Draft Title: Riparian Ecotone Citizen Science

On the 24/04 there will be a workshop dedicated to further elaboration of this draft white paper. For further information, please contact Dr.Bruna Gumiero (bruna.gumiero@unibo.it)

Authors: Bruna Gumiero[1], Leonardo Veronesi[2], Luisa Galgani[3], Steven Arthur Loiselle[3]

[1] CSGI - Center for Colloid and Surface Science, Via della Lastruccia 3, 50019 Zona Osmannoro FI, Italy;
Università degli Studi di Bologna, Italy;
Institute for Environmental Protection and Research - ISPRA, Via Vitaliano Brancati 48, 00144, Rome, Italy
[2] European Citizen Science Association - ECSA, c/o Museum für Naturkunde, Invalidenstraße 43, 10115, Berlin, Germany
[3] CSGI - Center for Colloid and Surface Science, Via della Lastruccia 3, 50019 Zona Osmannoro FI, Italy;
Department of Biotechnology, Chemistry and Pharmacy - DBCF, University of Siena, Via Aldo Moro 2, 53100, Siena, Italy

Introduction

Water courses constitute a dynamic sequence of ecosystems that exhibit both longitudinal variation—from the source to the mouth—and lateral diversity. The riparian corridors, integral to these water courses, play a crucial role, becoming inseparable from the river itself. The components of these ecosystems are primarily influenced by the water regime, affecting soil texture, water availability, and nutrient supply. In their natural state, these environments boast the capacity to sustain high biodiversity. It is characterized by hygrophilous forests suitable for humid and periodically submerged soils.

Riparian zones possess distinctive abiotic and biotic characteristics, including a flooding regime characterized by high temporal and spatial variability. This flooding regime gives rise to a mosaic landscape featuring both vegetated and bare fluvial landforms, serving as hierarchically organized habitats (Gurnell et al., 2016). Furthermore, these zones harbor unique biotic communities, comprising species that thrive in conditions of high water and nutrient availability while also enduring shear stress and temporary submersions (Naiman and Décamps, 1997).

The dependence of riparian zones on the flooding regime, considered along four dimensions—longitudinal (upstream–downstream), lateral (hillslope-channel), vertical (hyporheic-channel bed), and temporal (Ward, 1989)—sets them apart as functionally distinct from purely terrestrial or aquatic lentic ecosystems (Tockner et al., 2000).

The nature of the riparian zone will vary, depending on its location within the channel network and on regional climatic conditions (Decamps et al 2004). In the headwaters tributaries, the delivery of water, sediments and solutes from slope to channel is most important. In the middle section, transfers from slope to channel can remain important but the channel also becomes a significant input source to the floodplain. Wide, lowland floodplains receive significant inputs from the channel and themselves))become important source areas, especially during the flood recession and periods of low flow (Pinay et al., 2006). (*Pinay G., T. Burt and* GUMIERO B., *(**2006**). Floodplains in river Ecosystems. In:* ***Biological Monitoring of Rivers*** *Ed. By G. Ziglio, M. Siligardi and G. Flaim John Wiley & Sons, Ltd*.

Given their location and topography, floodplains are likely to form wetlands, temporary if not permanently. Even where the floodplain sediments are permeable, the combination of width and low gradient helps to maintain a high water table, with this control being accentuated as the floodplain width increases or where the alluvium is more fine-grained. Even above the water table, the soil is likely to remain close to saturation because of the capillarity fringe effect.

Riparian zones are present in all biomes from tropical rainforests to arid and arctic deserts, and range from large floodplain–river systems draining millions of cubic meters of water annually at a continental scale to small temporary streams.

Hydro-geomorphic Process Shaping Riparian Habitat in Alluvial Channel-Floodplain River Systems

The intricate interplay of hydro-geomorphic processes and vegetation dynamics establishes a nuanced geomorphic blueprint for riparian habitats, exhibiting variations across physiographic contexts, valley forms, and river styles. Riparian trees and shrubs assume a pivotal role in enhancing flow resistance and sediment cohesion within the riparian zone, actively influencing rates of aggradation and degradation (Garnel et al., 2015).

Geomorphic processes, affecting the diversity of entire river corridors and local scales, reflect species-specific responses to soil moisture/oxygenation, sediment deposition, inundation frequency, and the erosive action of flooding along a lateral gradient(Baattrup-Pedersen et al., 2013). Factors controlling riparian sediment and organic matter deposition actively contribute to the construction and evolution of riparian habitats (Word et al., 2002).

