Linking contemporary river restoration to economics, technology, politics, and society: Perspectives from a historical case study of the Po River Basin, Italy

Fabrizio Frascaroli, Giacomo Parrinello & Meredith Root-Bernstein

Ambio
A Journal of the Human Environment

ISSN 0044-7447

Ambio
DOI 10.1007/s13280-020-01363-3

Springer

Ambio
https://doi.org/10.1007/s13280-020-01363-3

KUNGL. VETENSKAPS-AKADEMIEN
THE ROYAL SWEDISH ACADEMY OF SCIENCES

REVIEW

Linking contemporary river restoration to economics, technology, politics, and society: Perspectives from a historical case study of the Po River Basin, Italy

Fabrizio Frascaroli, Giacomo Parrinello, Meredith Root-Bernstein

Received: 6 April 2020 / Revised: 21 June 2020 / Accepted: 29 June 2020

Abstract River restoration is a novel paradigm of 'mirescape' (land-and-water-scape) management that developed along with the emergence of aquatic ecology. River restoration can be seen as the application of an ecological perspective to return rivers to nature. However, the river restoration paradigm is also the contemporary iteration of historical phases of mirescape management. We review the long and varied recorded history of the Po River in northern Italy as a case study to illustrate the transformations and common themes of mirescape management. We find, first, that significant changes in mirescape management and river condition only occur in the context of larger social, political, technological and economic transformations. Second, we show how particular cultural understandings, economic interests, technological innovations and political powers have driven particular paradigms of mirescape management. These have tended towards increasing territorial separation of wet and dry. We find, third, that these separations lead not only to increasing economic precariousness for many, but also to increasingly severe disasters. We conclude that river restoration faces social and political challenges to becoming relevant at a mirescape scale, due to its lack of integration with land management, or with current social, political, technological and economic transformations. To act on this conclusion, we suggest philosophically aligned social movements that river restoration could work with to improve impact and uptake.

Keywords Landscape · Po River · River restoration · Socioecological · Socioeconomic · Systemic factors

INTRODUCTION

The restoration of degraded ecosystems has been an international priority for some years, reflected in Europe's H2020 focus on restoration and the UN's upcoming Decade on Ecosystem Restoration. The IPBES (International Panel on Biodiversity and Ecosystem Services) has also released a report outlining the challenges of land degradation (Scholes et al. 2018). River degradation and restoration are often considered and developed separately from issues of land degradation and restoration, but also get considerable attention. Globally, freshwater aquatic systems are degraded and at risk of stressors from climate change (Vörösmarty et al. 2010). In Europe, 95% of floodplains have been converted to agriculture or urban zones (Tockner and Stanford 2002). Only 2% of rivers in the United States are reported to be unaffected by previous management regimes, while over 70% of riparian forests have been cut down and flood storage capacity has declined (Palmer et al. 2007). Damming of rivers has "further contributed to the isolation of rivers from their riparian zones and alluvial plains" (Petts 1989). This isolation of rivers from their landscapes is a historical process that has followed the logics and imperatives of technical, economic and political developments (i.e. White 1995; Cioc 2002; Pietz 2015). Specifically, habitats where water and land mix dramatically and dynamically have been converted into either permanent water bodies or permanent dry land, leading to the isolation and separation of water and land habitats. The resulting 'habitat split' has negative effects on species such as amphibians and aquatic birds and mammals (otters etc.) (e.g. Becker et al. 2007). Different configurations separating water and land, and the ecologies they supported, have provided the resource basis (Brichet

Published online: 22 July 2020

and Hastrup 2018) for social dynamics, economies, institutions, and cultures, and their alteration.

The concept of "critical transition zones" can be used to capture the links and interfaces between soils, sediments and terrestrial and aquatic ecosystem processes (Wall et al. 2001). A watershed can have multiple transition zones such as estuaries, riparian areas, and wetlands. Adding a social element, we will refer to this interconnectedness and material imbrication as the "mirescape". 'Mire' refers to a wetland, which is one kind of mixing of water and land, but we also draw on the sense of 'mire' meaning 'stuck inside', 'mixed with' or 'involved.' The mirescape thus refers to the mixed, ephemeral and dynamic land-and-waterscape. While similar to "hydrosocial" (Swyngedouw 2009; Linton and Budds 2014) in its attention to the social dimension of natural processes, mirescape emphasizes the *intermixed and dynamic* interactions of water, earth, and society (de Micheau et al. 2018) and the amphibious landscapes they produce. Managing rivers has always been about managing mirescapes (Eagleson 1986).

Mirescape management has changed over time, both technically and with regards to its goals and motivations. While the emergence of a "restoration" paradigm in the 1980s is a response to dramatic changes in river states (Brown et al. 2018), it is also a continuation of previous trends in mirescape management. In this paper we trace the evolving configurations of the mirescape of the Po River in Northern Italy as a case study to highlight these points. With a length of over 650 km and a drainage basin of 74 000 km^2, the Po River is the longest and most important river in Italy. As such, the Po River Plain and its estuary have played a fundamental role as one of the most important and influential areas in the Italian peninsula—demographically, economically, politically—since antiquity (Lombardini 1868; Wickham 1981; Cazzola 1990). We review changing water management interventions leading to dramatic alterations in the condition of the mirescapes in the Po River Plain over the past 3 millennia. A series of changing regimes has been tightly linked to transformation in social, economic, and political regimes. In the final section, we discuss the current river restoration paradigm, how it differs from past mirescape management paradigms, and how it appears to be evolving in the Po River basin and in general.

HISTORY OF THE PO RIVER

The Bronze Age and Roman agriculture

Originally the Po River flowed further south than its present course, and had a 20 km wide meander belt. The Bronze Age Terramara cultural system in the Po River plain created villages protected by embankments, cultivated wheat in clearings in oak woodlands, and pastured livestock, probably in wetlands (Mercuri et al. 2006).

An important phase of water management began with the Romans. The major Roman treatise on agriculture, Columella's *Res rustica*, insisted on the necessity to *create* agricultural fields by drainage and ploughing (Bignardi 1969). This could be achieved through the territorial arrangement known as *centuriatio*, which consisted of the parcellation of an agricultural area—usually newly-conquered lands—into square allotments (*centuriae*), of ca. 50 ha, whose borders were delimited by canals or roads. Additional ditches ran parallel to the main axes, favouring the drainage of the marshy areas, and the irrigation of the fields (Capogrossi Colognesi 1982; Calzolari 2000).

The first *centuriatio* were impressed upon the lowlands of the Po River Plain, following the foundation of the colony of *Ariminum* (Rimini) in 268 BC (Bottazzi 2000; Calzolari 2000). However, as patches of marshland and woodland could not be entirely eradicated, wetlands continued to coexist with cultivated lands and play an important role for rural economies throughout the Roman Age (Calzolari 1986; Traina 1988; Bottazzi 2000).

The Roman history of the Po River offers a very old example of a centralized state using the separation of water from land to enact political control and maximize economic productivity. This regime was imposed on a different type of human–territory relation around rivers, consisting of small-scale economies that adapted flexibly to wetter and drier areas and periods through subsistence hunting, fishing, gathering and agriculture. Minotto (2014) describes such activities as *pascolar l'acqua* ("water husbandry"), a term first recorded in 1180, some 600 years after the Roman Empire had fallen (Wickham 1981).

Benedictine monks and *bonifica*

By the 1000s, the Po River Plain was newly dominated by *incolto* (uncultivated land), where woods, forests, and marshes had reclaimed large stretches of land (Wickham 1981; Chiappa Mauri 2002). The low-density rural population relied for subsistence on hunting, fishing, pig-farming and gathering complemented by sporadic agricultural work (Squatriti 1998; Chiappa Mauri 2002). However, a constant combat with waterlogging, the methodical excavation of ditches, and the use of embankments as defense against floods began to be reported around this time (Squatriti 1998). Benedictine monasticism in particular grew to be a very influential force on medieval water management.

