to be developed and used strongly in the future. In other words, for river restoration to be effective requires significant changes on the traditional way to plan land uses and river management: only long-term and well supported cost/benefit analysis and a wide social consensus will enable implementation of project that deliver a range of goods and services, see the experience of Danube River Basin summarized in this paper.

Decisions about river and floodplain restoration and rehabilitation ultimately require a trade-off between ecological goals, ecosystem services, competing land uses and costs (Reichert and Borsuk, 2005). As such, successful natural resource management is much more than good science; it requires working with landowners, meeting deadlines, securing funding, supervising staff, and cooperating with politicians. As demonstrated through the case studies and discussion in this paper, that participatory process technical tools require further development to allow for analysis and explanation of local stakeholder variability. Some of the case studies underline how the involvement of stakeholder needs time and the river restoration project can only be a starter. So to be more effective the participatory process must be integrated within the River Basin Management Plan as showed for the Danube River and for the rivers Rhein, Loire and Long Eau. Such development is crucial in providing a decision support mechanism that can help develop new of land and water plans that take account of societal needs and benefit this fragile natural environment.

If the failure of the old flood-risk strategy has given a big boost to ecological restoration, now the key challenge is to demonstrate the new strategy not only works but provides greater benefits. Maintaining the longevity of natural important floodplain features will only be feasible by demonstrating the wider importance of lateral physical and biological natural processes and the linkages of rivers and floodplains to maintain and improve a range of important services. Such understanding needs to be at the heart of future environmental policy decisions to ensure that multifunctional, sustainably floodplains can be achieved for future generations and wildlife. We need to build on current research and develop new information strategies and forums that allow policy makers and practitioners to have access to the latest scientific evidence on the benefits of new river management strategies.

7. Conclusions

So where are we now in terms of understanding how to develop future opportunities for restoring our floodplains and what is required to future proof the many essential environmental services delivered through river and wetland reconnection and habitat enhancement?

First of all there is a need to understand that although ecosystem recovery can be identified as developing in a specific trajectory over longer periods and at a regional scale; shorter term, smaller scale patterns can be much harder to predict. As a result of this local complexity there are often difficulties in explaining the benefits of river restoration for ecological benefit. By developing strategies that better understand floodplain restoration in the context of the basin scale it will become more feasible to develop the most appropriate restoration actions for a specific river type and location and to demonstrate benefit. For example the "*Consortia*" (local authorities) in Italy have a very close relationship with the land owners because a good percentage of "*Consortia*" income is derived from land owner and every activity they do in the area needs to be shared. In terms of academic principles the need to understand basin scale impacts is often cited, stating that we must learn to recognize how the hydrological, sediment and ecological controls within a catchment, impact upon management options for a specific site (Piégay et al., 2008b). Understanding the implication of these effects locally would be an effective way that Water Basin Authorities could develop land and water management strategies. However, how these are implemented on the ground especially where there additional trans-border issues is still under debate. Within the European Union countries at least, the CAP reforms may provide one way of enabling such strategies to be developed through the implementation of cross-compliance greener measures.

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Appendix A. Supplementary data

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