The dynamic nature of channel migration and floodplain renewal significantly shapes the ecological diversity of river corridors. The interruption and renewal of plant succession due to the destruction of existing floodplains and the creation of new surfaces for colonization shape the ecological fabric of riparian zones. The intricate interactions among water, sediment, aquatic-terrestrial landforms, and biotic elements govern functional processes and biodiversity patterns in the riparian zone, directly contributing to ecological integrity and social value. Habitat diversity within riparian and floodplain environments is intricately linked to the regular and repeated rejuvenation of successions associated with disturbances (Petts, 1990).

These distinctive characteristics, coupled with their intermediary position between aquatic and terrestrial environments, empower riparian zones to fulfill essential functions and provide "ecosystem services" crucial to the river, the surrounding territory, and, consequently, society.

Function and Ecosystem Services of riparian zones

Riparian vegetation, comprising trees, shrubs, and grasses adapted to wet environments, serves multifaceted ecological functions. These plants mitigate flooding by slowing floodwaters, facilitating recharge of shallow aquifers. The water recharged into these aquifers becomes crucial for sustaining river flow during dry periods. Moreover, riparian ecosystems act as natural filters, reducing sediment and nutrient levels, thereby enhancing water quality.

Vegetation is crucial for increasing the complexity and functionality of riparian ecotones, providing habitats, niches and the energy input essential for maintaining the trophic-functional structures of both river and riparian communities.

Temperature Regulation and Oxygenation: Riparian vegetation, through shading, mitigates the intensity of light in watercourses by up to 95%, preventing excessive periphyton and algal development. Additionally, the canopy of sheltering trees shield water from excessive heating, resulting in lower water temperatures, especially during heat-waves, supporting increased solubilization of oxygen (Garner et al., 2017; Trimmel et al., 2018). This fosters a positive correlation with greater biodiversity of river fishes and macroinvertebrates (Rios et al., 2006).

Habitat Diversity and Channel Morphology: Tree roots create heterogeneity along river banks, forming small inlets, recesses, and shaded areas that serve as ideal microhabitats, offering shelter and protection for fauna and flora. Fallen tree vegetation, known as Large Woody Debris (LWD), plays a pivotal role in shaping local hydraulic and geomorphological characteristics, influencing channel types, sediment deposition, and riverbed roughness. The trunks and large branches in the riverbed form important microhabitats essential for the survival of many components of the river community, especially during extreme events. In fact, during flood events, characterized by high current speed, river organisms find a quieter area in which to take refuge in the areas immediately downstream of the woody accumulations (Woody Debris Dam). During low flow periods, however, the pools that form near these accumulations remain the only areas in which a fundamental water reserve is maintained for the survival of fish species that cannot burrow into the humid sediments. So the presence of large woody material within watercourses enhances habitat diversity, influencing benthic and fish communities (Tabacchi et al., 2003). Finally, there is an intimate relationship between disturbance regimes, the production of large wood debris (LWD) and the development of riparian forests. In fact, the presence of this large debris plays a key role in the formation of vegetated islands that can join together to form a riparian forest.

Food for aquatic organisms (Energy inputs). Riparian vegetation is the main source of CPOM (Coarse Particulate Organic Matter), an organic component consisting mostly of leaf and small woody material, and which is transported by the wind and surface water runoff, but can reach the 'bed also for direct fall. The leaves that fall into small waterways constitute a fundamental source of food (50-99% of the total energy budget). This component performs both short and long-term trophic functions for debris-eating organisms and decomposer microorganisms (Deegan & Ganf, 2008). Some macroinvertebrate species synchronize their life cycles with the moment of greatest CPOM availability.

Buffer Zone. Riparian ecosystems act as natural filters, reducing the supply of sediments, nutrients and more generally pollutants of widespread origin to the river. An extensive scientific literature testifies to the important role played by riparian zones in regulating and improving the quality of surface waters involving both physical and biological mechanisms (Gumiero et al., 2013). Physical processes include the filtering and deposition of sediments and sediment-related pollutants, such as phosphorus and agrochemicals that are poorly soluble in water. During this stay they may encounter various phenomena such as chemical-physical degradation through light, UV, temperature and the catalyzing action of some soil constituents. Furthermore, riparian zones effectively remove dissolved inorganic nitrogen and phosphorus present in excess in water runoff from surrounding agricultural or urban areas, thus providing a high potential in controlling eutrophication of water bodies. One of the main biological processes capable of removing nitrate nitrogen by reducing it to atmospheric nitrogen (N2) is denitrification, which occurs in riparian micro-sites in anaerobic conditions rich in organic carbon (gumiero et al., 2011). In this case, riparian vegetation has an indirect but fundamental role in providing food to the denitrifying bacterial community. The assimilative absorption by plants and microorganisms also contributes significantly to the removal, even if temporary, of inorganic nitrogen and phosphorus. It has been demonstrated that in the absence of a buffer zone that removes nutrients deriving from agricultural fields in which extensive use of fertilizing substances is made, water eutrophication phenomena may occur (Gumiero et al., 2015).

