Asian Journal of Water, Environment and Pollution, Vol. 15, No. 2 (2018), pp. 203–215.
DOI 10.3233/AJW-180033

Analysis of Global River Restoration Experiences: Learnings and Policy Measures in the Indian Context

Madhura Bedarkar*, Urvashi Gill Dhingra[1], Mahima Mishra and Santosh Gopalkrishnan

Symbiosis Institute of Business Management Pune, Symbiosis International University, India
[1]Symbiosis School of Economics, Symbiosis International University, India
✉ madhurabedarkar@sibmpune.edu.in

Received September 15, 2017; revised and accepted March 26, 2018

Abstract: A majority of rivers across the globe are severely impacted due to human-induced activities. As a response to this challenge, river restoration efforts have been undertaken worldwide to rejuvenate and restore rivers to their natural state. India is no exception to this. This paper discusses river restoration programmes undertaken across the world to draw learning for river restoration in India. It also presents a critical analysis of river restoration in India, with specific reference to three case studies. The method adopted for this study is benchmarking based on literature review on global river restoration experiences, supported by structured expert interviews.

The paper concludes that there are certain issues with river restoration in India. River restoration projects are criticized on several grounds such as poor design, over-emphasis on beautification or 'cosmetic make-over' of the river and lack of public involvement and awareness. Consequently, despite of spending gigantic amounts on restoration, very little is being achieved. The study recommends that river restoration projects should have well-defined objectives, based on which a pre and post impact assessment should be conducted. There should also be greater involvement and participation of local communities, which is essential for sustaining the restored river.

Key words: River restoration, benchmarking, global river restoration experiences, river restoration in India, impact assessment, community participation.

Introduction

By definition, a river is a dynamical landscape (Nienhuis and Leuven, 2001). Rivers have played a crucial role in the evolution of human societies. Many great civilizations such as, Mesopotamians, Egyptian, Chinese and Indus valley civilizations evolved alongside great rivers like Tigris and Eupharates, Nile, Yellow river and Indus, respectively (Postel and Richter, 2012).

Rivers are valued for a variety of reasons, including spiritual, aesthetic, ecological and practical (Postel and Richter, 2012). However, over the past 6000 years, humans have distorted river courses through heavy engineering, releasing pollutants, over-extraction, etc. (Nienhuis and Leuven, 2001). This created concerns regarding sustaining these rivers to their natural state and consequently to the emergence of restoration efforts (Palmer et al., 2005).

River restoration has become a global phenomenon (Palmer et al., 2005; Giller, 2005). It is also seen as a 'highly profitable business' (Bernhardt et al., 2005). Wohl et al. (2005) define restoration as "assisting the

*Corresponding Author

establishment of improved hydrologic, geomorphic, and ecological processes in a degraded watershed system and replacing lost, damaged, or compromised elements of the natural system". River restoration consists of activities intended to protect and rehabilitate physical and biotic processes of a river (Koehn et al., 1997).

However, there is a lack of agreement on what constitutes river restoration (Palmer et al., 2005). There has also been public debate and controversies around its components and outcomes. For instance, Christian-Smith and Merenlender (2010) point out that majority of restoration initiatives consist of road repair, riparian stabilization and instream structures but doesn't address social drivers of watershed change.

The paper contains four sections. While the first section presents a comprehensive literature review on river restoration in the USA, Europe, Australia, Asia and Latin America; the second section discusses river restoration plans in India with reference to three restoration case studies: Sabarmati Riverfront Development Project, Mula-Mutha Pollution Abatement Project and Adyar Poonga ecological restoration project.

To gain further clarity on the matter of river restoration across globe and in India, expert interviews were conducted. The third section presents a thematic analysis of inputs received through these expert interviews.

In the last section, for improving river restoration efforts in India, an attempt has been made to provide recommendations to river authorities in India, such as Ministry of Water Resources, River Development and Ganga Rejuvenation and Ministry of Environment, Forest and Climate Change at the central level, water resources departments at the states level and municipal corporations/councils at the local level. The recommendations are based on findings of the literature review and expert interviews.

Literature Review and Benchmarking of Global River Restoration

River restoration is not a phenomenon confined to a set of developing or under-developed countries. Rather many developed countries such as the USA, the U.K. and Australia undertook restoration of their rivers much earlier, making river restoration a global phenomenon.

To address the concerns relating to rivers, several global deliberations were held. For instance, the United Nations Water Conference held in Argentina in 1977 highlighted concerns about fresh water. Similarly, the Thirteenth Stockholm Water Symposium held in 2003 deliberated on drainage water security (Chattopadhyay and Harilal, 2017). The key initiatives in the area of protection and effective usage of water are: the Ramsar Convention on wetlands (1971), the Convention on biological diversity (1992) and UN Watercourses Convention (1997). This section discusses river restoration in the USA, Europe, Australia, Latin America and Asia.

River Restoration in the USA

Palmer and Allan (2006) cover the degradation of rivers and streams in the USA, wherein water quality is not the only issue. The extraction of surface and groundwater is so excessive that some major rivers no longer flow to the sea along the year. Water shortage is also faced by communities. The Clean Water Act (CWA) was passed in 1972 to address the issues relating to fresh water, which helped in controlling point source pollution. Consequently, during 1973-1998, the US rivers were cleaner. However, again in 2004, the Environmental Protection Agency (EPA) pointed out the deterioration in water quality of rivers. Palmer and Allan (2006) share several efforts made by Dept. of Agriculture, EPA, cities and town authorities to contain pollution.

In USA, river restoration has been carried out on a massive scale[1]. Bernhardt et al. (2005) put forth that large projects on rivers such as Kissimmee and the Glen Canyon are well documented. However, there are several smaller restoration efforts whose restoration methods and outcome were ignored. This prompted Bernhardt along with a team of stream scientists to develop a database on river restoration projects, irrespective of their magnitude across all the fifty states of the USA. The objective was to pull out common factors leading to successful River Restoration Programmes (RRPs). This effort culminated into the generation of a database, National River Restoration Science Synthesis (NRRSS) containing details of more than 37,000 projects.