The Benedictine monks had a primary role in medieval land reclamation and agriculture across much of Western Europe (Darby 1956; Jandolo 1989). In Italy, they

leveraged key technical advances, including the invention of weirs for water-power, canals, locks, flood defenses, and dredging (Petts 1989), to realize important works of reclamation and agricultural development in much of the Po River Plain (Jandolo 1989; Cazzola 1989a; Chiappa Mauri 2002; Ciriacono 2006).

The Benedictines are celebrated not only for their works of reclamation and water management, but also for first introducing three-yearly crop rotation and their entrepreneurial successes (Jandolo 1989; Loffi 1996). All of these attitudes are part of a specific understanding of the Christian relation to nature. For the Benedictines, agricultural labor and the resulting landscape represented a way to redeem both humans and land from an original condition of sin (Penco 1989). The Italian term for reclamation, *bonifica,* is first documented in the 12th century (Traina 1988), and can be understood in the Benedictine sense of *bonum facere*, i.e. 'making, turning into good', applied to both people and land.

Renaissance hydraulic engineering

During the period of the Renaissance (15–16th centuries), water management in the Po River Plain became focused on creating a construct of expectancies and favorable physical dynamics to be imposed on the erratic behavior of the mirescape. This approach largely reflected major transformations in the perception of time and space, which had started in the Middle Ages. The spread of the mechanic clock from the 1300s brought to European urban societies an entirely novel image of time as a uniform, abstract, quantifiable, and essentially "unnatural" entity (Landes 1984). Analogously, the emergence of linear perspective in the arts, that is, of a "completely rational" and "purely mathematical" model of space (Panofsky Panofsky 1960; Farinelli 2003), played a role in shaping expectancies about how nature could be both represented and made to present itself. In the realm of water management, these new ideas gave rise to a hydraulic model, whose dynamics could be forecast, standardized, replicated, and therefore governed with a higher degree of certainty and regularity (Scott 1998).

The Late Middle Ages and the Renaissance also witnessed a gradual reemergence of centralized political authorities, after the dissolution of the Roman Empire and the following political fragmentation. A strengthened political authority favored the conditions for turning water management into a form of financial speculation, whereby private investors converted to arable land and resold terrains that had originally been acquired for very low costs as *incolto* (Cazzola 1987, 2003b; Cherubini 1996).

These developments were accompanied by considerable advances in hydraulic engineering and new technologies for managing the separation of water and land. These new possibilities both allowed and forced engineers and managers to grapple with questions of how rivers *ought* to be, rather than how they were or how they used to be. As a consequence, the magnitude and ambition of some of the hydraulic projects undertaken in the 15th and 16th centuries grew remarkably, coming to affect the geomorphologic configuration of entire basins (Cazzola 2003b). In some instances, these efforts to reform the landscape had explicit political drivers and consequences, and mirescapes could be made and unmade to serve political interests. The current configuration of the Po Delta is the most emblematic example in this sense. Indeed it formed as a result of the *Taglio di Porto Viro* ("cut of Porto Viro"; Fig. 1), a diversion of the mouth of the Po River that the Republic of Venice created to prevent the siltation of the lagoons of Venice by moving the area of silt deposition farther south (Bertoncin et al. 2014). The choice of location for the new mouth of the Po River, however, was not random or benign, and resulted in the rapid formation of deltaic deposits in front of the Castle of Mesola, where the competitor of the Republic of Venice, the Duke of Ferrara, had planned to build a port to rival Venice. Within a decade since the diversion, Mesola was several kilometers inland behind new expanses of marshland, and in no position to be a port. The hydraulic engineering prowess of Venice was thus a weapon in the struggle for territorial control and economic dominance taking place between the Republic of Venice, the Duchy of Ferrara and the Papal State.

Industrial revolution

By the 1800s, the new technologies of the Industrial Revolution had enabled increasingly ambitious reclamation interventions. Pre-industrial reclamation relied on gravity, since the lack of sustained winds in the Po River Plain prevented the use of windmills to pump water. Applying fossil fuels and steam engines to drainage pumps eliminated those constraints and opened a new era of drainage and land reclamation in the Po River Plain, making it possible to raise water from lower to higher ground. The new technologies attracted major investments, not only from local landowners but also from international financial centers. In the early 1880s, in the area between the Adige River and the Po River, 18 major drainage plants were operating draining an overall surface of more than 32 000 ha (Commissione Agro-Idrografica Provinciale di Rovigo 1884). Even more important was the investment in drainage ventures south of the Po River. After a few unsuccessful experiments in the 1850s and 1860s, major investments from foreign ventures like the Ferrarese Land Reclamation Company in the early 1870s boosted drainage to an unprecedented extent (Porosini 1978).

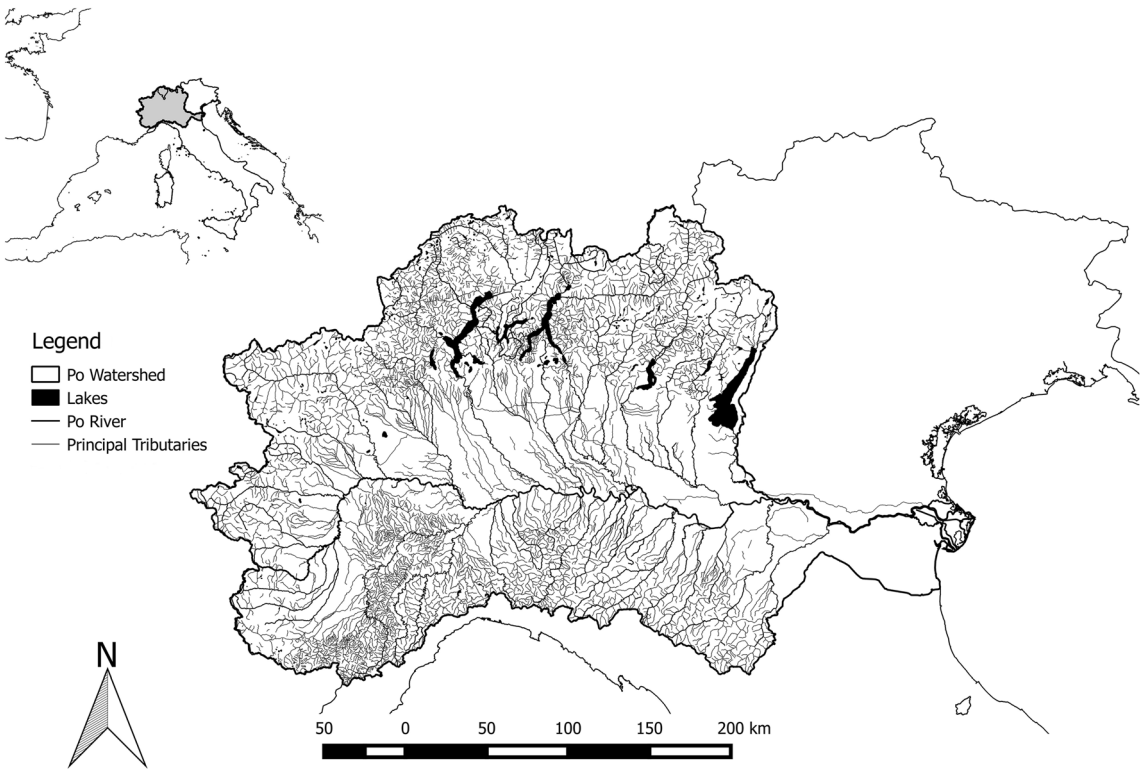

Fig. 1 Map of the Po River Basin in northern Italy, showing the Po River Delta on the far right

Despite the increasing modernization and industrialization of water management and modes of production, household wetland exploitation, also a feature of peasant livelihoods across Europe throughout the mediaval and early modern periods, and across the world at different times (Rippon 2000; Ash 2017), also persisted in several areas of the Po River Plain until the late 1800s and early 1900s (Cazzola 1996), guaranteeing modest but secure revenues and enabling micro-networks of trade and commerce (Bevilacqua 1996). The remaining mirescapes of the Po River Plain were rich in plant and animal resources (Grigolato 1843; Targioni Tozzetti 1871; Dal Fiume 1897):

> "fish alone could meet the needs of the population; one can catch sturgeons and tenches in the Po; from the brackish lagoons near the sea, fish is even exported to other countries" (Bocchi 1879, p. 68).