Bank consolidation and Sediment control (clearer water). The dense root systems of riparian vegetation, both woody and herbaceous, effectively limit erosion and excessive supply of mineral sediments. The species typical of riparian zones, i.e. those equipped with adaptations for this specific environment, are more effective in consolidating the soil than occasional or opportunistic species (Simon et al., 2002). The bank's erosion resulted in a 30-fold reduction in erosion on vegetated soil compared to exposed ones (Beeson & Doyle, 1995).

Ecological corridor. Riparian zones are critical for functional integrity of riverscapes and conservation of riverscape biodiversity. Due to its structure, the riparian forest is an ecological corridor for plant and animal species, both linked to the aquatic environment and purely terrestrial (Tabacchi et al., 1998). As an ecological corridor, the riparian ecotone plays an essential role in maintaining environmental connectivity, favoring the movements of biota and the exchange of matter and energy between different units of the river landscape (Naiman & Décamps, 1997; Bennet, 2003). Riparian areas, in fact, constitute excellent communication routes capable of breaking isolation. Connectivity is maintained in all spatial planes: it is therefore defined as longitudinal - between the upstream and downstream areas -, lateral - between the river bed and the alluvial plain - and vertical - between the surface of the water bodies and the water underground of the aquifers (Camporeale et al., 2013).

Riparian systems can act as local refugia for species, thus serving as population sources to support recolonization of disturbed habitats, such as commercial timberlands and intensive agricultural land. Bats and birds use forested riparian corridors as flyways, foraging grounds, and roosting sites. During the migratory season, the avifaunal richness of riparian zones is at least an order of magnitude higher than the nearby uplands due to increased foraging opportunities and overwintering sites. Amphibian dependency on riparian buffers is extremely high, for ex. in the Pacific Northwest of the United States, where 47 species are either obligate or facultative stream associates. Many turtles are particularly dependent upon riparian buffers for dispersal, foraging, hibernation, and oviposition. Floral biodiversity, particularly bryophytes, pteridophytes, and herbaceous plants, is remarkably high in

riparian buffers. Marked floristic species turnover rate (beta diversity) between riparian buffers and adjacent uplands heightens species complementarity along the aquatic-upland gradient, which also generates a greater landscape-scale species richness (gamma diversity). The EU's 2030 biodiversity strategy is reported "In order to have a truly coherent and resilient Trans-European Nature Network, it will be important to set up ecological corridors to prevent genetic isolation, allow for species migration, and maintain and enhance healthy ecosystems. In this context, investments in green and blue infrastructure and cooperation across borders among Member States should be promoted and supported, including through the European Territorial Cooperation"
https://www.europarc.org/news/2020/07/iucn-guidelines-for-ecological-corridors/

Improve air quality The riparian forest, like all woods and forests, improves air quality by reducing CO2 levels (Kravčík et al., 2007; Garner et al., 2017).

Recreational areas. Riparian vegetation provides cultural services, i.e. non-material benefits of an aesthetic, recreational, perceptive, recreational, religious nature, etc... (Ferrari & Pezzi, 2013).

landscape Improvement

Climate regulation

https://freshwaterblog.net/2016/11/22/conservation-and-restoration-of-riparian-zones-under-multiple-pressures/

To be continued

Groundwater recharge

Flood Control Riparian zones are assumed to mitigate/reduce the effect of floods as they slow water runoff, trap sediment, and enhance infiltration (Letsinger 2003). The riparian vegetation plays a pivotal role in mitigating flooding by decelerating floodwaters, facilitating the recharge of shallow aquifers. In perennial stream settings, there is abundant literature confirming that riparian vegetation affects flood hydrology by attenuating the flood wave, enhancing deposition and reducing bank erosion.

In summary Riparian Zones play a crucial role in supporting various ecological functions that contribute to the overall health and balance of riverine environments. These multifaceted functions encompass acting as a refuge for regional biodiversity, regulating climate, mitigating floods, and filtering water and nutrients. Additionally, they provide essential shading for stream channels and exhibit high primary productivity (Naiman and Décamps, 1997; Palmer and Bennett, 2006).