RRPs in the USA have well-defined objectives such as, enhancing water quality, managing riparian zone, improving in-stream habitat, creating fish passage, bank

[1] Bernhardt et al. (2005) compiled a database on river restoration projects in the USA, titled as National River Restoration Science Synthesis (NRSSS) including 37,099 restoration projects in the USA. However, the database doesn't include major restoration projects carried on Kissimmee river, Grand Canyon, San Francisco Bay, Columbia and Missouri rivers. The study estimates that around US $ 14 to 15 billion has been spent on river restoration between 1990 and 2005.

stabilization, reducing property damage and so on. The number of RRPs increased from the year 1995, though the density of RRPs (measured as number of projects per thousands of river km) varied from region to region (Bernhardt et al., 2005). Speed et al. (2016) point out that the restoration efforts in the USA are taken up to restore natural resources which have "economic, cultural or spiritual importance".

The common restoration methods adopted in the USA have been connecting floodplains, modifying streams, improving recreational amenities, but there are also projects wherein existing dams were removed. For instance, in 2014, the 64-metre high Glines Canyon Dam on river Elwha (Washington State) was removed with the objectives of restoring the river as a natural system, for the benefit of humans, aquatic and other wildlife (National Geographic, 27 August 2014).

It is evident that there exists a variety of scale in river restoration efforts in the USA, ranging from stream restoration to removing large dams. Another very important feature of restoration efforts in the USA is involvement of communities and governmental and non-governmental agencies.

Five case studies on restoration in the USA, viz. Guadalupe, Kissimmee, Missouri, Mississippi and Chesapeake Bay are discussed here.

Guadalupe River Project and Guadalupe Creek Restoration Project

To address frequent winter flooding of river Guadalupe, two projects were undertaken namely, Guadalupe River Project and Guadalupe Creek Restoration Project. The projects involved ecological restoration like extensive plantation of native vegetation to stabilize the channel and reduce erosion, designing special low flow channel for fish migration and spawning, diversion of flood water to an existing floodplain. It led to protection and preservation of habitat that fish need to migrate and spawn. For residents, recreation, open spaces, interpretation centres were created, giving them access to river corridor. The restoration method showcases integration of mix-use planning (Gole, 2014).

Kissimmee River Restoration Project

For the river Kissimmee, channelization was undertaken during 1962 to 1971. Though the channelization helped in reducing impact of floods, it affected the environmental attributes of the river (Whalen et al., 2002). This caused public outcry, which served as the foundation for restoration initiative. The Kissimmee River Restoration Project was undertaken to restore ecological integrity of river flood-plain system in 1999. The project is a combination of 22 sub-projects. For evaluating the performance of the restoration project, 60 performance measures were developed with established metrics and endpoints. At present, the project is more than halfway completed and will be completed by 2020.

Missouri River Recovery Plan and Missouri River Ecosystem Restoration Plan

The Missouri River Recovery Plan (MRRP) and Missouri River Ecosystem Restoration Plan (MRERP) are efforts led by the U.S. Army Corps of Engineers (USACE) in association with U.S. Fish and Wildlife Service to protect and recover ecosystem of the river. The Missouri River Mitigation Act was passed in 1986. MRRP involves development of sandbar habitat, shallow water habitat and wetland and terrestrial habitat. It also includes on-going data collection and monitoring to assess the impact of restoration activities. MRERP is a collaborative, long term study undertaken to guide USACE's restoration, recovery and mitigation efforts for Missouri river for the next 30 to 50 years (USACE[a] Undated).

Upper Mississippi River Restoration Programme

The Upper Mississippi River Restoration Programme was undertaken to enhance habitat for restoring and maintaining a healthier and more resilient upper Mississippi river ecosystem. The programme involves habitat restoration activities, along with continuous monitoring and research. The programme was introduced in 1986 and has completed 55 habitat restoration projects. The programme serves as the model for aquatic restoration and monitoring efforts (USACE[b] Undated).

Chesapeake Bay Programme

Since 1983, the Chesapeake Bay Programme has led restoration of Chesapeake Bay, the third largest estuary in the world. Several written agreements have been signed to reduce pollution and restore the ecosystem of the bay. After decades of work, the U.S. Environmental Protection Agency (EPA) established pollution reduction targets for seven jurisdictions in Chesapeake Bay watershed in 2010.

From these case studies, it could be noted that restoration of rivers and water bodies has received tremendous significance in the USA. River restoration is characterized by multi-year programmes with defined objectives, emphasis on ecological restoration, involvement of multiple stakeholders, continuous monitoring and enactment of legislation to protect rivers and riverine ecosystem (EPA, 2017).

River Restoration in Europe

Europe has plenty of restoration projects completed or under progress. The United Kingdom alone aims to restore 1500 river km. It has 2700 projects listed in its National River Restoration Inventory. It could be an outcome of European Union Water Framework Directive (EUFMD), requiring all European rivers to be restored to a 'good status' by 2027 (Yale School of Forestry and Environmental Studies, 2013).

A variety of restoration techniques and methods have been implemented in Europe as well. There are instances across the Europe of clearing existing dams on many rivers (the Duero, Spain; the Loire, France). In case of river Skjern in Denmark, a marshland was created. The Netherlands adopted a unique approach for restoring its rivers, titled as 'making room for river', wherein dikes were removed or pushed back by 300 to 350 metres, even in densely populated areas (Yale School of Forestry and Environmental Studies, 2013). In Zurich, a clean water concept called as 'Zurich stream daylighting programme' is introduced to daylight as many streams (especially the covered or underground ones) as possible. In Oslo, 'de-culverting' of streams is adopted, which led to recovering the value of natural streams and improving water quality of larger streams (European Environmental Agency, 2016).

Some other interventions adopted include dumping trees in streams to slow down water flow and erosion (Sweden), developing riverine forests (Upper Danube stretches), connections of settlements to sewers, introducing waste-water treatment plants, etc. However, there are still some strong challenges in Europe. For instance, the Environmental Agency of England still finds it very difficult to keep the river Thames (a benchmark for many Indian RRPs) clean due to increasing population, decreasing investments and rising volume of untreated sewage.

Three European cases of restoration are discussed in this sub-section viz. Thames, Rhine and Danube.

Restoration of River Thames

The river Thames is the longest river in England and passes through a heterogeneous landscape. It is significant to the U.K. as it supplies two-third of London's drinking water and serves as the country's most important waterway for commercial transport. However, water quality deteriorated in the 19th century due to discharge of industrial waste and untreated sewage. During the years 1832 to 1865, there was an outbreak of cholera and in 1958, the House of Common session had to be cancelled due the 'Great Stink'. In 20th century, pollutants decreased as heavy industry and tanning processes ceased and sewage treatment improved driven by EU legislations. River Thames received the Theiss International River Prize by International River Foundation in 2010.

