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Riverine Ecology in India and Its Management: A Review

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Abstract: ***Riverine ecosystems in India play a vital role in supporting ecological stability, cultural heritage, agricultural productivity, biodiversity, and socio-economic development.*** (Srivastava, 2007; Anonymous, 2012; Team, 2012) ***However, rapid anthropogenic activities—including untreated sewage discharge, industrial effluents, agricultural runoff, hydrological modifications, and climate pressures—have severely degraded river health.*** (Samudrani, 2016; Board, 2018) ***This research paper examines the ecological parameters of Indian river systems, environmental flows, pollution loads, biodiversity loss, and evaluates two major rivers—Ganga and Yamuna—as representative case studies. The study synthesizes secondary data to outline existing conditions and proposes sustainable management strategies focusing on environmental flows, pollution abatement, climate adaptation, biodiversity conservation, and integrated river basin management.***

Keywords: Riverine Ecology, Environmental Flow, Pollution, Indian Rivers, Ganga Basin, Yamuna River, Biodiversity Conservation

1. Introduction

Rivers in India have historically shaped settlement patterns, economic activities, cultural identity, and biodiversity ecosystems. (A. Agarwal, 2010; Team, 2012) They provide drinking water, irrigation, hydroelectric energy, transportation, and sustain millions of livelihoods. (Srivastava, 2007) However, accelerated human interventions have led to habitat loss, reduced flow regimes, extreme pollution, and collapse of aquatic biodiversity. (Samudrani, 2016; Board, 2018) This paper evaluates the ecological characteristics of Indian rivers, the significance of environmental flows, pollution challenges, biodiversity loss, and river basin management strategies.

2. Aim

To examine the disturbances in riverine ecology in India and assess their direct and indirect impacts on human life and freshwater ecosystems.

3. Objectives

- To examine the environmental flow patterns of major Indian rivers and their floodplain ecosystems.
- To analyse the status of river water in terms of both quality and volume.
- To assess the diversity of flora and fauna supported by riverine ecosystems.
- To propose effective measures and management approaches for sustainable water use and long-term river conservation.

4. Limitations

The study is restricted to the availability of secondary data and does not include primary field investigations.

5. Methodology

The research adopts a systematic secondary-data review method, synthesizing reports, journal articles, river basin assessments, government data, WWF publications, and hydrological studies. (Joshi, 1994; S.K. Sundaray, 2007) Case studies of Ganga and Yamuna rivers illustrate ecological challenges and management strategies.

6. Overview of Indian Rivers

Indian rivers are classified based on origin into:

1) **Himalayan Rivers** (Ganga, Indus, Brahmaputra) – perennial, high sediment load, large basins. (B. Gopal, 2006)
2) **Peninsular Rivers** (Godavari, Krishna, Kaveri, Narmada, Tapi) – seasonal, shallow valleys, lower erosion. (K.S. Rao, 2006)
3) Indian rivers originate from three primary watersheds: Himalaya–Karakoram Ranges, Vindhya–Satpura–Chotanagpur Plateau and Western Ghats.

6.1 Himalayan Rivers

Himalayan rivers are characterized by deep gorges, intense erosion, and perennial flow regimes. (S.K. Sundaray, 2007) Their fragile catchments frequently experience soil erosion, resulting in heavy siltation downstream. Human interventions further disturb natural flow regimes through dams, barrages, and hydropower tunnels. (Joshi, 1994)

6.2 Peninsular Rivers

Peninsular rivers flow through hard rock terrain, with limited meandering and seasonal variability due to monsoon dependence. (K.S. Rao, 2006)