The significance of these ecological functions extends beyond the natural realm, directly impacting society through key ecosystem services (Felipe-Lucia et al., 2014; Vidal-Abarca Gutiérrez and Suárez Alonso, 2013). Among these services, some hold direct economic relevance, including flood control, support for agriculture, forestry, industry, and urbanization. Moreover, riparian zones enhance various outdoor recreational activities, such as waterfall visits, exploration of gorges, hiking, canoeing, and fishing.

Ecosystem Services

In essence, the ecosystem services provided by riparian zones are indispensable for maintaining the ecological equilibrium of riverine environments. These services not only influence the health of aquatic ecosystems but also significantly contribute to the well-being of human communities that rely on these natural systems. Highlighting the paramount importance of riparian zones, the following outlines the most critical services they offer:

1. **Flood Regulation:** Riparian vegetation helps mitigate flooding by slowing down and absorbing floodwaters, reducing the impact of extreme events on both riverbanks and adjacent areas.
2. **Water Quality Improvement:** Riparian ecosystems act as natural filters, reducing sediment and nutrient levels in water through the absorption and retention of pollutants, thus enhancing water quality downstream.
3. **Aquifer Recharge:** The vegetation in riparian zones facilitates the recharge of shallow aquifers by allowing water to infiltrate the soil, contributing to groundwater storage essential for sustaining river flow during dry periods.
4. **Habitat Provision:** Riparian areas offer diverse habitats for various species of flora and fauna, supporting biodiversity. The complexity of these ecosystems provides niches and breeding grounds for numerous organisms.
5. **Temperature Regulation:** The shading effect of riparian vegetation helps regulate water temperature in rivers, preventing excessive heating. This is particularly important for maintaining suitable conditions for aquatic organisms and preventing the proliferation of certain unwanted species.
6. **Oxygenation of Water:** By shading and cooling water, riparian vegetation contributes to higher dissolved oxygen levels, creating a healthier environment for aquatic life.

7. **Food Source for Aquatic Organisms:** Leaves and woody material from riparian vegetation serve as a crucial source of food, especially Coarse Particulate Organic Matter (CPOM), supporting the energy needs of aquatic organisms.

8. **Bank Stabilization:** The root systems of riparian plants help stabilize riverbanks, reducing erosion and maintaining the integrity of the river channel.

9. **Recreation and Aesthetic Values:** Riparian zones provide opportunities for recreational activities such as fishing, hiking, and birdwatching. The aesthetic appeal of these areas contributes to human well-being and cultural value.

10. **Buffering of Pollutants**: The vegetation in riparian zones acts as a buffer, trapping and filtering pollutants from adjacent terrestrial environments, particularly from agricultural runoff.

11. **Carbon Sequestration**: Riparian vegetation plays a role in carbon sequestration, helping to mitigate climate change by storing carbon in plant biomass and soil.

12. **Educational and Scientific Value:** Riparian zones offer opportunities for environmental education and scientific research, contributing to our understanding of ecosystems, biodiversity, and hydrological processes.

13. **Erosion Control:** The root systems of riparian plants help bind soil particles together, preventing erosion and reducing the transport of sediment into water bodies.

The ecosystem services framework has gained widespread acceptance as a valuable tool for directing management strategies aimed at preserving and restoring ecosystems. Nevertheless, its implementation faces considerable challenges due to the complexity and dynamics of the environment that interfere with the ability of ecosystems to provide services (Haines-Young and Potschin, 2010; Lautenbach et al., 2012; Allan et al., 2013). The spatial and temporal dynamics of ecosystem service provision demand increased attention.

Initially, the framework was embraced as a means to reconcile social and ecological needs and visions, assuming a harmonious delivery of services for designers and managers. However, limitations to this harmonious perspective have surfaced, notably the realization that a targeted approach to ecosystem services does not always align with biodiversity goals and vice versa (Adams), sparking a robust debate and the emergence of the Ecosystem Services to Biodiversity research discipline (Cardinale et al.).

Most operational assessments of ecosystem services (Burkhard et al., 2010; De Groot et al., 2010; Paetzold et al., 2010; Pinto et al., 2010) have focused on evaluating a state at a specific point in time, often neglecting the spatial and temporal dynamics of ecosystems. Riparian corridors present a unique opportunity for exploring this aspect, given their dynamic networks influenced by strong directional connectivity that integrates processes across multiple scales and significant distances over time (McCluney et al., 2014). However, the contextual flow and network structuring within watersheds have yet to be studied concerning the provision of ecosystem services.