Specific communal rights such as the *vagantivo* ("roaming") granted free access to the wealth of resources in the wetlands. The advance of reclamation, however, gradually undermined this economy, as traditional practices of hunting, fishing, and craftmaking were displaced and eradicated by crops grown for export (Cazzola 1989b, 1996). This was accompanied by transformations of property and access regimes, either by revoking communal access to wetlands, or by privatizing traditional forms of communal land ownership. Violent waves of resentment and resistance to reclamation works spread among the local peasants (Cazzola 1989b, 1996). Unemployment increased where the mirescape-based traditional economy collapsed, and there were epidemics of pellagra, a potentially fatal disease caused by lack of vitamin B-3, which is naturally found in foods that the peasants could no longer access, such as meat, fish, grains, seeds and mushrooms.

It is also at this point in history that management of upstream parts of the Po River watershed began to dramatically impact downstream and estuary dynamics. Deforestation of the Po River watershed in the 18th and 19th century led to soil erosion and downstream river siltation, which, by the end of the nineteenth century started to be addressed through reforestation and the creation of upstream dams. Upstream transformations accelerated with the development of hydropower, first mechanical and then electrical. By the 1890s there were 12 000 watermills in the Po River watershed (Parrinello 2018). Most of these were grist mills, but some drove industrial textile factories. The inconstant flow of water had to be supplemented with steam power to keep the factories running (Parrinello 2018). The manufacture of turbines to produce electricity around the turn of the century facilitated the industrialization of the Po River watershed, and the eventual formation, by the early 20th century, of a "coordinated…hydrographic network" in which water

shortages in one area could be compensated with hydroelectricity from another area (Parrinello 2018).

The expansion of embankments and deforestation throughout the Po River catchment also led to an increase in the volume of water draining into the river and its canals (MAIC DGA 1892). This resulted in major floods in 1872, 1879, and 1882 (Comuni e Consorzi Idraulici del Bacino Veronese e Padano 1882). These disasters coincided with the worst phase of the nineteenth century agrarian crisis. Produce such as wheat, maize and rice, which were the staples of the reclaimed wetlands economy, experienced a sharp fall in prices (Cazzola 1996). Agricultural laborers were particularly affected, losing employment both in agriculture and reclamation. In 1884 and 1885 a major uprising occurred, inspired by new socialist ideas. The movement, known as "La Boje" ("it boils") lasted for several months despite military repression. In response, by the turn of the century the government funded a major new drainage canal in the Polesine lowlands, which became the centerpiece of infrastructural stabilization and a new hydrological and social order.

Economic speculation was not the only driver of draining and reclaiming wetlands. The link between mirescapes and malaria was also often evoked, in a political and medical discourse in which malaria was associated with rural backwardness (Novello 2003; Carter 2007). In this wake, the very meaning of *bonifica* began to shift by the mid 1800s, becoming gradually entangled with ideas of sanitation, hygiene, and environmental health in rural and urban settings alike (Mioni 1976). The "Law Baccarini" from 1882 was an important step in officializing this transition and a more intensive participation, also financial, of the state in matters of *bonifica*. Similarly, the law began to identify as *bonifica* not only drainage of the lowlands, but also interventions of reforestation in the upper basins to reduce soil erosion and river siltation, and regulation of river flow via dams (Bevilacqua and Rossi-Doria 1984). This approach would combine with the exploitation of water to produce hydroelectric power, contributing largely to the next phase of river management in the Po River watershed.

Fascist *bonifica integrale* and the mid 20th C

During its rule over the country (1922–1943), the Fascist regime developed a specific approach to water management and land reclamation. Some of the distinctive characteristics of this approach included: an even stronger use of state incentives to support reclamation; combating malaria as a prominent rationale for wetlands drainage; using grand works of reclamation for channeling malcontent and stabilizing social turmoil in the countryside; and further integrating the management of the lowlands and floodplains with that of the upper basins through reforestations, canalizations, and the creation of reservoirs (Serpieri 1929; Giandotti 1937; Mioni 1976; Bevilacqua and Rossi-Doria 1984). The regime labeled this overall approach as *bonifica integrale* ("integral reclamation") and viewed it as a central means to strengthen society, and ultimately the "Italian race", through a thorough reorganization of the countryside. Such an idea was clearly encapsulated in slogans like "*Bonificare la terra per bonificare l'uomo, bonificare l'uomo per bonificare la razza*," ("Reclaim the land to reclaim the man, reclaim the man to reclaim the race") (cited in Carter 2006). The law on *bonifica integrale* from 1928—known with the emblematic name of "Law Mussolini"—was deemed to be "the regime's fundamental law" (Mariani 1976). Besides its concrete applications, the notion of *bonifica integrale* encapsulated nearly everything the regime allegedly stood for: discipline, order, affluence, masculine willpower, national potency, the celebration of Italy's rural heritage, and, at the same time, the futuristic exaltation of machinery, technology, and their efficacy as instruments of power and dominion. In Fascist discourse, land reclamation thus offered a representation of the regime's efficiency and triumphing ideological principles (Armiero and Hardenberg 2013).

While Fascist reclamation seemingly succeeded in maintaining political stability, *bonifica integrale* did not intervene on the fundamental contradiction opened by the mid-nineteenth century reclamation: a mirescape that excluded the vast majority from regular access to income while physically reducing or eliminating other possibilities of subsistence. Moreover, while presented as the restoration of a pre-existing "hydraulic order", the water management policy of the fascist regime effectively produced major transformations at the scale of the entire Po River basin. These effects are visible in the massive development of hydroelectric reservoirs and power plants. Between 1918 and 1943 alone, 91 hydroelectric reservoirs were built in the Italian portion of the upstream Po watershed (ANIDEL 1958; Parrinello 2018). In addition to these reservoirs, the interests of electricity production and agricultural improvement, combined under the banner of *bonifica integrale*, led to the construction of major infrastructures such as the dams regulating the outflow of the lakes Maggiore, Como, Iseo, and Garda (Consolini 1954).

The large-scale alteration of the river basin's hydrology, ecology, and morphology in the name of control and productivity did not prevent the occurrence of disasters like a major flood in 1951. That event was most tragically felt in the lowlands of the Delta, where around 100 000 hectares of farmland were flooded, and the entire hydraulic system of canals and pumps was heavily damaged by the flood (Ministero dei Lavori Pubblici 1952). In addition, due to the flooding, about 150 000 people were evacuated from

the area known as Polesine, and returned to conditions of unemployment. The 1951 flood is the most dramatic episode in a sequence of disasters that began with the inundation of the Reno River and Po River in 1949 (Cazzola 2000), and continued with major floods of the Po River in 1951, 1953, 1957, 1959, 1966, 1968, 1974, 1979, 1994, and finally 2000 (Tomasi 2004).

THE EMERGENCE OF AN INTERNATIONAL RIVER RESTORATION PARADIGM

In the wake of those disasters and other criticalities, such as the declining discharge rates of the Po River during the summer months, a discourse about the need to restore (or re-naturalize) rivers began to emerge in Italy, as in the rest of the Western world, in the second part of the 20th century. In this section we argue, however, that river restoration is not, as one might assume, simply the reversal or removal of all previous historical social influences on a river. Rather, it represents another iteration on forms of mirescape management. The key conceptual innovation in this phase is that, in contrast to previous paradigms, rivers are now seen as something to be reconnected with the land but disconnected from the social.