However, water quality is still an important issue in the Thames Estuary as it faces increasing pollution and degrading habitat quality. The river receives storm discharges from the major main sewage system and network. Thames Water[2] has planned sewage water treatment work around the tidal Thames and construction of a 2.5 km major new sewer, London Tideway Tunnel, to tackle the issues of point source pollution from the sewerage system and overflow.

Wharton and Gilvear (2007) analyzed the role of river restoration in the UK in accordance with the objectives of the European Union Water Framework Directive. However, they observe that the analysis of river restoration in UK remained piecemeal and was not approached as a catchment-wide strategy.

Restoration of River Rhine

In 1950, due to deterioration of water quality, the International Commission for the Protection of Rhine (ICPR) was developed by countries such as Switzerland, France, Germany, the Netherlands, Luxembourg and the European Union since 1976. Agreements were drawn between these countries to reduce emissions, heavy metal load and improvement in oxygen concentration. A significant improvement has been noticed in the water quality in the past 15 years due to new integrated policies and urban wastewater management strategies (Speed et al., 2016). In 2001, 'Rhine 2020' was adopted by ICPR with the objectives of continuous improvement in habitat and water quality (ICPR, undated).

Restoration of River Danube

There had been several multilateral agreements and international administration governing river Danube. At present, the non-navigational use of the river basin is governed by the Convention on Co-operation for the Protection and Sustainable Use of the Danube or Danube River Protection Convention (DRPC) and International Commission for the Protection of the Danube River (ICPDR) (International Water Governance, Undated).

[2] Thames Water Utility Limited, commonly known as Thames Water, is the private utility company responsible for public water supply and waste water treatment in several parts of the U.K.

Several basin-wide programmes and projects were initiated by ICPDR to protect water resources of the Danube (Speed et al., 2016; International Waters Governance, undated).

River Restoration in Australia

In Australia, the deterioration in freshwater quality is associated with agricultural activities. We discuss restorations of two Australian rivers: Murray-Darling and Glenelg.

Murray-Darling Basin Plan

The concerns grew over the degraded water quality in Murray-Darling basin, the most significant basin in Australia. The concerns were caused due to high levels of dryland salinity across the basin and heavy loads of nutrients from fertilizers causing algal blooms. At the same time, river flows were affected due to over-allocation and over-abstraction of water for irrigation (Speed et al., 2016).

For addressing the issue, a basin-wide Murray-Darling Basin Plan was adopted under the Water Act 2007 to ensure that water is shared between all users including environment (MDBA, Undated).

The federal government invested substantial amount in water-saving infrastructure, developing water-trading markets and on-farm efficiency projects (Speed et al., 2016).

Glenelg River Restoration Plan

River Glenelg is the largest river in south-west Victoria. The river which was known for its pristine and abundant water and fertile soil, faced degradation due to the establishment of pastoral stations, land clearance and rabbit infestation. A multi-pronged approach was adopted which involved implementation of several interventions, such as sand management, fencing and revegetation, estuary management, urban waterway restoration, wood-reinstatement, environmental flow releases, weed control, removal of fish barriers, etc. (Riverspace, undated).

Arthinton and Pusey (2003) discuss restoration of rivers Snow and Brisbane in Australia. They suggest establishment of water banks, which would act like financial banks operated by river managers empowered to buy and sell water on behalf of the environment. The water bank would receive resources in the form of penalties for failure to maintain environmental flow targets to be paid to the river managers. Citizens could be encouraged to give voluntary contribution to fund water banks.

Brooks and Lake (2007) assessed completed river restoration projects from four management authorities in Victoria. Examining records of around 2247 restoration projects, they found that riparian management projects are the most common ones, followed by bank stabilization and in-stream habitat improvement. However, only 14 percent of the projects have some form of monitoring being carried out. Yet, the authors note improvements in design, implementation, monitoring and reporting of stream restoration projects due to obligatory, statewide reporting on the one hand and an increased emphasis on project design and monitoring on the other.

River Restoration in Latin America

Latin America has abundant water resources as the region contains four of the world's largest rivers: Amazon, Parana, Orinoco and Magdalena. Around 31 percent of world's freshwater resources are in Latin America (The World Bank, 2013). However, water resources have degraded due to poor farming practices, human-induced salination, unregulated industrialization, poverty and population growth (Barlow and Clarke, 2004).

Mondragon-Monroy and Honey-Roses (2016) discuss four cases of river restoration in Latin America: The Bogota, Medellin and Magdalena rivers in Columbia and the river Rimac in Peru. River restoration in Latin America dates back to 1970s when public demanded for recovery of the river's space and sanitation. The objectives of river restoration initiatives are diverse and range from environmental quality and landscape, improving fluvial transportation to connecting neighbourhoods across the rivers. The common restoration methods are creating corridors, parks and greenways, renewed areas including recreational amenities and bicycle paths.

The World Bank (2013) observes that enormous progress has been made in the past two decades in the region in terms of access to water, river basin management, participatory approach to decision-making process and managing water supplies. However, there are still certain challenges such as, creating storage and distribution infrastructure, developing scientific ways to allocate water across different sectors to ensure economic growth and protecting water security in future, although 96 percent of Latin Americans have access to clean and safe water sources.

River Bogota Environmental Recuperation and Flood Control Project

This is a World Bank supported project and has four key components: Optimize and expand salitre treatment

plants, controlling floods, preparing environmental and water studies and project management and administration (The World Bank, 2016).

Programme for Recuperation of the Navigability of the Magdelana River

This project is an attempt by the Columbian government to improve fluvial transport in the river. It involves works such as dredging, channel improvement, construction of protective levees through public-private partnership.

It is difficult to comment on the impact of these two projects due to paucity of literature and poor documentation by implementing agencies (Reynoso and Saenz, 2012; Marzari-Hariart et al., 2014).

River Restoration in Asia

The river restoration efforts in some Asian countries such as Japan, China and Singapore are discussed here. The study of river restoration in Asia is more relevant for the river restoration programme in India, known as National River Conservation Plan (NRCP) due to a variety of reasons.