Despite the proven benefits, riparian areas continue to experience loss and degradation, particularly due to urbanization and agriculture (Burton and Samuelson, 2008; Naiman et al., 2010; Poff et al., 2011). As early as 1997, Poff et al. highlighted that the removal of riparian vegetation, wetland drainage, and floodplain exploitation leads to larger floods, causing extensive property damage.

Floods pose a recognized risk, incurring billions of dollars in direct and indirect costs globally (Hallegatte et al., 2013). This hazard results from high-velocity flood flows causing infrastructure damage, increased erosion of floodplains, and canal bank instability, negatively impacting water quality and ecosystem health. While governments readily appreciate direct costs associated with infrastructure and revenue losses, the indirect costs tied to declining ecosystem services are rarely quantified. To address these, many municipalities invest in programs to enhance catchment or river "resilience" through integrated catchment management plans.

In water-limited regions, excessive human water use from agricultural and urban development often overshadows environmental water needs, intensifying ecosystem water stress. Significantly, there is insufficient consideration of riparian water needs in water resource management.

Consequently, riparian ecosystems, recognized as biodiversity hotspots, face intense pressure from multiple stressors. Addressing these challenges requires a holistic approach that integrates ecosystem services, biodiversity conservation, and sustainable water management into overarching environmental strategies.

Policy and management

Despite their scientifically recognised importance for human wellbeing, degradation of riparian zones is common and in some areas is even increasing (Janssen et al., 2020). Indeed, many aspects of riparian zone management are being driven by the development of human activities rather than by the maintenance of their ecological functions and associated benefits. Even when “high level” policy and legislative measures are in place to solve problems related to ecosystem function (e.g. European Union Green Deal, (EC, 2019), UN Decade on Ecosystem Restoration (UN, 2019)), there is little or no explicit mention of riparian zones. Therefore, explicit recognition and sustainable management are urgently needed to conserve and restore key riparian zone functions and services for current and future generations.

The European community asks us to implement sustainable watercourse management plans and to integrate the objectives of the various directives (WFD 2000/60, Floods 2007/60, Renewable Energy 2009/28, etc.). The need therefore arises for a global approach to the management of the river basin which, in harmony with the "designing with nature" school of thought, starts from the knowledge of the territory, its hydrographical network and their evolutionary tendencies to support them rather than contrast them. Again, the need emerges to raise awareness that the solution to river basin problems often does not lie in the implementation of works, or drastic "cleaning of the river" but in correct management of the territory based on the ecological and social knowledge of the territory. To achieve these goals it is important not to use preconceived tools or methods but to follow a "step by step" approach which ensures that all possible opportunities are evaluated to bring the rivers back to a state of naturalness or health as close as possible to the expected state or reference for that type of river stretch.

The degradation of riparian areas is mainly attributed to deforestation along riverbanks, especially in inhabited regions, exacerbated by the combined pressures of agriculture, population growth, urbanization, river engineering and biological invasions. Ongoing deforestation and river engineering are expected to worsen the situation in the near future, still being perceived as the cause rather than the solution in response to extreme events. This degradation has profound consequences, leading to significant impacts on biodiversity and human well-being, given the vital ecosystem services provided by riparian zones.

Unfortunately, the importance of riparian zones is often underestimated and their sustainable management does not have adequate support in decision-making processes at various levels. While some natural science and management factors contribute positively to sustainable practices, policy-related elements, such as international funding, often fall short. While some countries are increasingly supporting recovery efforts, results are not always immediately evident due to the complex and long-term nature of the recovery process.

Recognizing the fundamental interconnection of riparian areas with ecosystems both upstream and downstream, there is a critical need for policy coordination. Various authorities, including those responsible for nature conservation, energy, watershed management and agriculture, play a vital role in addressing this problem.

> Policymakers must recognize that actions in riparian zones have far-reaching effects, impacting ecosystems and the people who reside and work in these areas where ecological and social processes are closely interconnected. Consequently, it is imperative to prioritize an integrated socioeconomic and environmentally dynamic perspective.

The paper of Urbanic et al (2022) highlights the insufficient integration of riparian zones in European policies, pointing out that the EU Water Framework Directive (WFD) does not explicitly mention riparian ecosystems as a quality element, leading to their continued degradation. The roles of riparian zones in flood mitigation and water quality protection are not adequately considered in related directives and national regulations. Although the revised EU Common Agricultural Policy (CAP) of 2021 incorporates sustainable ambitions, the means of rewarding farmers for sustainable riparian zone management remain unclear. The legal definition of riparian zones as an area of fixed width is identified as an obstacle, neglecting the complexity of riparian ecosystems. The current global and European political context, including initiatives like the UN Decade on Ecosystem Restoration and the EU Green Deal, presents an opportunity to address issues related to riparian zone management. The text advocates for EU directives and legislations to explicitly recognize riparian vegetation's crucial role in functioning fluvial ecosystems, emphasizing the need to consider riparian zone sustainable management as a key element in green initiatives and related policies.

