River Management and Restoration: A Strategic Approach

Esha Yadav

Abstract

Pollution of major rivers and their tributaries, ultimately responsible for causing ecological imbalance. River restoration nowadays has become a need for an hour across the globe because rivers have been degraded, leading to the disappearance of biodiversity. Since river ecosystems form an integral part of human life, their proper maintenance, conservation, and most importantly, river ecosystem restoration is critical for human civilization's wellbeing. Some things to keep in mind while restoring the river ecosystem include stabilizing and enhancing the river ecosystem's functions and services. The river ecosystem serves a lot in terms of ecological functioning, so it is essential to restore the damaged and polluted rivers to their normal status. In this chapter, we will discuss some important methods and technologies of river restoration.

Introduction

India is one such country in the world that is bestowed with a good number of rivers and tributaries, which are helpful not only in agriculture but also in the country's inland transport system. Rivers also form the basis for domestic and industrial water supply, hydroelectricity generation, inland fishing, and are responsible for deposition of fertile soil in the plains and formation of deltas. With global warming, urbanization, and the intensification of human activities, and great pressures on river ecosystems have caused ecosystem degradation, the decline in habitats and biodiversity, and the loss of function (Li *et al.*, 2022). River degradation has led to an extensive loss of habitats and additional pressures on the aquatic and terrestrial species that use them. It also affects the quality of our drinking water, resilience to climate change, and ability to store and hold back flood water. Damage to river systems has been so extensive that an urgent need has emerged to conserve and restore these systems.

As India heads towards an ever-deepening water crisis, we seek to create efficient solutions for managing water resources. River restoration is the management of rivers to reinstate natural processes to restore biodiversity, providing benefits to both people and wildlife. Ecological restoration technologies (ERTs) in rivers are effective measures for improving habitat and biodiversity, which has the advantage of recovering ecosystems and biodiversity and promoting the formation of healthy rivers. River and catchment restoration can deliver multiple benefits

including improvements to water quality, biodiversity, water supply security and reductions in flood risk and pollution. To design successful as well as self-sustaining restoration actions in river ecosystems, achieving a predictive understanding of hydro-ecological relationships is of prime importance (Palmer and Ruhi, 2019).

Concept of River Restoration and Management

River restoration and management is the process of repairing and improving a river's ecosystem and water quality. This is the process of recovering the degraded, damaged, and destroyed ecosystem of the river by restoring the ecological structure, function, and biotic integrity. Technologies were applied to recover water quality, habitat, biodiversity, and biotic integrity in the river, including various techniques, methods, theories, and management strategies.

River restoration is used to describe a variety of modifications of river channels and adjacent riparian zones and floodplains, and of the water, sediment, and solute inputs to rivers. These modifications share the goal of improving hydrologic, geomorphic, and/or ecological processes within a degraded watershed and replacing lost, damaged, or compromised elements of the natural system (Wohl *et al.,* 2005). Restoration includes river management and engineering that ranges from isolated structural modifications such as bank stabilization or riparian fencing, to manipulations of ecosystem processes and biota across large river basins over decades (Warne *et al*., 2000; Bloesch and Sieber, 2003). Bernhardt and Palmer (2011) make a significant distinction between restoration projects designed primarily to reconnect rivers and projects designed primarily to reconfigure rivers. Reconnection efforts typically involve the removal of infrastructure that had previously been installed to limit the interaction between rivers and their floodplains. In contrast, reconfiguration efforts aim to change the physical structure of the stream or its riparian zone through reshaping, replanting or reconstruction. River restoration measures can be classified according to the elements of the river ecosystem (Table-1)

Table-1: River Restoration Measures

Element of River Ecosystem	River Restoration measures
Catchment	• Catchment management

Flow Regime	• Flow management • Stormwater management • Dam removal • Floodplain reconnection
Habitat (riparian)	• Riparian management • Land acquisition
Habitat (instream)	• Instream habitat improvement • Bank stabilization • Channel reconfiguration
Water Quality	• Water quality management
Biodiversity	• Instream biodiversity management
Others	• Aesthetic • Recreation • Education

Goals of River Restoration

A key distinction between river restoration and other management actions is the intent to reestablish ‘‘natural’’ rates of certain ecological and chemo-physical processes and/or to replace damaged or missing biotic elements. That is, restoration is often fundamentally about enhancing ecological integrity (Angermeier, 1997; Baron *et al.*, 2002). The ecological restoration of near-natural rivers is not only to solve the problems of the river itself, but also to achieve the harmonious coexistence between man and nature in the whole river basin, surrounding areas and even beyond (Peilin *et al.*, 2019).