Firstly, these countries belong to Asian monsoon region, drawing learning from their restoration experiences is more suitable for Indian river restoration plans. These countries have been experiencing a higher population growth rate and population density. Around 60 percent of the world population lives in Asia (United Nations, 2017). The continent has also been experiencing greater urbanization. The World Urbanization Prospects (2011) estimates that around 53 percent of the world urban population would be living in Asia. As a consequence of rapid population growth and urbanization, several Asian countries have been suffering from water stress. Howes and Wyrwoll (2012) identify water management as one of Asia's 'wicked' environmental problems. Drivers such as excessive water extraction, pollution from human waste and industry, poor infrastructure, and construction of dams have led to degradation of Asia's fresh water resources.

The river restoration work undertaken in Asian countries is well documented by Japan River Restoration Network and Asian River Restoration Network. Japan has been practicing river restoration since a very long time. It began conducting continuous surveys for assessing and monitoring water quality since 1950s and developed sewerage systems and waste treatment plants. It was followed by emphasis laid on promoting accessibility of rivers and creating riverfront amenities, along with improving urban landscapes. It is to be noted that the number of river restoration projects in Japan is as high as in the USA (Nakamura et al., 2006). River restoration gained momentum in the year 1990 when the initiative, 'Nature-oriented River Works' ("Ta Shizen Gata Kawa Zukuri") was launched by the River Bureau. The objective of this initiative was to conserve and restore river corridors and their rich biodiversity (Nakamura et al., 2006). Japan also amended its existing river-related laws or enacted new ones to reach its goals relating to river restoration. Thus, the present-day river management in Japan is also guided by the River Law amended in 1997. River restoration in Japan has gained strong and continuous support from local NGOs, communities which resulted in initial grassroot activities extending into major restoration initiatives. For example, several interdisciplinary associations such as The River Ecology Research Group of Japan, The Society of Ecology and Civil Engineers, The Ecological Society of Japan and The Japanese Society of Civil Engineering were set up (Nakamura et al., 2006).

In China, early river management adopted engineering-based river interventions such as constructing dams and concretizing river banks, ignoring the functioning of riverine ecosystem. Fortunately, with China's socio-economic development, policy makers and academicians began to pay due importance to scientific river restoration. Like India, there is a thrust on restoring urban rivers, with RRPs completed in 40 cities (Speed et al., 2016). The objectives of RRPs are more evolved and matured; for instance, riparian vegetation restoration, restoration of water quality, improving landscape ecology are cited as triggers for restoration. A variety of restoration methods and measures are adopted due to region-specific objectives of restoration projects and variations in catchment areas of rivers. It is evident in case of China that approach to river restoration has shifted from engineering-based project to a more integrated one.

Asian River Restoration Network (ARRN) and Japan River Restoration Network (JRRN) also discuss river restoration initiatives in other Asian countries such as Taiwan, Singapore, South Korea, etc. Restoration cases of five Asian rivers, Singapore, Cheonggyecheon, Yangtze, Yellow and Tama are presented.

Restoration of River Singapore

The river Singapore went through drastic transformation since the launch of a large-scale, 10-year project in 1977. The sources of pollution along the river bank were not only identified but also removed with strong political will. The project also involved redevelopment of

business and residential properties along the waterfront. In 2006, the Public Utilities Board, Singapore's national water authority introduced the 'ABC Water Programme' for sustainable storm water. Restoring the river also resulted in sustainable urban tourism for Singapore (Savage et al., 2004).

Restoration of River Cheonggyecheon

A unique and very interesting example of river restoration can be found in Seoul, South Korea. River Cheonggyecheon became an underdrain in 1968 as it was covered by a road and also an elevated road. In 2002, it was restored by removing the road (Water & Wastewater International, Undated; Lah et al., 2015).

Restoration of River Yangtze

The 'Living Yangtze Program' was adopted in 1998, which involved wetland and forest restoration. It also included relocation of around 2.4 million. It focused on restoration of forest wetlands. The Program spans across 25 years and will continue till 2023 (Asian River Restoration Network, Undated; Pittock and Xu, 2010).

Restoration of Yellow River Delta

The restoration of Yellow river included bringing water to wetlands and avoiding salt water intrusion. The objective of the restoration project was to improve hydrological process and soil conditions to provide suitable habitat for wetland vegetation and birds. Cui et al. (2009) observe that there is an obvious improvement in soil chemical and physical condition of degraded wetland ecosystem. Also, ecosystem restoration is evident due to nutrient retention and increased flora and fauna.

Restoration of River Tama

The objective of restoring river Tama was to transform the green river to white river. Restoration activities included artificial widening and sediment augmentation, removal of invasive species and restoration of gravel bed. There are obvious signs of recovery as the population of endangered species increased (Japan River Restoration Network, Undated; Nakamura, 2006).

River Restoration in India

Rivers assume a significant role in the lives of Indians as they provide for potable water, irrigation, cheap means of transportation, electricity and also, livelihoods to a large number of people. This simply explains why nearly all major Indian cities are situated by river banks. Hindu mythology revolves around Indian rivers, wherein rivers are personified and worshipped as deities (National Institute of Hydrology Roorkee, Undated).

India has 12 major river basins, with total catchment area of 25.3 lakh sq. km. put together. The largest river basin is formed by rivers Ganga, Brahmaputra and Meghna, with catchment area of 11 lakh sq. km. There are four other major river basins, namely, Indus, Mahanadi, Godavari and Krishna, with catchment area more than 1 lakh sq. km. There are 46 medium river basins with a combined catchment area of about 2.5 lakh sq. km. River basins account to 81 percent of India's geographic area (India-WRIS WebGIS, 2015; National Institute of Hydrology, Roorkee, Undated).

However, Indian rivers are plagued with pollution, with most of them left to be nothing more than sewage carrying drains. The major source of pollution is untreated sewage disposed off into rivers as only 37 percent of sewage generated is treated (MOEFCC, 2016). Moreover, it is to be noted that India being the second most populated country in the world, accommodates 17.5 percent of world's population but holds only 4 percent of the world's fresh water resources. As a consequence, the country is experiencing greater water demand, while per capita water availability has been decreasing from 2309 cubic metres in 1991 to 1588 cubic metre in 2010. The India-WRIS webGIS projects it to deteriorate further to 1401 cubic metre in 2025 and 1191 cubic metre in 2050. India is identified as a country with high water stress by the World Resources Institute (Gassert et al., 2013).