The riparian zone fails to be clearly integrated into the main European environmental policies which contain gaps and conflicts linked to the management of riparian zones. Furthermore, effective implementation of riparian zone policy must be based on good coordination at European level. The lack of coordination between administrations has already been identified as an obstacle to the management of natural resources (Cortina-Segarra et al., 2021). Only the Habitats Directive clearly indicates the importance of riparian zones in particular as an ecological ecosystem but lacks links with other legislation to support its objectives (González et al., 2017). It should also not be forgotten that when riparian zones are indirectly considered as in the Water Framework Directive, implementation at national level is usually difficult due to conflict of political interests. For example, the WFD tends to be fragmented into national policies relating to flood and water quality management and riparian zone sustainability management objectives, conflicting with the Renewable Energy Directive regarding hydropower (Jansson et al., 2000). Disappointing case studies can be found across Europe that exemplify the consequences of divides, conflicts, and fragmentation (Gumiero et al., 2013).

Based on current scientific knowledge, the ecological functions of riparian zones influence several policy areas, e.g. agriculture, watershed management and nature conservation. It is necessary to articulate the benefits of sustainable management of riparian zones in different policies and integrate conservation and restoration activities into the operational phase. This can best be done by regularly involving and training stakeholders from different policy sectors and national authorities in policy development as an element of co-creation and seeking to learn from field experiences, ideally using data and information consolidated from management processes adaptive.

Management and restoration

There are many challenges in managing dynamic riparian zones due to complexity, uncertainty and fragmented responsibilities between different authorities. To address these issues, adaptive management is suggested, emphasizing collaboration and incorporating clear system definitions, recurrent monitoring and regular evaluation. Adequate monitoring, often overlooked, is essential to adapt management plans to include emerging issues.

Taking note of the gap between scientific knowledge and decision-making in environmental policy, it is strategic to define a common framework for organizing and disseminating results across scientific disciplines. The science-policy interface co-creation model is advocated to facilitate knowledge exchange and co-creation, providing an evidence-based approach applicable to managers. Furthermore, it is important to consider local knowledge and experiences in riparian zone management, requiring the gradual transfer of basic knowledge between stakeholders for shared understanding.

It is essential to motivate all those involved in the co-creation of policies, encouraging citizen participation by highlighting the advantages of riparian areas. The ultimate goal is the implementation of improved riparian zone management practices to achieve resilient ecosystems and sustainable human well-being.

Urbanic etal (2022) proposes five actionable recommendations:

1 -Adopt an integrated socio-economic and environmentally dynamic view on riparian zones: There is urgent need to recognize riparian zones as critical assets and promote their sustainable management.

2 - Update the EU Directives and national legislations: Urges the integration of riparian zones into European policies based on scientific evidence to enhance water resources management and spatial planning.

3 - Effectively coordinate all riparian zone related policies: Highlights the risk of isolated policies in different sectors and calls for better articulation through joint evaluations at various scales.

4 - Implement adaptive management with an appropriate monitoring and assessment: Acknowledges the complexity of riparian zones, advocating for adaptive management with regular monitoring to adjust practices in line with objectives.

5 - Implement policy co-creation approach and foster knowledge transfer: Addresses gaps between scientific knowledge and decision-making, suggesting a co-creation model to enrich decision-making and contribute to riparian zone sustainability, resulting in resilient ecosystems and sustainable human well-being.

The perception of society

It has been long established in the scientific literature that the efforts towards river restoration are not only desirable, but necessary in order to achieve a richer biodiversity, better water quality, and better answers by the ecosystem in case of flood events (Basak et al., 2021; Smith et al., 2014; Veermat et al., 2016).

One of the key aspects of river restoration is the necessity to let nature do its course, that is to let trees, bushes and other vegetation grow back naturally on river banks among other processes (Feld et al., 2011; Wohl et al., 2005).

And here comes the problem, since while scientists agree on this the public often does not, which in turn can shape the public debate into having rivers and canals cleaned, thus having politicians campaigning for it, against scientific evidence.