By the late 20th century, the international scientific community began to regard rivers as degraded ecological and geomorphological entities (Petts 1989; Ward et al. 2001; Beechie et al. 2010; Strayer and Dudgeon 2010). This reframing can be broadly contextualized within emerging global environmentalist discourses and the development of conservation and restoration as applied disciplines (Smith et al. 2014). By framing rivers as objects of study of geomorphology and ecology, scientists were able to claim rivers as properly "natural" rather than cultural or socioeconomic objects, and were successful in presenting themselves as the appropriate caretakers of rivers (Williams 2001).

River restoration presents itself as an applied field dealing strictly with water flow, sediments, freshwater plants and animals, and cost–benefit analyses (Ward et al. 2001; Brouwer et al. 2015). Today rivers, estuaries and wetlands are seen as providing essential habitats for biodiversity and ecosystem services for society (Ramsar Convention on Wetlands 1994; Giblett 1996; Saunders et al. 2002; Turner 2005). This ecological reinterpretation of rivers as natural phenomena means that goals for mirescape management are defined in terms of ecological and geomorphological data and theory. River restoration aims to establish a self-regulating riparian landscape with "predisturbance" physical, chemical and biological characteristics and functions (Ward et al. 2001), taking a more holistic, less command-and-control approach than hydroengineering (de Boer and Bressers 2011; Brierly and Hooke 2015). Specific goals include bank stabilization, channel reconfiguration, reconnection to the floodplain, fish passage creation, dam removal, aquatic and terrestrial habitat improvement, species protection, water quality management, and so on (Bernhardt et al. 2007). A focus on processes and watershed scales has been recommended as best representing the variability and heterogeneity of natural systems (Wohl et al. 2005) although in reality projects are usually small-scale and focused on geographical or sediment forms (Bernhardt et al. 2007).

Even since its emergence, changing theorizations of ecological dynamics and the role of baselines have altered how river restoration is planned and designed. Recent literature incorporates the idea of multiple possible trajectories (e.g. Dufour and Piégay 2009). This entails also moving from history as template to historical knowledge as a guide (Higgs et al. 2014). By embracing multiple baselines or trajectories, long time frames, and holistic management (Beechie et al. 2010), river restoration is merging with discourse and practice around rewilding, which seeks ecosystem process restoration through species reintroduction and minimal or passive management (Jørgensen 2015). Thus, the literature now includes ideas about beaver reintroduction to create pond ecosystems (Brown et al. 2018), moose reintroduction to move nutrients across aquatic-terrestrial gradients (Bump 2018), and leaving dead tree debris in streams (Thompson et al. 2018).

Modern river restoration practices have developed and been widely applied in Europe and North America since the 1980s (Angelopolous et al. 2017). In the EU, river restoration is primarily funded through the LIFE and INTERREG funding cycles (Angelopolous et al. 2017). Two hundred and sixty four river restoration projects were carried out in France between 2000 and 2009 (Morandi et al. 2014), and over 37 000 river restoration projects were carried out in the US between 1996 and 2002 (Bernhardt et al. 2007). Although river restoration represents an industry in itself, it remains unevenly applied and suffers from an inability to demonstrate success to its sponsors using principles of ecological science (Williams 2001; Smith et al. 2014).

THE PO RIVER SINCE THE 1980S: TOWARDS IMPLEMENTING THE RIVER RESTORATION PARADIGM

The Po River is not a prime example of the river restoration paradigm in that it remains largely unrestored (and entirely un-rewilded), and has seemingly lost its status as a site of mirescape management innovation (Manieri 2016). It thus provides a case study of the challenges of disarticulating

mirescapes from social exploitation and reorienting their management to produce inherent natural values and data. Along the Po River and its tributaries, a growing awareness of the ecological significance of river systems has led to the establishment of protected areas, as well as to a revision of approaches to water management inherited from the mid-twentieth century. A prominent example is the introduction of the principle of the "*deflusso minimo vitale*", a criterion that established that dams and other water infrastructure have to ensure a discharge sufficient for the survival of biotic communities (first introduced in the Law 18 May 1989 n. 183). Further, between 1975 and 1985, the *consorzi di bonifica* were re-districted into only 200 larger entities, entirely "defined on the ground of the respective catchments" (Medici 1992; Cazzola 2003b). The rationale was to use hydrographical basins as ideal and more "natural" environmental units for water management and land planning (ANBI 1992). For this purpose, River Catchment Authorities were also created after 1989, one for each drainage basin, including for the entire Po River (Autorità di bacino del fiume di Po, or AdbPo). More recently, the idea of wetland restoration or "re-naturalization" (WWF Italia 2005), and its potential benefits for ecosystem functioning, especially flood prevention or absorption (McAllister et al. 2000), has entered the repertoire of water management in the Po River Plain.

Numerous LIFE and INTERREG-funded wetland restoration projects have taken place along the Po River over the past couple of decades (Root-Bernstein and Frascaroli 2016). They are, arguably, merely small simulacra of natural ecosystems, cut off from the larger watershed system and serving few ecological or social functions (Cronon 1996; Root-Bernstein and Frascaroli 2016). The implementation of new zones and competencies representing 'natural' boundaries, without anyone having the political power to dissolve the old zones and competencies, has contributed to a fragmentation of governance and management (Biermann et al. 2009; Manieri 2016; Root-Bernstein and Frascaroli 2016). No party has the power to implement projects over a scale and extent large enough to also produce evidence of a resulting good ecological condition to possible sponsors. Especially emblematic is the AdbPo, which should be the institution supervising and coordinating actions over the entire Po River basin but, in practice, has always had limited decision-making authority.

This fragmentation of powers is layered onto another problem caused by conceiving of rivers as substantially disarticulated from economics, politics and technology. This conception makes river restoration dependent on charitable financial mechanisms such as the EU's H2020 programme funding science and restoration. In contrast, local and regional political ambitions or economic projects and innovations appear no longer able to drive place-based mirescape management. One might see this as positive: without political, technological and economic drivers, environmental degradation and loss of biodiversity should be reduced. On the other hand, the river restoration approach so far appears unlikely to receive the societal investment and involvement that would allow it to reorganize the mirescape on a significant scale. At the time of our research in the Po River Delta (Root-Bernstein and Frascaroli 2016), stakeholders hoped that the establishment of a UNESCO Man and Biosphere Reserve in 2015 would lead to a new institutional configuration with the capacity to override decision-making impasses and impose restoration at a meaningful scale. UNESCO, at the time, suggested that this was not the role of Man and Biosphere Reserves. This highlights the search for new political, economic, technological and cultural frameworks or tools, or novel uses of existing ones, to allow the restoration ecology approach to scale up.

DISCUSSION AND CONCLUSIONS

Each river in the world has its own trajectory of modification and management, depending on place and history (Petts 1989; Ashmore 2015; Mossa 2016). We have used the particularly illustrative history of the Po River in Italy to demonstrate how socio-economic, political and cultural factors have repeatedly reshaped the management of water and land, including the current approach known as river restoration (Table 1). Key to the extraction and valuation of water-related resources in terrestrial territories has been the ever sharper division of water and land, expanding from the rectilinear clearing and drainage works of the Romans to the mechanical steam-powered pumps of the Industrial Revolution, and the massive and complex engineering capacities of the present. This same process has resulted in an increase in territorial instability and disaster events, while also incrementally removing all small-scale human–mirescape interactions, economies, and local ecological knowledge bases. Although enacting a *different* vision of the relationship between humans and the territory, river restoration does not *restore* any previous mode of human–mirescape interaction. In a historical framework, claims that river restoration returns rivers to a "natural state" cannot be taken at face value, but may be seen as enacting, and acquiring funding flows for, a specific view of rivers as natural but only marginally social phenomena.