Besides deteriorated water quality and quantitative stress, Indian rivers are vulnerable to a varied impact of climate change. Gosain et al. (2006) measure the impact of the climate change on 12 Indian rivers. The study points out that under the GHG scenario, the country may experience severe droughts in some parts and intense floods in other parts. There may also be reduction in the quantity of the available runoff. River basins of Mahi, Pennar, Sabarmati and Tapi shall face water shortage. While river basins belonging to large rivers like Ganga, Narmada, Cauvery and Krishna shall witness seasonal or regular water-stressed conditions. River basins of Godavari, Brahmani and Mahanadi are predicted to face severe flood conditions. The study recommends changes in land use, cropping pattern, water conservation and flood warning systems as strategies to cope up with climate change.

There are several non-governmental organizations which are attempting to restore rivers across India. For instance, a consortium of NGOs including WWF India, SANDR, INTACH, Toxics Link and PEACE India, celebrates 'India Rivers Week' to educate and

generate awareness about rivers among people. WWF India has contributed substantially to rejuvenation of river Ganga, especially through a variety of initiatives such as 'Thames-Ganges Twinning Programme - 2010-2014, Ganga basins: Dolphin conservation programme, Wetlands Conservation Programme, Policy Initiatives and Education and Awareness Campaign and 'Rivers for Life, Life for Rivers' (WWF India, undated).

Let's see what the governmental intervention in restoring rivers is. The Central Pollution Control Board (CPCB) in India has identified 302 polluted river stretches across 275 rivers in India, for restoring water quality (CPCB, 2015). The total length of the polluted river stretches put together is 12,363 kms. These river stretches are bifurcated into five priority classes, based on the level of biochemical oxygen demand (BOD). Table 1 shows categorization of river stretches into priority classes and also riverine length under the respective priority classes.

Table 1: Categorization of river stretches into priority classes

Priority class	*BOD level* (mg/l)*	*Riverine length in km*
I	>30	2726
II	20-30	1145
III	10-20	1834
IV	6-10	2492
V	3-6	4166

*Permissible limit is 3 mg/l
Source: CPCB (2015)

Government of India has undertaken an ambitious river restoration programme since the year 1985. River restoration in India began with the launching of Ganga Action Plan (GAP) as a centrally sponsored scheme in 1985. In 1995, it was extended as the National River Conservation (NRCP) to include other rivers. The objective of NRCP was to improve water quality of rivers through implementation of pollution abatement schemes in identified polluted river stretches[3]. The programme intends to cover polluted stretches of 31 rivers in 75 towns, spread across 14 states (MOEFCC, 2016), excluding Ganges and its tributaries. Except for GAP[4], pollution abatement activities for all major rivers in the country are under the purview of Ministry of Environment, Forests and Climate Change (MOEFCC). As of July 2016, total sewage treatment capacity of 2373 mld is being created under NRCP.

Three key case studies on restoration of rivers Sabarmati and Mula-Mutha are discussed in this section. There is a strong rationale for selecting these cases. Sabarmati riverfront development project has been portrayed as a pioneering river restoration project in India and has inspired some major river projects Yamuna Action Plan, Gomti Action Plan and so on (Pradhan, 2014). The second case study presented here deals with pollution abatement project of river Mula-Mutha, which has received the highest cost allocation under NRCP (MOEFCC, 2016). Both these projects have received criticism on several grounds (Mathur 2012; Pradhan 2014 & CSE 2007).

The third case study is on Adyar Poonga river restoration. It is selected for discussion here as it serves as a unique project involving setting up an ecological park for rehabilitating coastal and estuarial ecology. Table 2 presents the details of NRCP and these three river restoration projects.

Sabarmati Riverfront Development Project

Sabarmati Riverfront Development Project (SRFDP) was launched in 2005 with a 3-fold objective: environmental improvement, creating social infrastructure and sustainable development. A special purpose vehicle, Sabarmati Riverfront Development Corporation Ltd.

Table 2: Selected river restoration projects under NRCP

RRP	*States*	*Sanctioned cost (Rs. crore)*	*STP capacity created (mld)*
Sabarmati Riverfront Development Project	Gujarat	546.40	232
Mula-Mutha Pollution Abatement Project	Maharashtra	990.26	0
Adyar Poonga	Tamil Nadu	404.26	264
NRCP	All over India	4517.83	2373.41

Source: MOEF, 2016

[3] In the year 2015, the Central Pollution Control Board (CPCB) declared 302 polluted river stretches across India for restoring water quality.
[4]Since 1 August, 2014, GAP is handled by Ministry of Water Resources, River Development and Ganga Rejuvenation.

(SRFDCL) was set up as wholly owned entity by Ahmedabad Municipal Corporation.

Sabarmati is a monsoon river, thereby seasonal in nature (CSE, 2007). However, to make it perennial, water from Narmada River Canal was channeled to Sabarmati river. Storm water and sewage system with interceptor lines of 10 km of length were built across both the banks of the river, which collect in sewage discharged through 38 points. These sewer lines were diverted to the newly built sewage treatment plants/ sewage pumping stations. A two-level promenade was built along both the banks of the river. On the reclaimed land, many parks, gardens and sports facilities have been created (SRFDCL, Undated).

However, this ambitious project of state government of Gujarat has also been criticized heavily on several grounds. Firstly, it has been noted that the ecological character of the river has changed as its channel was uniformly narrowed to 275 metres, while naturally the average width of the river had been 382 metres. Thus, due to this 'pinching of the river', its original character has changed. Its seasonal nature is destroyed. Secondly, it is criticized for the treatment given to river banks. Reclaiming of river banks has damaged fauna and biodiversity on the edges. There has been ignorance towards protection, sustenance and enhancement of the riverine ecosystem. Thirdly and more importantly, the question is whether it is even Sabarmati river water. The water which flows through Sabarmati channel is actually brought from Narmada main canal. The water brought from Narmada canal is meant for drought prone areas of Kachchh Saurashtra and North Gujarat (Pradhan, 2014). Fourthly, the reclaimed land and the narrowing of the channel have been affecting the carrying capacity of the river.