So what is the public's perception of riparian vegetation? A landmark study found that students' perception of wood in river varied depending on the practices in their place of residence, with students less accustomed to seeing wood in rivers depicting the presence of it as a danger and in need of human intervention (Piegay et al., 2005). Experts are more likely to find wood in rivers as a desirable characteristic compared to laypeople (Chin et al., 2014), and in general held a more positive perception of natural river ecosystems compared to laypeople (Le Lay et al., 2013). Even after flood events such experience is not the main explanatory variable in the perception of wood in rivers, still with experts favoring it over laypeople (Ruiz-Villanueva et al., 2018).

Even though a greater biodiversity has been observed to have a positive impact on people's mood (Cameron et al., 2020), what usually drives the public's perception of river ecosystems are aesthetic and cultural values (Thiele et al., 2019), something that experts need to take into account but not always do, usually with qualitative methods (Schultz et al., 2022) but with advocates of quantitative methods in the shape of surveys especially (Le Calvez et al., 2021).

By looking at the literature, it appears that the public's perception of rivers is driven by socio-cultural values (Garcia et al., 2020), therefore what has been established in the past decades as good practices of intervention on rivers still held a grasp on nowadays possibility of action, both for the good and for the bad.

In some cases indeed it is for the good, as communities recognise an increased value of the river after restoration efforts (Polednikova and Galia, 2020), as found by Verbrugge and van den Born (2018), who surveyed a community next to a planned intervention on a river in the Netherlands, and the answers were a positive evaluation "especially in terms of improving flood safety. Social bonding, scenic beauty, and recreational value correlated positively with the evaluation scores. Our findings emphasize the importance of place as a social environment in residents' responses to re-landscaping river interventions and we discuss opportunities to engage local communities and sustain social processes in river management."

Engaging local communities is always a desirable objective, especially in the context of the Water Framework Directive that has highlighted the importance of such participatory practices.

This is summarized well by Schultz et al. (2022): "Ecological restoration is the process of repairing ecosystems that have been degraded by human activity. Because success depends upon the support of communities, engaging with the cultural values held by local people is critical to the restoration process. Cultural values are closely held beliefs about what is important to local communities, grounded in historical and contemporary cultural relationships with ecosystems."

The difference between public and professional's perception in the case of river banks and river restoration can be highlighted by a recent flood event in Italy, the one of Emilia Romagna in 2023, after which the public discourse covered the matter thoroughly, discussing ways to avoid new events and what could have been done differently to prevent it. This has been especially the case for local newspapers, which indeed can shape the discourse in the affected areas.

Providing a little context, the flood event extended between 14 and 17 of May 2023, with 21 rivers overflowing and another 22 streams hitting the critical level, due to conspicuous precipitation events that occurred for days before the 14th of May and intensified in the highlighted period, which caused the overflowing in an already saturated situation (ISPRA report on the events report).

Shortly after the flood event, WWF Italy published a review covering 10 fake news that were spread regarding the flooding event, an article that was reposted by some local newspapers (Corriere di Bologna website) and supported by the declarations of other experts, as the president of geologists for the Emilia Romagna region (Ravenna Notizie website) and meteorologist and scientific divulgator Luca Mercalli (Ravenna Notizie website).

Nonetheless, many more local newspapers reported the words of local politicians blaming the lack of cleanness among the main causes of the flood event, with some blaming green activists for preventing them to clean rivers. Lega advisor for Emilia Romagna mr. Pompignoli was reported blaming the presence of vegetation along river banks (Il Resto del Carlino website; Corriere Romagna website). Not only politicians, but also exponents of other local institutions such as the ANBI (Associazione Nazionale dei Consorzi per la Gestione e la Tutela del Territorio e delle Acque Irrigue) president were reported blaming the lack of cleanness in rivers (Today website), with Coldiretti regional chairman and Ministro dell'Ambiente e della Sicurezza energetica dell'Italia mr. Pichetto Fratin blamed environmental activists that prevent them from cleaning rivers (Il Sole 24 Ore, radio version website).

Particularly serious are finally the words of Confagricoltura Piacenza chairman, who said that “facts demonstrate that the nowadays keywords such as ‘restoration’ and ‘biodiversity’ are curse words, and [result in] the homicide of the evolved Western society which has more than 2000 glory years of history” (my translation, Il Piacenza website).

This highlights how even though the right information are at disposal, and some local newspapers indeed try to spread them, there is still a considerable amount of disinformation being carried out by other newspapers through the words of local politicians and other institutional individuals, who are trying to blame somebody else instead of taking action and try to mitigate the situation.