The most commonly stated goals for river restoration are as follows:

(1) To enhance water quality

(2) To manage riparian zones

(3) To improve in-stream habitat

(4) To develop fish passage

(5) To stabilize river banks

River ecological restoration technology refers to the selection of various methods to repair the damaged aquatic ecosystem's biological populations and ecological structure, strengthen the main functions of the aquatic ecosystem, rebuild a healthy ecological water body, and make the ecosystem achieve a virtuous circle of self-sustainment and self-coordination based on the principle of ecosystem (Bernhardt, 2005).

Technologies for Ecological River Restoration

The technical measures of ecological river restoration mainly include river water quantity control technology, river pollution control technology, river habitat restoration technology and biodiversity restoration technology (Wu *et al*. 2001, Lu *et al*., 2014; Zheng *et al*., 2016; Liu *et al*., 2019; Xu *et al*., 2019)

Restoration Technology for River Water Quantity Control

Control of Sluice Dam Flow

This technology is mainly aimed at the lack of ecological base flow due to the excessive sluice dam, which can increase the ecological base flow in the river channel through the regulation of the excess water quantity and time of the sluice dam, thus improving the ecological damage problem caused by the control of the sluice dam. It is mainly used in rivers which lack ecological base flow due to excessive sluice dams.

River Water Supply

This technology is mainly used to supplement the water body that is lacking of ecological basic flow by water transfer in or out of the basin. This technology can not only replenish water in river channels, but also replace the river water in the dead area by scouring and diluting the polluted water area, to change the river from an anaerobic state to an aerobic state. It can also reduce the pollution load of the water body in a short period, improve the living environment of aquatic animals and aquatic plants, promote the self-purification ability of the river and improve the quality of the water environment. It is suitable for water deficient rivers or as a supplementary measure to improve river water quality.

Diversion Ecological Restoration

It is mainly used to break the confluence effect of the base flow. In the dry season with a small amount of water, the river can be intercepted by establishing an ecological plug system to form braided flow and increase the contact surface between the river and the river vegetation. It is mainly applicable to the restoration of rivers with a lack of ecological flow and often broken flow.

Restoration Technology for River Water Quality Remediation

Chemical Purification Technology

The technology includes a chemical treatment of polluted water to remove pollutants in the water. The chemical purification method is quick in effect, high in repair efficiency, and easy to operate. However, since the chemical agent is added, the treatment cost is relatively large, and it is easy to cause secondary pollution. It applies to restore water bodies that require emergency treatment, generally only as an emergency measure.

Sediment Dredging Technology

This technology refers to removing pollutants in contaminated sediment by physical methods (mechanical dredging or hydraulic washing). This is the most widely used treatment technology to reduce the release of sediment pollutants upward overlying water body and alleviate endogenous pollution. The technology has a quick effect on pollution treatment, but it is difficult to control the dredging depth accurately due to the large amount of engineering, high investment, and the risk of causing sediment re-suspension pollution of water. It is mainly suitable for the restoration of some seriously polluted river sections with sediment.

Microbial Remediation Technology

This technology uses microbial agents to change the redox state of pollutants and then reduce or eliminate the concentration of pollutants. Compared with other remediation techniques, microbial remediation has many advantages, such as fast propagation, variety, short growth period, good purification effect, easy management and low cost. It is suitable for quick repair of seriously polluted rivers.

Channel Oxygen Enhancement Technology

The technology can also be called artificial oxygenation technology, mainly refers to the improvement of the river base, the setting of stone cage dam, the construction of river habitat islands and the construction of deep pool-flash, to increase the hydraulic cycle, accelerate the

rate of redox reaction between dissolved oxygen and pollutants, and increase the activity of aerobic microorganisms to achieve the purpose of degrading organic pollutants. It is mainly suitable for remediation of polluted water with static or slow flow in front of a dam.

Ecological Floating Island

The technology is a floating island with aquatic or terrestrial plants and habitats for wildlife. Using floating islands as carriers, plants are planted on the water surface to absorb pollutants and reduce the content of chemical oxygen demand, total nitrogen, total phosphorus, and heavy metals. At the same time, the plant roots on the floating island have a huge surface area, which provides a good solid carrier for microbial growth in water. The technology has a small amount of engineering and can realize the sustainable utilization of resources. It is suitable for small rivers with no shipping requirements. It is generally selected in the wider part of the river, or the artificial excavated estuary, set a floating island, also can be designed a small floating island, sporadically multi-point distribution.

Artificial Wetland Technology

This technique mainly uses the triple synergy of physical, chemical, and biological methods in natural ecosystems to remove pollutants from water bodies. The artificial wetland is built around the river or on the flood plain. Sewage is introduced into the constructed wetland through terrain or a water pump, and the sewage is treated back into the river. In the case of a rainstorm, storm runoff can be introduced into the constructed wetland for treatment, to reduce non-point source pollution. It is suitable for the heterotopic treatment of river water quality in vast rural areas with abundant land, low level of economic development, shortage of energy and relative lack of technical force.