The project was at standstill during August 2006 to March 2007, for almost a span of eight months due to heavy floods. National Institute of Hydrology and Indian Institute of Technology (Roorkee) were appointed to re-assess the project design with respect to river's carrying capacity and to study the impact of the project on river's ecology. The report submitted by IIT (Roorkee) stated that riverfront development is not a flood control scheme and Ahmedabad Municipal Corporation will have to undertake other measures to retaliate floods. Rather, channelizing of river water, constructing concrete walls increase possibility and intensity of floods. The project has largely been criticized for poor rehabilitation of

Table 3: Thematic analysis of expert interviews

Aspects	*Common themes*	*Unique themes*
What are your views on river restoration in India?	India does not have 'a real river restoration' • There is only one completed river restoration project, Sabarmati Riverfront Development • Absence of any guidelines • Lack of common understanding about which activities can be termed as restoration • An expensive activity in terms of financial and socio-economic cost	• River restoration in India involves the concretization of river banks, which is ecologically harmful to the river • Absence of basin wide approach • Fragmented approach to water management, often separating fresh and groundwater management
What lessons could be drawn from global river restoration efforts/experiences?	Restoration should involve following interventions: • Biological/ecological restoration • Extensive public consultation and involvement • Continuous activity involving monitoring of river's health	Generating awareness regarding adoption of a 'toxin-free lifestyle' by public
Considering the fact that river restoration is a global phenomenon, which region (the USA, Europe, Asia, Latin America, Australia) or country could be referred to for formulating and implementing river restoration plans in India?	Global efforts need to be studied with respect to pressures, state interventions Uniqueness of every river requiring a specific and suitable approach	River rejuvenation in Rajasthan Local, grass-root level initiatives such as 'Jalyukta Shivar Yojana' in Maharashra or Bhungroo in Gujarat

evicted. According to Mathur (2012), 14,000 households were officially evicted directly and indirectly.

Pollution Abatement of Mula-Mutha River Project
The proposed restoration project covers 44 km of the river and will be implemented by the local governing body, Pune Municipal Corporation (PMC).

The initial project details can be segregated into three important components: (i) creating infrastructure for augmenting the present sewage treatment capacity, (ii) using technology for monitoring infrastructural facilities created and (iii) generating public awareness and capacity building.

The project has received criticism for its over-emphasis on beautification of the river (*The Indian Express*, 6 July 2017). The project has yet to be implemented.

Adyar Cooum River Restoration Project
The rivers Adyar and Cooum run through Chennai and meets Bay of Bengal forming an estuary. With a few small inlets in between it extends up to the sandbar at the edge of the sea. The river has a huge amount of flora and fauna due to its climatic conditions. However, due to emptying of sewage from various industries the biological activities in the region were affected. In order to restore the vegetation of the freshwaters an ecological park named Adyar Poonga was set up by the government of Tamil Nadu in 2011 in the Adyar Estuary area of Chennai. The estuary from the eastern part of the ThiruViKa bridge and the Adyar Creek covers 358 acres. The basic objective behind setting up the ecological park was to beautify the area near Adyar estuary and creek by restoring the degraded area and rehabilitating the coastal ecology of Adyar creek owing to the uncontrolled exploitation of the wetland due to urbanization (Chennai River Restoration Trust, 2017).

Thematic Analysis of Expert Interviews

To support the findings of literature review, interviews were also conducted with experts and representatives of governmental authorities and non-governmental organizations (NGOs). The following three key aspects were explored in these interviews:

(i) Perspectives on river restoration in India
(ii) Lessons to be drawn from global river restoration experiences
(iii) Regions/cases to be referred for formulating and implementing river restoration in India

Experts shared that river restoration in India has several limitations. Moreover, India lacks the 'real restoration story' as there is only one completed river restoration project, i.e., Sabarmati Riverfront Development. The project has been criticized on several grounds, concretization of riverbanks being one of them. River restoration, as a phenomenon, lacks a common understanding in India as it denotes different activities for different stakeholders. For instance, for governmental authorities, river restoration denotes augmenting the existing sewage treatment capacity and other engineering work. However, for NGOs/community organizations, river restoration has a wider connotation. It not only includes improving water quality, harnessing groundwater management or involving community, but it is largely about restoring the health of river and sustaining it. Restoration efforts should also emphasize on passive restoration, such as urging citizens to adopt a toxin-free lifestyle. In India, river restoration lacks a basin-wide approach as the focus is largely on restoring stretches.

When probed about lessons to be drawn from global river restoration projects, the experts pointed out that restoration should involve biological restoration of the river, which would result in habitat improvement and riparian restoration. River restoration should also have extensive public consultation and awareness generation about the state of the river and the various elements of the restoration plans. Another important insight was that restoration should not be treated as a one-time activity, but rather as continuous and evolving one. This is more important as rivers face different stresses across different stages of development. There should be monitoring mechanism for continuously assessing the health of river.

Regarding the third aspect of the expert interviews, experts voiced that it is essential to study the global efforts with respect to pressures, state and interventions. However, it is very important to recognize the uniqueness of every river. Rivers differ in the context of their micro-climate, regime, flow, geology, etc. Thus, every river requires a specific and suitable restoration approach.

Recommendations for River Restoration Plans in India

Based on literature review and expert interviews, the study makes the following recommendations for river restoration plans in India:

1. Adopt Clearly Defined Goals from the Initial Stages of the Project

Restoration work must have clear goals which act as guidelines for restoration work. These goals should be realistic, keeping in mind certain irreversible changes which have come about in the catchment rather than to achieve an unachievable historical state of the river. The aim of restoration should be to reach a state of least degradation and make the river more resilient to stresses by restoring natural river processes.

2. Develop Precise Metrics to Evaluate the Achievement of Established Goals

To evaluate the success of river restoration project with respect to achievement of goals, a precise metrics with end points must be developed. These metrics should be quantitative emerging out of scientific and technical studies. Restoration work should not be carried in piece-meal approach. Hence, the metrics must be holistic in nature encompassing ecological, hydrological, geomorphologic, water quality, wetland vegetation characteristics, etc.

3. Adopt an Interdisciplinary Framework for Restoration

Restoration approach should be based on an interdisciplinary framework considering social, cultural, economic, ecological, scientific aspects of water. This will also be helpful in gaining political support for restoration.

4. Establish Clear-cut Communication Channels for Community Involvement and Participation

River restoration is a dynamic process which requires educating the multiple stakeholders on the multiple objectives of restoration at all times. Hence, the communication to the stakeholders must be clear and continuous. It is equally important to address the concerns raised from time to time.

5. Restoration Work Should be Ecologically Effective

River restoration should not only lead to a cosmetic makeover of the river but should be ecologically effective. Ecologically effective restoration minimizes long term damages on the river and is self-sustaining requiring minimum maintenance in the future.