A key point implied by our historical analysis is that a joint focus on land use as well as water management is necessary for achieving a functional ecological restoration of mirescapes. Over history, this has often been achieved through authoritarian political systems or asymmetric

Table 1 Summary of the main societal conditions in each period and their effect on the Po River Mirescape

Historical period	Approximate dates	Politics	Economics	Technology	Society	Mirescape state and transformation
Bronze Age Terramara cultural group	1650–1200 B.C.	Unknown	Wheat farming in forest clearings and shepherding, probably in wetlands. Probably, credit and barter system	Embankments to protect villages	Unknown	Large river meanders. Floodplains, forests, extensive wetlands. Small clearings in woodlands for crops
Roman Period	268 B.C–600 A.D.	Colonization by the Roman Empire	Parcellation of agricultural fields; parallel hunting/fishing/gathering/ shepherding by peasants. Colonial monetary economy	Drainage ditches, measurement	Colonial control of resources and production	Drainage. Land conversion to agriculture. Creation of agricultural fields of 50 ha each
Middle Ages	1000–1400 A.D.	Feudal states and Church	Agriculture commercialized by Benedictine monks, parallel hunting/fishing/gathering/ shepherding by peasants. State monetary economy	Weirs, canals, locks, dredging, reclamation. Crop rotation	Benedictine monks' Christian ethic of redemption of man and land	Re-establishment of forests. Increasing land reclamation for agriculture
Renaissance	1400–1500 A.D.	Feudal states and Church. Increasing stability	Financial speculation on reclaimed land. Parallel hunting/fishing/gathering/ shepherding by peasants	Hydraulic engineering	Advances in engineering, sciences and arts give impression of an increasingly controllable world	Increasing reclamation and river alteration for economic and political purposes. Formation of the delta

Table 1 continued

Historical period	Approximate dates	Politics	Economics	Technology	Society	Mirescape state and transformation
Industrial Revolution	1800–1900	Unification of Italy. Law Baccarini (1882) allowing state finance of reclamation. Peasants' land access rights increasingly revoked and land increasingly privatized	Persistent hunting/fishing/shepherding/gathering livelihoods and micro-trading by peasantry. Increasing wage labour. Export of crops. International and national speculation on reclamation. Factory production driven by hydropower	Hydropower, hydroelectricty, steam engines and fossil fuels. Turbines. Drainage pumps. Dams. Embankments. Reforestation upstream	Series of flood disasters leading to deaths, diseases of malnutrition, socialism, social unrest, increasing interest in malaria control and sanitation	Decrease in wetlands, conversion to agriculture. Upstream deforestation, erosion, and reforestation
Fascist period	1922–1943	Single party regime. *Bonifica integrale* policy supporting reclamation and landscape management	The region is a major industrial zone, as well as a major agricultural zone. Export economy	Major dams and hydroelectic reservoirs	Fascist ideology of discipline, order, affluence, masculine willpower, national potency, rural heritage, technological domination expressed via *bonifica integrale*. Series of damaging floods	Increasing regulation of water bodies for power production
Late 20th–early 21st century	1980s–present	Democratic state. EU member. River Catchment Authorities under the authority of the AdbPo. Po Delta Man and Biosphere Reserve established	EU Economic and Monetary Union. Funding for restoration through EU nature conservation grants. Traditional peasant economy vestigal or extinct	Environmental engineering. Species reintroductions	Rivers as nature. Nature as opposed to and separate from society. Nature as the realm of environmental science. Return of rivers to pre-anthropogenic states	Restoration of wetlands, especially downstream

power relations. The current contexts of multi-scale democratic decision-making and institutional fragmentation pose a new set of challenges in this sense. Similarly, the existence of multiple economic interests, which tie up a particular way of doing things, can also be an impediment. For example, dam removal (Bednarek 2001) is unlikely while consumers and producers continue to have economic interests in the electricity those produce. Synergies with new forms of management institutions and new economic innovations and productive technologies should be key to better implementation of river restoration. Thus, those interested in implementing river restoration need to actively seek out partnerships with innovative political, economic and technological institutions and systems that are compatible with a philosophy of porous boundaries and natural dynamics.

A dynamic, spatially complex, and shifting mirescape requires socioeconomic and political adaptations to living with cyclical change, flexibility, and multiple values (i.e. multiple resources, uses, forms of exploitation, livelihoods). Urban development and urban civic initiatives have provided testing grounds for new ways of organizing social and economic life to meet similar kinds of challenges. Considerable professional expertise has been formed around the management of ephemeral urban communities oriented towards social solidarity, creativity, and resource and infrastructure revalorization (Pinard and Vivant 2017; Cumbers et al. 2018). Community-scale resource management organizations can be sustainable and deliver capacity building and social equity (e.g. Armitage 2014; Burivalova et al. 2017). Another set of approaches develops what are known as "diverse economies," associations and communities of enterprise not based solely on money (Roelvink et al. 2015). Social entrepreneurs are an emerging generation of business creators focussed on social reform via sustainability, local products, craft skills, new information technologies, working with marginal communities, and so on (Nicholls 2008). Adaptive capacity and indigenous and local knowledge (ILK) increasingly are important concepts within the larger global discussion on adaptation to climate change (Eakin et al. 2010; Engle and Lemos 2010), and ILK remains a source of ways of living in flooding environments, for example (Martin et al. 2010; Morita 2016). While potentially allowing for forms of management that reduce disaster risks by reducing the split between water and land, flexible and adaptive small-scale diverse economies might resemble globalized and technologically innovative versions of the earliest historical human–river socio-ecological relationships. Whatever the future comes to resemble, the identification of restoration with ecology and geomorphology, to the exclusion of innovations in economics, politics and technology, can only be seen as reductive and an impediment to application and uptake. An interdisciplinary and engaged approach in dialogue with socioeconomic and political innovations is essential to achieve socio-ecological restoration, including disaster prevention and mitigation, in mirescapes.

Acknowledgements During the preparation of this paper MR-B was supported by a Marie Curie FP7 COFUND Agreenskills Plus Fellowship, and by the Center of Applied Ecology and Sustainability (CONICYT PIA/BASAL FB0002). FF is thankful to Gísli Pálsson and the University of Iceland for having first solicited the research that is partly the basis of this paper.

REFERENCES

Angelopoulos, N.V., I.G. Cowx, and A.D. Buijse. 2017. Integrated planning framework for successful river restoration projects: Upscaling lessons learnt from European case studies. *Environmental Science & Policy* 76: 12–22.

ANBI Associazione Nazionale delle Bonifiche Irrigazioni e Miglioramenti Fondiari (ed). 1992. *La Bonifica nella Trasformazione del Territorio e della Società* Bologna IT: Edagricole.

ANIDEL Associazione nazionale imprese produttrici e distributrici di energia elettrica. 1958. *Le dighe di ritenuta degli impianti idroelettrici italiani 7 vv* Milano: Rizzoli.

Armiero, M., and W. Hardenberg. 2013. Green Rhetoric in Blackshirts: Italian Fascism and the Environment. *Environment and History* 19: 283–311.

Armitage, D. 2014. Social-ecological change in Canada's Arctic. In *Climate change and the coast: Building resilient communities*. CRC Press: Boca Raton.

Ash, E.H. 2017. *The draining of the Fens: Projectors, popular politics, and state building in early modern England*. Baltimore: Johns Hopkins Studies in the History of Technology.

Ashmore, P. 2015. Towards a sociogeomorphology of rivers. *Geomorphology* 251: 149–156.