Stabilization Pond Technology

The technology is a basin system with reservoirs as the point and ditches as the line, using natural low-lying land to dam or manually excavate reservoirs to reduce non-point source pollution.

Restoration Technologies for River Habitat Improvement

Habitat Restoration Technology

The technology is mainly used to restore the living places of fish and benthic animals, such as spawning grounds, feeding grounds, resting grounds and channels. Sites simulating aquatic

animal preferences are often constructed by constructing fishways, deep trap-shoals, matrix restoration, riparian mulch, and setting up mounds and groins. It is suitable for water restoration with a single habitat type.

Restoration Technology of Flood Land and Riparian Zone

This technique mainly considers that the tidal flat and riparian zone will be submerged periodically, and it is often an important place for the predatory fish in the tidal flat to take bait and lay eggs in the fertile period, so the vegetation in the tidal flat and riparian zone can be restored effectively to the habitat of aquatic organisms. It is suitable for water restoration with single vegetation type and some non-point source pollution.

Ecological Island

This technology mainly simulates the river-heart continent of natural river channel, enriches the habitat diversity of river channel, creates a variety of flow patterns, provides a diversified habitat for fish and enriches the habitat diversity of fish. It is suitable for water restoration with single habitat type and single velocity type.

Ecological Bank Protection

This technology mainly uses block stone, sand-free concrete tank, and aquatic plant to carry on the bank protection technology synthetically. Planting aquatic plants at constant water level with blocks of stone at the foot of the slope can take good account of erosion prevention and plant growth. It is also possible to use sand-free concrete member retaining trough at the foot of the slope to plant aquatic plants in the trough and fill pebbles to construct diverse biological habitats. It is suitable for water restoration in riparian zone with single habitat type, low biodiversity and some non-point source pollution.

Restoration Technologies for River Biodiversity Restoration Technology

Vegetation Restoration Technology for River Banks

This technology practices ecological principles to create a variation of habitat types and different forms of ecosystems through the restoration of plant communities composed of grass, forest and other wetland plants in river plains. It is suitable for various types of river ecosystem restoration.

Construction of Aquatic Biological Food Chain

The technology refers to the establishment of ecological floating islands or biological fences to create a good habitat for aquatic organisms and microorganisms, provide a place of life, and

restore the food chain. It is suitable for water restoration with low biodiversity and some degraded habitats.

Fish Restoration Technology

The technology mainly includes the addition of fish facilities, artificial fishing firewood sets, fish stockings, and other categories. The establishment of artificial reefs increases the habitat of fish and benthic organisms, and increases the fishing bait and living space of fish and the stocking of fish, not only completing the food chain, but also playing a role in controlling algae, water bloom, and purifying water quality. It is suitable for restoring water bodies with low fish diversity, incomplete biodiversity and a certain degree of destruction.

Trends of River Restoration Technique

River ecological restoration is a major historical issue, and there is still a long way to go to protect and restore water ecology. The research and practice of river ecological restoration should follow the principle of adaptation to local conditions, the principle of multi-disciplinary research, the principle of combination of government guidance and market introduction, and the combination of ecological restoration and pollution control (Bennett *et al*. 2013).

1. Improve overall ecosystem integrity and biodiversity, rather than focusing on the status of single species, by using process-based techniques such as floodplains reconnection.
2. Engage with the interests and motivations of different stakeholder groups as early as possible. Discuss objectives, and identify opportunities and barriers, before planning activities.
3. Evaluate restoration projects using robust monitoring techniques over long timescales (>5 years) to determine outcomes and inform future restoration.

Conclusion

The purpose of river restoration is to improve the structure and function of the river ecosystem by increasing biodiversity of the river. River ecological restoration projects need to improve the entire ecosystem rather than focus solely on improving the water quality (Xu, 2018). Therefore, at present, physical, chemical and biological composite technologies are mainly used to carry out ecological restoration of river ecosystem. Bioremediation can improve the ecological environment of urban rivers to a certain extent, and it also has good economic and social benefits. Therefore, constructed wetlands, biological floating islands and other bioremediation

technologies were more in line with the requirements of environmental protection, and are gradually being paid attention to, becoming the main direction of the development of the river (Wohl *et al*. 2015).

River ecological restoration is a major historical issue, and there is still a long way to go to protect and restore water ecology. To realize the goal of river ecological restoration, governments at all levels and the water administrative departments should attach great importance to it. The broad participation and support of the whole society should be needed, and the long-term and unremitting efforts of the vast number of water workers, environmental protection workers, and ecological builders are also required to achieve the desired results.

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