Conclusion

In India, we need a scientific and systematic approach to managing our rivers. Studies validate that Indian rivers are vulnerable to impact of climate change, in terms of both frequency and severity. Thus, we need an adaptive approach to managing floods and droughts.

It should also be acknowledged that each river is unique and needs a solution in terms of restoration, suitable to its hydrological, ecological and geomorpholigical conditions. The present 'one size fits all' approach of NRCP will not result in restoring rivers in India.

River restoration programmes in India should adopt a scientific approach, based on environmental modelling techniques, engineering design and scientific monitoring. There should also be greater community participation and involvement. River restoration should be looked upon as a continuous, multi-year activity, wherein restoration approach should evolve to address the pressures and challenges of economic growth from time to time.

More importantly, every restoration plan should have well-defined and measurable objectives which could be linked to impact assessment.

Acknowledgement

The authors are grateful to the subject experts, heads of NGOs and officials of Pune Municipal Corporation for their inputs.

References

Arthington, A.H. and B.J. Pusey (2003). Flow restoration and protection in Australian rivers. *River Research and Applications*, **19(5-6):** 377-395.

Barlow, M. and T. Clarke (2004). The struggle for Latin America's water. *NACLA Report on the Americas*, **38(1):** 15-43.

Asian river restoration network (Undated). Restoration of Yangtze River. Retrieved from: http://www.a-rr.net/jp/en/waterside/world/docs/04-0017Eng.pdf.

Bernhardt, E.S., Palmer, M.A., Allan, J.D., Alexander, G., Barnas, K., Brooks, S. and D. Galat (2005). Synthesizing US River Restoration Efforts. *Science*, **308(5722):** 636-637.

Brooks, S.S. and P.S. Lake (2007). River restoration in Victoria, Australia: Change is in the wind, and none too soon. *Restoration Ecology*, **15(3):** 584-591.

Central Pollution Control Board (2015). River stretches for restoration of water quality. CPCB, Govt. of India, New Delhi.

Central Pollution Control Board and Ministry of Environment & Forest (2012). Status of water quality in India. CPCB & MOEF, Govt. of India, New Delhi.

Centre for Science and Environment (2007). Concerns over Sabarmati Riverfront Development Project. *Down*

to Earth, 15 April, 2007. Centre for Science and Environment, New Delhi.

Chattopadhyay, S. and K.N. Harilal (2017). River Restoration in Kerala: Developing a Co-Evolutionary Framework and River Restoration Action Plan for Thiruvananthapuram City.

Chennai River Restoration Trust (2017). Eco-restoration of Adyar Creek. Government of Tamilnadu. Retrieved from: http://www.chennairivers.gov.in/Adyar-Poonga-PhaseI/adyar_poonga_Phase-1.html.

Christian-Smith, J. and A.M. Merenlender (2010). The Disconnect between Restoration Goals and Practices: A Case Study of Watershed Restoration in the Russian River Basin, California. *Restoration Ecology*, **18(1):** 95-102.

Cui, B., Yang, Q., Yang, Z. and K. Zhang (2009). Evaluating the economic performance of wetland restoration in the Yellow River Delta, China. *Ecological Engineering*, **37(7):** 1090-1103.

EPA (2017). Restoration of Chesapeake Bay. United States Environmental Protection Agency. Retrieved from https://www.epa.gov/restoration-chesapeake-bay.

European Environment Agency (2016). Restoring European Rivers and Lakes improves quality of life. EEC, Denmark. Retrieved from https://www.eea.europa.eu/highlights/restoring-european-rivers-and-lakes.

Gassert, F., Reig, P., Luo, T. and A. Maddocks (2013). Aqueduct country and river basin rankings: a weighted aggregation of spatially distinct hydrological indicators. World Resources Institute, December. Available at: http://wri.org/publication/aqueduct-country-river-basin-rankings. Retrieved from: http://www.wri.org/sites/default/files/aqueduct_coutnry_rankings_010914.pdf

Giller, P.S. (2005). River Restoration: Seeking Ecological Standards. Editor's Introduction. *Journal of Applied Ecology*, **42(2):** 201-207.

Glenelg Hopkins CMA (Undated). What is the Glenelg River Restoration Project? Glenelg Hopkins Catchment Management Authority. Retrieved from: http://ghcma.vic.gov.au.ascet.co/projects/current-project/what-is-the-glenelg-river-restoration-project/.

Gole, S. (2014). Urban Riverfront Management. *Journal of Ecological Society*. **26 & 27:** 59-70.

Gosain, A.K., Rao, S. and D. Basuray (2006). Climate change impact assessment on hydrology of Indian river basins. *Current Science*, **90(3):** 346-353.

Haldar, S., Mandal, S.K., Thorat, R.B., Goel, S., Baxi, K.D., Parmer, N.P. and K.H. Mody (2014). Water Pollution of Sabarmati River—A Harbinger to Potential Disaster. *Environmental Monitoring and Assessment*, **186(4):** 2231-2242.

Howes, S. and P. Wyrwoll (2012). Asia's wicked environmental problems. ADBI Working Paper Series, No. 348. Asian Development Bank Institute, Tokyo. Retrieved from: https://www.econstor.eu/bitstream/10419/101223/1/687959632.pdf.

ICPR (Undated). History – Balance of the Rhine Action Programme (1986-2000). International Commission for Protection of Rhine. Retrieved from: https://www.iksr.org/en/international-cooperation/rhine-2020/history-1986-2000/

India-WRIS WebGIS (2015). India's Water Wealth. Central Water Commission, Ministry of Water Resources, Govt. of India and Indian Space Research Organization, Dept. of Space, Govt. of India. Retrieved from: http://www.india-wris.nrsc.gov.in/wrpinfo/index.php?title=India%27s_Water_Wealth

International Waters Governance (Undated). Danube River Basin. Retrieved from: http://www.internationalwatersgovernance.com/danube-river-basin.html.

Koehn, J.D., Nicol, S.J. and A.M. Lucas (1997). River Restoration through Integrated Management. Project No. R7001. Report to Murrya-Darling Basin Commission. Canberra.

Lah, T.J., Park, Y. and Y.J. Cho (2015). The Four Major Rivers Restoration Project of South Korea: An Assessment of Its Process, Program, and Political Dimensions. *The Journal of Environment & Development*, **24(4):** 375-394.