Autorità di Bacino del Fiume Po [AdbPo]. 2008. *Un Futuro Sostenibile per il Po: Azioni per la Valorizzazione del Capitale Umano Naturale e Culturale delle Terre del Po Progetto Valle del Fiume Po: Progetto Strategico Speciale*. Parma IT: AdbPo

Bacchi, T. 1985. Conquista del territorio e modificazione dei modelli insediativi. Le aziende fondiarie nel Ferrarese (secoli XI-XII)". In *Le Campagne Italiane Prima e Dopo il Mille*, ed. B. Andreolli., V. Fumagalli, V. and M. Montanari, 133–161. Bologna IT: Editrice CLUEB.

Bocchi, F.A. 1879. *Trattato geografico-economico comparativo per servire alla storia dell'antica Adria e del Polesine di Rovigo in relazione a tutta la bassa vallata padana*. Adria IT: Premiata Tipografia Eredi Guarniere.

Becker, C.G., C.R. Fonseca, C.F.B. Haddad, R.F. Batista, and P.I. Prado. 2007. Habitat split and the global decline of amphibians. *Science* 318: 1775–1777.

Bednarek, A.T. 2001. Undamming rivers: A review of the ecological impacts of dam removal. *Environmental Management* 27: 803–814.

Beechie, T.J., D.A. Sear, J.D. Olden, G.R. Pess, J.M. Buffington, H. Moir, and M.M. Pollock. 2010. Process-based principles for restoring river ecosystems. *BioScience* 60: 209–222.

Bernhardt, E.S., E.B. Sudduth, M.A. Palmer, J. David Allan, J.L. Meyer, G. Alexander, J. Follastad-Shah, B. Hassett, et al. 2007. Restoring rivers one reach at a time: Results from a survey of US river restoration practitioners. *Restoration Ecology* 15: 482–493.

Bertoncin, M., A. Pase, and D. Quatrida. 2014. La construtión géo-historique du Delta du Pô. In *Les zones humides*

méditerranéennes hier et aujourd'hui | Le zone umide mediterranee ieri e oggi, ed. M. Franchomme, C. Labeur, D. Quatrida, and R. Simonetti, 313–330. Padova IT: Padova University Press.

Bevilacqua, P. 1996. *Tra Natura e Storia Ambiente Economie Risorse in Italia*. Roma IT: Donzelli Editore.

Bevilacqua, P., and M. Rossi-Doria. 1984. Lineamenti per una storia delle bonifiche in Italia dal XVIII al XX secolo. In *Le Bonifiche in Italia dal '700 ad Oggi*, ed. P. Bevilacqua and M. Rossi-Doria, 3–78. Bari IT: Editori Laterza.

Biermann, F., P. Pattberg, H. Van Asselt, and F. Zelli. 2009. The fragmentation of global governance architectures: A framework for analysis. *Global Environmental Politics* 9: 14–40.

Bignardi, A. 1969. L'attività bonificatoria degli Etruschi e dei Romani. *La Bonifica* 3–4: 193–200.

Bottazzi, G. 2000. La colonizzazione romana: città e territori centuriati. In *Un Po di terra. Guida all' ambiente della bassa pianura padana e alla sua storia* ed. C. Ferrari and L. Gambi, 397-413. Parma, IT: Diabasis.

Brichet, N., and F. Hastrup. 2018. Industrious landscaping: The making and managing of natural resources at Søby Brown Coal Beds. *Journal of Ethnobiology* 38: 8–24.

Brierley, G., and J. Hooke. 2015. Emerging geomorphic approaches to guide river management practices. *Geomorphology* 251: 1–5.

Brouwer, R., O.J. Kuik, O. Sheremet, Y. Jiang, D.K. Brands, H. Gerdes, M. Lago, M. Hinzmann, et al. 2015. *Cost-effective restoration measures that promote wider ecosystem and societal benefits*. European Commission publication.

Brown, A.G., L. Lespez, D.A. Sear, J.J. Macaire, P. Houben, K. Klimek, and B. Pears. 2018. Natural vs anthropogenic streams in Europe: History, ecology, and implications for restoration river-rewilding and riverine ecosystem services. *Earth-Science Reviews* 180: 185–205.

Bump, J.K. 2018. Fertilizing riparian forests: Nutrient repletion across ecotones with trophic rewilding. *Philosophical Transactions of the Royal Society B* 373: 20170439.

Burivalova, Z.F., L.P. Hua, C. Koh, C. Garcia, and F. Putz. 2017. A critical comparison of conventional certified and community management of tropical forests for timber in terms of environmental economic and social variables. *Conservation Letters* 10: 4–14.

Calzolari, M. 1986. *Territorio e Insediamenti nella Bassa Pianura del Po in Età Romana*. Poggio Rusco IT: Banca Popolare Agricola di Poggio Rusco.

Calzolari, M. 2000. Età romana: le terre lungo il Po. In *Un Po di Terra: Guida all'Ambiente della Bassa Pianura Padana e alla Sua Storia*, ed. C. Ferrari and L. Gambi, 381–396. Reggio Emilia IT: Diabasis.

Capogrossi Colognesi, L. 1982. *L'Agricoltura Romana: Guida Storica e Critica*. Bari IT: Laterza.

Carter, E.D. 2007. Development narratives and the uses of ecology: Malaria control in Northwest Argentina 1890–1940. *Journal of Historical Geography* 33: 619–650.

Cazzola, F. 1990. Terra e bonifiche nel delta padano (secoli XV-XVIII) In *Uomini terra e acque: politica e cultura idraulica nel Polesine tra Quattrocento e Seicento: atti del XIV Convegno di studi storici organizzato in collaborazione con l'Accademia dei Concordi Rovigo 19-20 novembre 1988* a cura di Convegno di studi storici Franco Cazzola Achille Olivieri e Accademia dei Concordi di Rovigo 11–24 Rovigo: Minelliana.

Cazzola, F. 1996. *Storia delle campagne padane dall'Ottocento a oggi*. Milano: Bruno Mondadori.

Cazzola, F. 2003a. Dalle carte dei consorzi di bonifica: sviluppo agricolo e trasformazione del territorio. In *Archivi Storici nei Consorzi di Bonifica dell'Emilia-Romagna Guida Generale*, ed. E. Fregni, 11–19. Bologna IT: Patron.

Cazzola, F. 2003b. Le bonifiche cinquecentesche nella Valle del Po: governare le acque creare nuova terra. In *Arte e Scienza delle Acque nel Rinascimento*, ed. A. Fiocca, D. Lamberini, and C. Maffioli, 15–35. Venezia IT: Marsilio Editori.

Cazzola, F. 1987. *Le bonifiche nella Valle Padana: un profile Rivista di Storia dell'agricoltura* 2: 38–66.

Cazzola, F. 1989. La terra costruita: Ferrara e la bonifica. In *Terra ed Acqua: Le Bonifiche Ferraresi nel Delta del Po* ed. A.M. Visser Travagli and G. Vighi, 101–124. Ferrara IT: Gabriele Corbo Editore.

Cazzola, F. 1989b. Il paesaggio agrario emiliano: permanenze e trasformazioni. In *Studi sul Paesaggio Agrario in Europa (Convegno su Il Paesaggio Agrario Europeo dal Medio Evo all'Età Contemporanea Cesena 22-24 April 1987)*, ed. R. Villari, 223–241. Bologna IT: Società Editrice Il Mulino.

Cazzola, F. 2000. Lo sviluppo storico delle bonifiche idrauliche. In *Un Po di Terra: Guida all'Ambiente della Bassa Pianura Padana e alla Sua Storia* ed. C. Ferrari and L. Gambi Reggio, 487–515. Emilia IT: Diabasis.

Cherubini, G. 1996. *L'Italia Rurale del Basso Medioevo*. Bari IT: Editori Laterza.