European cases

As we have seen with Italy, although in a specific case, the narrative surrounding flooding events and river restoration and conservation efforts is two-faced: from one side there are institutions such as WWF that are trying to spread the current scientific knowledge regarding the issue, while on the other side there are politicians and other individuals - who of course carry interests with them - that are trying to create their own narrative, or rather to preserve the historical narrative that sees the current scientific knowledge as a threat to established practices and interests.

Consequently, the public's opinion on the matter is also divided between the ones who sustain the adoption of the current scientific knowledge and want to put it into practice, and those who sustain the 'old ways' as they are either not aware of the scientific knowledge or have interests in keeping things as they currently are. It has also been proved that in Italy there are differences between the experts and laypeople's perceptions on river landscapes (Le Lay et al., 2013).

But what about the other European countries? We can suppose with relative certainty that perception varies depending on the specific cultural values of populations, thus it can be instructive to look at them to see what are the differences, if any. The following cited publications cannot be exhaustive about the perception in the whole country, nor they ask the same questions thus comparative possibilities are limited, but they can still be a useful snapshot and offer some insights.

In France Cottet and colleagues (2013) found no relevant differences in the perception of experts and laypeople, although it must be noted that it was not directly related to river corridors and floodings but rather wetlands, which in this case we consider as a proxy.

Ruiz-Villanueva and colleagues (2018) found that in Spain the perception of experts and laypeople vary about the presence of wood in rivers, with experts favouring it, although recent flooding events do not seem to have power in shaping such perception.

In the UK Cameron and colleagues (2020) observed that self-reported well-being in respondents increased when they passed time in green areas with higher biodiversity than classical city surroundings, while Westling et al. (2014) found that the recurring factors that shaped people's perception of a river landscape after a restoration project were "scenic beauty; the condition of riparian vegetation and of river channel morphology; opportunities to observe flora and fauna; cleanliness of the riverine environment; access available to the river; connections between the river and the surrounding landscape; disturbance and change in the familiarity of the landscape following restoration". It can be noted that there are some contrasting factors, as the opportunity to observe flora and fauna collide with the cleanliness of the riverine environment.

In the Netherlands Verbrugge and van den Born (2018) found that the public perception of a planned river restoration project was positive, especially regarding flood safety. At the same time they highlighted how social bonding to the place is a key aspect that needs to be taken into consideration.

In Germany Thiele et al. (2019) found a significant difference in the aesthetic perception of historical riparian zones compared to new riparian zones, which is due to the fact that the historical riparian zones have been highly cultivated and thus have a higher anthropogenic impact, which makes them less appealing to the public. Deffner and Haase (2018) observed that more than 80% of the respondents to their survey rated the restored river sections positively, and after discovering the costs of restoring only 6% declared themselves contrary to the project. Weiss et al. (2023) found instead that while the overall projects of river restoration are valued positively, many respondents reject one or more components of such projects, depending on "individual concerns, the quality of communication, attachment to the site, and age" of the respondents.

In the Czech Republic Polednikova and Galia (2020) found with a photo survey that people recognized an increased value of the river after a restoration program in terms of (a) "ecological and hydromorphological function, (b) aesthetics and landscape function, (c) flood protection", but not in terms of recreational functions.

In Switzerland Seidl and Stauffacher (2013) investigated the differences in perception between different categories, such as farmers, citizens, etc. They found that farmers rate higher the aspects of flood protection and naturalness compared to other categories of the population.

This is not meant to be an exhaustive representation of the different perceptions about river restoration around Europe, but rather a starting point to look at the issue. We have to some extent visualized how different perceptions can be, in both negative and positive directions. What is even more interesting is that such perceptions can be directly contrasting, as in the case of France and Spain where in the former there were no relevant differences found in laypeople and experts perceptions (Cottet et al., 2013), while in the latter there is indeed a difference in laypeople and experts perception (Ruiz-Villanueva et al., 2018).

Finally, there can be no common solution adoptable in every situation, instead solutions need to vary depending on the context, they need to be unique in some sense, while still being grounded on scientific evidence.

Riparian zones and CS

In the 21st century, river geomorphology has strengthened and diversified further within the scope of “river science”, but has also gained social, behavioral and even political insights through “citizen science” and “co-design” in river projects. The professional challenges related to climate and biodiversity emergencies bring us back to the question “how should they be applied?” The increasingly public profiles of, for example, flood risk policies require river scientists to participate in recommending and co-designing options such as rehabilitation, restoration and rewilding. We must play a role in scenario-definition and adaptive management, promoting viable collaboration between the natural and social sciences, especially in the contested field of design.

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