Mathur, N. (2012). On the Sabarmati Riverfront. *Economic and Political Weekly*, **47:** 64-75.

MDBA (Undated). What is in the basin plan? Murray-Darling Basin Authority. Government of Australia. Retrieved from: https://www.mdba.gov.au/basin-plan/whats-basin-plan

Mazari-Hiriart, M., Pérez-Ortiz, G., Orta-Ledesma, M.T., Armas-Vargas, F., Tapia, M.A., Solano-Ortiz, R. and C. Díaz-Ávalos (2014). Final opportunity to rehabilitate an urban river as a water source for Mexico City. *PloS one*, **9(7):** e102081.

Ministry of Environment and Forest (2016). National River Conservation Plan. MOEF, Govt. of India, New Delhi.

Mondragón-Monroy, R. and J. Honey-Rosés (2016). Urban River Restoration and Planning in Latin America: A systematic review. University of British Columbia. https://open.library.ubc.ca/cIRcle/collections/facultyresearchandpublications/52383/items/1.0319069

Nakamura, K., Tockner, K. and K. Amano (2006). River and Wetland Restoration: Lessons from Japan. *AIBS Bulletin*, **56(5):** 419-429.

National Institute of Hydrology Roorkee (Undated). Rivers of India. National Institute of Hydrology, Roorkee, India. Retrieved from: http://nihroorkee.gov.in/rbis/India_Information/rivers.htm.

Nienhuis, P.H. and R.S.E.W. Leuven (2001). River Restoration and Flood Protection: Controversy or Synergism? *Hydrobiologia*, **444(1):** 85-99.

Palmer, M.A. and J.D. Allan (2006). Restoring rivers. *Issues in Science and Technology*, **22(2):** 40-48.

Palmer, M.A., Bernhardt, E.S., Allan, J.D., Lake, P.S., Alexander, G., Brooks, S. and D.L. Galat (2005). Standards

for Ecologically Successful River Restoration. *Journal of Applied Ecology*, **42(2):** 208-217.

Postel, S. and B. Richter (2012). Rivers for Life: Managing Water for People and Nature. Island Press.

Pune Municipal Corporation (2016). Name of Project: Pollution abatement of River Mula-Mutha at Pune (Maharashtra) under NRCP. PMC, Pune.

Reynoso, A.E.G. and I.Z. Saenz (2012). Reflections on the Magdalena River Master Plan in Mexico City. *In:* Oswald Spring Ú. (eds), Water Resources in Mexico. Hexagon Series on Human and Environmental Security and Peace. Vol 7. Springer, Berlin, Heidelberg.

Riverspace (Undated). Glenelg River Restoration Project. Retrieved from: http://www.riverspace.com.au/item/glenelg-river-restoration-project/.

Savage, V.R., Huang, S. and T.C. Chang (2004). The Singapore River thematic zone: Sustainable tourism in an urban context. *The Geographical Journal*, **170(3):** 212-225.

Speed, R., Tickner, D., Naiman, R., Gang, L., Sayers, P., Yu, W. and Z. Zhongnan (2016). River Restoration: A Strategic Approach to Planning and Management. UNESCO Publishing.

The Economic Times (2013, March 26). Sabarmati: Third most polluted river in the country. Retrieved from: http://economictimes.indiatimes.com/slideshows/nation-world/real-pictures-of-stinking-and-sluggish-sabarmati-river/bod-was-found-to-be-4-6-times-the-desired-level/slideshow/19209362.cms

USACE[a] (Undated). Missouri River Recovery Program. US Army Corps of Engineers. Retrieved from: http://moriverrecovery.usace.army.mil/mrrp/f?p=136:1:0.

USACE[b] (Undated). Upper Mississippi River Restoraton. US Army Corps of Engineers. Retrieved from: http://www.mvr.usace.army.mil/Missions/Environmental-Protection-and-Restoration/Upper-Mississippi-River-Restoration/About-Us/.

Water & Wastewater International (Undated). South Korea's four rivers restoration. Water World, USA. Retrieved from: http://www.waterworld.com/articles/wwi/print/volume-27/issue-6/regional-spotlight-asia-pacific/south-korea-s-four-rivers-restoration.html

Whalen, P.J., Toth, L.A., Koebel, J.W. and P.K. Strayer (2002). Kissimmee River restoration: A case study. *Water Science and Technology*, **45(11):** 55-62.

Wharton, G. and D.J. Gilvear (2007). River Restoration in The UK: Meeting the Dual needs of the European Union Water Framework Directive and Flood Defense. *International Journal of River Basin Management*, **5(2):** 143-154.

Yale School of Forestry and Environmental Studies (2013). A Successful Push to Restore Europe's Long-Abused Rivers. Yale School of Forestry & Environmental Studies, USA. Retrieved from: http://e360.yale.edu/features/a_successful_push_to_restore_europes_long-abused_rivers

Calendar of Events

5th International Conference on Coastal and Ocean Engineering (ICCOE 2018)
27th to 29th April 2018
Shanghai, China
Website: http://www.iccoe.org/
Contact person: Ms. Sophia Du
Organized by: CBEES

8th International Conference on Environment and Industrial Innovation (ICEII 2018)
27th to 29th April 2018
Shanghai, China
Website: http://www.iceii.org/
Contact person: Ms. Zero Jiang
Organized by: Shanghai Maritime University

Water Pollution 2018
22nd to 24th May 2018
A Coruña, Spain
Website: https://www.wessex.ac.uk/conferences/2018/water-pollution-2018
Contact person: Irene Moreno Millan
Organized by: Wessex Institute, UK & University of A Coruña, Spain

4th International Conference on Advances in Environment Research (ICAER 2018)--EI Compendex, Scopus
28th to 30th May 2018
Hong Kong, China
Website: http://www.icaer.org/
Contact person: Ms. Lydia. Liu
Organized by: ICAER Committees

Stormwater Victoria Conference
6th June to 8th November 2018
Melbourne, VIC, Australia
Website: http://svconference.com.au/
Contact person: Rebecca Nguyen
Organized by: Stormwater Victoria

International Conference on Air Pollution and Water Treatment (APWT 2018)
15th to 17th June 2018
Shanghai, China
Website: http://www.apwt2018.net/
Contact person: Ms. Rebecca
Organized by: IAASE

21st International Water Technology Conference
28th to 30th June 2018
Port Said, Egypt
Website: http://iwtc.info
Contact person: Walaa Tarek