Chiappa Mauri, L. 2002. Popolazione popolamento sistemi colturali spazi coltivati aree boschive ed incolte. In *Storia dell'Agricoltura Italiana Vol II: Il Medioevo e l'Età Moderna*, ed. G. Pinto et al., 23–57. Firenze IT: Edizioni Polistampa.

Cioc, M. 2002. *The Rhine: An Eco-Biography 1815-2000*. Seattle: University of Washington Press.

Ciriacono, S. 2006. *Building on Water: Venice Holland and the Construction of the European Landscape in Early Modern Times*. New York, NY: Berghahn Books.

Commissione Agri-Idrografica Provinciale di Rovigo. 1884. Relazione della Commissione Agri-Idrografica Provinciale sull'Elaborato della locale Sezione tecnica di Finanza relativa ai corsi d'acqua ed ai stabilimenti industriali di questa Provincia 20 ottobre 1884 Box 295 folder 1571 MAIC DGA VI Versamento Archivio Centrale dello Stato.

Comuni e Consorzi Idraulici del Bacino Veronese e Padano. 1882. All'eccellentissimo Consiglio dei Ministri e all'Onorevole Camera dei Deputati Petizione dei Comuni e Consorzi Idraulici del Bacino Veronese e Padano danneggiati dalla rotta di Legnago. Rovigo: Reale stabilimento tipografico di Giuseppe Vianello.

Consolini, A. 1954. *Regolazione dei grandi laghi lombardi*. Vallecchi Firenze.

Cronon, W. 1996. The trouble with wilderness: Or getting back to the wrong nature. *Environmental History* 1: 7–28.

Cumbers, A., D. Shaw, J. Crossan, and R. McMaster. 2018. The work of community gardens: Reclaiming place for community in the city. *Work, Employment and Society* 32: 133–149.

Dal Fiume, C. 1897. Contributo allo studio dell'avifauna del Polesine. *Atti della società veneto-tridentina di scienze naturali residente in Padova* 3: 1–40.

Darby, H.C. 1956. *The Draining of the Fens*. Cambridge, UK: Cambridge University Press.

De Boer, C., and H. Bressers. 2011. *Complex and dynamic implementation processes: Analyzing the renaturalization of the Dutch Regge river*. Enschede: University of Twente Books.

de Micheaux, F.L., J. Mukherjee, and C.A. Kull. 2018. When hydrosociality encounters sediments: Transformed lives and livelihoods in the Lower Basin of the Ganges River. *Environment and Planning E: Nature and Space* 1: 641–663.

Dufour, S., and H. Piégay. 2009. From the myth of a lost paradise to targeted river restoration: Forget natural references and focus on human benefits. *River Research and Applications* 25: 568–581.

Eagleson, P.S. 1986. The emergence of global-scale hydrology. *Water Resources Research* 22: 6S–14S.

Eakin, H., A.M. Lerner, and F. Murtinho. 2010. Adaptive capacity in evolving peri-urban spaces: Responses to flood risk in the Upper Lerma River Valley, Mexico. *Global Environmental Change* 20: 14–22.

Engle, N.L., and M.C. Lemos. 2010. Unpacking governance: Building adaptive capacity to climate change of river basins in Brazil. *Global Environmental Change* 20: 4–13.

Farinelli, F. 2003. *Geografia Un'Introduzione ai Modelli del Mondo* Torino IT: Einaudi.

Giblett, R. 1996. *Postmodern wetlands: Culture, history, ecology*. Edinburgh: Edinburgh University Press.

Giandotti, M. 1937. *Idrologia della bonifica integrale* 3 vols Firenze: G Barbera.

Grigolato, G. 1843. *Piante acquatiche e palustri del Polesine* Rovigo: Antonio Minelli.

Higgs, E., D.A. Falk, A. Guerrini, M. Hall, J. Harris, R.J. Hobbs, S.T. Jackson, J.M. Rhemtulla, et al. 2014. The changing role of history in restoration ecology. *Frontiers in Ecology and the Environment* 12: 499–506.

Jandolo, E. 1989. La bonifica benedettina. In: *La Bonifica Benedettina,* ed. A. Ferrabino and V. Cappelletti, 27–49. Roma IT: Istituto della Enciclopedia Italiana.

Jørgensen, D. 2015. *Rethinking rewilding Geoforum* 65: 482–488.

Landes, D.S. 1984. *Storia del Tempo: L'Orologio e la Nascita del Mondo Moderno* Milano IT: Arnoldo Mondadori Editore.

Linton, J., and J. Budds. 2014. The hydrosocial cycle: Defining and mobilizing a relational-dialectical approach to water. *Geoforum* 57: 170–180.

Loffi, B. 1996. Dalla selva alla coltivazione. In *Contributo allo Studio delle Acque della Provincia di Cremona*, ed. Provincia di Cremona, 75–86. Cremona IT: Provincia di Cremona.

Lombardini, E. 1868. *Studi idrologici e storici sopra il grande estuario adriatico: i fiumi che vi confluiscono e principalmente gli ultimi tronchi del Po susseguiti da considerazioni intorno ai progetti per la regolazione delle acque alla destra di questi*. Milano: Teodoro Laengne.

Manieri, F. 2016. The Po River Basin: Managing a Complex System Lessons from the Past Recommendations for the Future. Uppsala Dep of Archaeology and Ancient History.

Mariani, R. 1976. *Fascismo e "Città Nuove"*. Milano, IT: Feltrinelli Editore.

Martin, J.F., E.D. Roy, S.A. Diemont, and B.G. Ferguson. 2010. Traditional Ecological Knowledge (TEK): Ideas, inspiration, and designs for ecological engineering. *Ecological Engineering* 36: 839–849.

McAllister, L.S., B.E. Peniston, S.G. Leibowitz, B. Abbruzzese, and J.B. Hyman. 2000. A synoptic assessment for prioritizing wetland restoration efforts to optimize flood attenuation. *Wetlands* 20: 70–83.

Medici, G. 1992. San Donà di Piave 5 giugno 1992: la bonifica per la protezione del suolo e per l'uso e la tutela delle acque. In: *La Bonifica nella Trasformazione del Territorio e della Società,* ed. *ANBI,* 29–46. Edagricole, Bologna IT.

Mercuri, A.M., C.A. Accorsi, M.B. Mazzanti, G. Bosi, A. Cardarelli, D. Labate, and G.T. Grandi. 2006. Economy and environment of Bronze Age settlements–Terramaras–on the Po Plain (Northern Italy): First results from the archaeobotanical research at the Terramara di Montale. *Vegetation History and Archaeobotany* 16: 43.

Ministero di Agricoltura, Industria e Commercio [MAIC], Direzione dell' agricoltura [DGA]. 1892. *Carta idrografica d'Italia: cenni sulle bonificazioni nelle provincie venete ed in quella di Mantova*. Roma: Bertero.

Ministero dei lavori Pubblici, Servizio Idrografico Centrale 1952. La piena del Po del novembre 1951. *Giornale del Genio Civile* 1: 5–12.

Minotto, A. 2014. Raccontare disegnare incidere l'acqua e la terra. Storie di geografia popolare nella laguna meridionale di Venezia nel Medioevo. In *Les zones humides méditerranéennes hier et aujourd'hui/Le zone umide mediterranee ieri e oggi*, ed. M. Franchomme, C. Labeur, D. Quatrida and R. Simonetti, 29–46. Padova: Padova University Press.

Mioni, A. 1976. *Le Trasformazioni Territoriali in Italia nella Prima Età Industriale*. Venezia IT: Marsilio Editori.

Morandi, B., H. Piégay, N. Lamouroux, and L. Vaudor. 2014. How is success or failure in river restoration projects evaluated? Feedback from French restoration projects. *Journal of environmental management* 137: 178–188.

Morita, A. 2016. Infrastructuring Amphibious Space: The Interplay of Aquatic and Terrestrial Infrastructures in the Chao Phraya Delta in Thailand. *Science as Culture* 25: 117–140.

Mossa, J. 2016. The changing geomorphology of the Atchafalaya River Louisiana: A historical perspective. *Geomorphology* 252: 112–117.

Nicholls, A. (ed.). 2008. *Social entrepreneurship: New models of sustainable social change*. Oxford: OUP.

Novello, E. 2003. *La Bonifica in Italia: Legislazione Credito e Lotta alla Malaria dall'Unità al Fascismo*. Milano IT: Franco Angeli Editore.

Palmer, M., J.D. Allan, J. Meyer, and E.S. Bernhardt. 2007. River restoration in the twenty-first century: Data and experiential knowledge to inform future efforts. *Restoration Ecology* 15: 472–481.

Panofsky, E. 1960. *Reinassance and renascences in Western Art*. New York, NY: Harper and Row Publishers.

Parrinello, G. 2018. Systems of power: A spatial envirotechnical approach to water power and industrialization in the Po Valley of Italy ca 1880–1970. *Technology and Culture* 59: 652–688.

Penco, G. 1989. Estensione e diffusione della bonifica benedettina. In *La Bonifica Benedettina*, ed. A. Ferrabino and V. Cappelletti, 51–84. Roma IT: Istituto della Enciclopedia Italiana.

Petts, G.E. 1989. Historical analysis of fluvial hydrosystems. In *Historical Change of Large Alluvial Rivers*, ed. G.E. Petts, R. Möller, and A.L. Roux. Chichester: Wiley and Sons.

Pietz, D. 2015. *The Yellow River: The Problem of Water in Modern China*. Cambridge Mass: Harvard University Press.

Pinard, J., and E. Vivant. 2017. La mise en évènement de l'occupation temporaire: quand les lieux artistiques off inspirent les opérateurs in de la production urbaine. *L'Observatoire* 2: 29–32.

Porisini, G. 1978. *Bonifiche e agricoltura nella bassa Valle Padana (1860-1915)*. Milano: Banca commerciale italiana.

Ramsar Convention on Wetlands 1994. Convention on Wetlands of International Importance especially as Waterfowl Habitat as amended in 1982 and 1987 Paris 13th July.

Rippon, S. 2000. *The Transformation of Coastal Wetlands: Exploitation and Management of Marshlands Landscapes in North West Europe during the Roman and Medieval Periods*. Oxford: Oxford University Press.

Roelvink, G., K.S. Martin, and J.K. Gibson-Graham (eds.). 2015. *Making other worlds possible: Performing diverse economies*. London: U of Minnesota Press.

Root-Bernstein, M., and F. Frascaroli. 2016. Where the fish swim above the birds: Configurations and challenges for wetland restoration in the Po Delta Italy. *Restoration Ecology* 24: 773–784.

Saunders, D.L., J.J. Meeuwig, and A.C.J. Vincent. 2002. Freshwater protected areas: Strategies for conservation. *Conservation Biology* 16: 30–41.

Scholes, R.J., L. Montanarella, E., Brainich, N., Barger, B., Ten Brink, M., Cantele, and F. Kohler. 2018. IPBES (2018): Summary for policymakers of the assessment report on land

degradation and restoration of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.
Scott, J.C. 1998. *Seeing like a state: How certain schemes to improve the human condition have failed*. New Haven, CT: Yale University Press.
Serpieri, A. 1929. Lo stato fascista e il capitalismo agrario: la bonifica integrale. In *Il Capitalismo Italiano del Novecento*, ed. L. Villari, 192–208. Bari IT: Editori Laterza.
Smith, B., N.J. Clifford, and J. Mant. 2014. The changing nature of river restoration. *Wiley Interdisciplinary Reviews: Water* 1: 249–261.
Squatriti, P. 1998. *Water and Society in Early Medieval Italy AD 400–1000*. Cambridge UK: Cambridge University Press.
Strayer, D.L., and D. Dudgeon. 2010. Freshwater biodiversity conservation: Recent progress and future challenges. *Journal of the North American Benthological Society* 29: 344–358.
Swyngedouw, E. 2009. The political economy and political ecology of the hydro-social cycle. *Journal of Contemporary Water Research & Education* 142: 56–60.
Targioni Tozzetti, A. 1871. *La pesca in Italia Volume 2 Parte 2* Genova: Tipografia del R Istituto dei Sordo-Muti.
Thompson, M.S., S.J. Brooks, C.D. Sayer, G. Woodward, J.C. Axmacher, D.M. Perkins, and C. Gray. 2018. Large woody debris "rewilding" rapidly restores biodiversity in riverine food webs. *Journal of Applied Ecology* 55: 895–904.
Tockner, K., and J.A. Stanford. 2002. Riverine flood plains: Present state and future trends. *Environmental Conservation* 29: 308–330.
Tomasi, P. 2004. Gli eventi storici nel Parmense in Provincia di Parma: Assessorato Ambiente e Tutela del Territorio (ed) *Dentro le Alluvioni.* Bologna IT: Pitagora Editrice: pp 441–449.
Traina, G. 1988. *Paludi e Bonifiche del Mondo Antico* Roma IT: L'Erma di Bretschneider
Turner, R.E. 2005. On the cusp of restoration: Science and society. *Restoration Ecology* 13: 165–173.
Vörösmarty, C.J., P.B. McIntyre, M.O. Gessner, D. Dudgeon, A. Prusevich, P. Green, S. Glidden, S.E. Bunn, et al. 2010. Global threats to human water security and river biodiversity. *Nature* 467: 555.
Wall, D.H., M.A. Palmer, and P.V. Snelgrove. 2001. Biodiversity in critical transition zones between terrestrial freshwater and marine soils and sediments: Processes linkages and management implications. *Ecosystems* 4: 418–420.
Ward, J.V., K. Tockner, U. Uehlinger, and F. Malard. 2001. Understanding natural patterns and processes in river corridors as the basis for effective river restoration. *Regulated Rivers: Research & Management: An International Journal Devoted to River Research and Management* 17: 311–323.
White, R. 1995. *The organic machine: The remaking of the Columbia River*. New York: Hill and Wang.
Wickham, C. 1981. *Early Medieval Italy*. Totowa NJ: Barnes and Noble Books.
Williams, P.B. 2001. River engineering versus river restoration In *ASCE Wetlands Engineering & River Restoration Conference Reno American Society of Civil Engineers.*
Wohl, E., P.L. Angermeier, B. Bledsoe, G.M. Kondolf, L. MacDonnell, D.M. Merritt, and D. Tarboton. 2005. River restoration. *Water Resources Research* 41: W10301.
WWF Italia 2005. *Il Governo dell'Acqua in Italia: Rilancio o Crisi? [Ed A Agapito Ludovici]* Roma IT: WWF Italia ONLUS.

AUTHOR BIOGRAPHIES

Fabrizio Frascaroli is an interdisciplinary conservation scientist. He currently works on biocultural approaches to conservation in Italy at Lòm.
Address: Associazione Lòm Onlus, 03030 Rocca d'Arce, FR, Italy.
Address: Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Università di Bologna, Bologna, Italy.

Giacomo Parrinello is assistant professor in environmental history at Sciences Po.
Address: Centre d'Histoire Sciences Po, Paris, France.

Meredith Root-Bernstein (✉) is a conservation scientist, visiting researcher at the Musée de l'Homme and associated post-doc at the Center of Applied Ecology and Sustainability and the Institute of Ecology and Biodiversity both in Santiago, Chile.
Address: Musée de l'Homme, Paris, France.
Address: Instituto de Ecología y Biodiversidad, Santiago, Chile.
Address: Center for Sustainability and Applied Ecology, Santiago, Chile.
Address: 28 rue Castagnary, Paris 75015, France.
e-mail: mrootbernstein@gmail.com