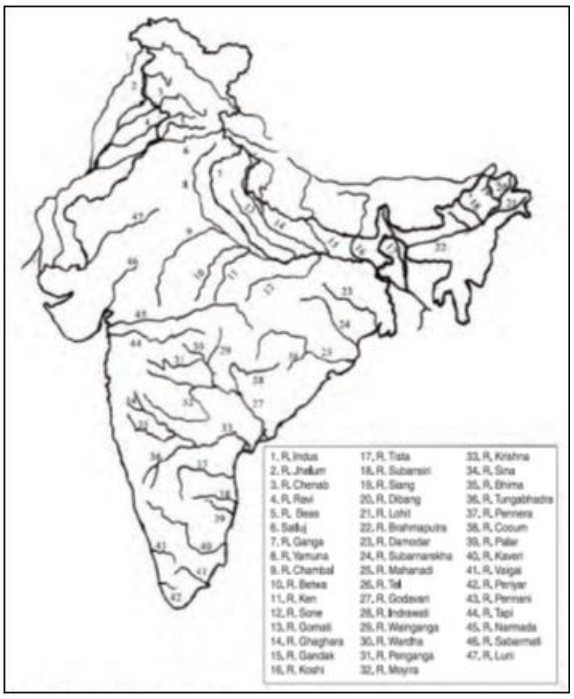

Figure 1: Major Rivers of India (B. Gopal, 2006)

7. River Ecosystem

A river ecosystem encompasses interactions between biotic (flora, fauna, microorganisms) and abiotic components (geomorphology, water chemistry, flow regimes). Human activities such as deforestation, basin alterations, hydropower construction, and urbanization severely alter these processes. (Srivastava, 2007; Team, 2012)

Key stressors include:

- Untreated sewage and industrial effluents (Samudrani, 2016; Board, 2018; B.D. Richter, 1997)
- Agricultural runoff
- Mining and construction
- River regulation and water diversions
- Habitat fragmentation
- Climate-induced hydrological variability

8. Key Ecological Parameters

Essential parameters for river health assessment include: (IUCN, 2010)

- Environmental flows (e-flows)
- Status of flora and fauna
- Land-use and development indices
- Water resource balance sheet
- Flood and drought risk warnings
- Integrated river health assessment

9. Environmental flows

Environmental flow regimes maintain ecological integrity by supporting habitat processes, sustaining groundwater recharge, regulating sediment transport, and enabling fish migration. (IUCN, 2010; B.D. Richter, 1997)

9.1 Low Flows

Maintain habitat availability, dissolved oxygen levels, soil moisture, and drinking water sources for wildlife.

9.2 High Pulse Flows

Shape channel morphology, prevent vegetative encroachment, flush pollutants, aerate spawning grounds, and maintain salinity gradients.

9.3 Large Floods

Enable fish spawning, nutrient deposition, floodplain recharge, and biodiversity enrichment.

Table 1: Importance of Environmental Flows (Team, 2012; IUCN, 2010)

Low (base) flows	***Normal Levels:*** • Provide adequate habitat for aquatic organisms • Maintain suitable water temperatures, dissolved oxygen, and water chemistry • Maintain water tables levels in the floodplain and soil moisture for plants • Provide drinking water for terrestrial animals • Keep fish and amphibian eggs suspended • Enable fish to move to feeding and spawning areas • Support hypothetic organisms (those living in saturated sediments)0 ***Drought Levels:*** • Enable recruitment of certain floodplain plants • Purge invasive introduced species from aquatic and riparian communities • Concentrate prey into limited areas to benefit predators
High pulse flows	• Shape physical character of river channel, including pools and riffles • Determine size of stream bed substrates (sand, gravel, and cobble) • Prevent riparian vegetation from encroaching into channel • Restore normal water quality conditions after prolonged low flows, flushing away waste products and pollutants • Aerate eggs in spawning gravels and prevent siltation • Maintain suitable salinity conditions in estuaries

Large floods	• Provide migration and spawning cues for fish • Trigger new phase in life cycle (e.g. in insects) • Enable fish to spawn on floodplain, provide nursery area for juvenile fish • Provide new feeding opportunities for fish and waterfowl (e.g. River Birds: Duck, Goose, Swan). • Recharge floodplain water table • Maintain diversity in floodplain forest types through prolonged inundation (different plant species have different tolerance) • Control distribution and abundance of plants on floodplains • Deposit nutrients on floodplain • Deposit gravel and cobbles in spawning areas • Flush organic materials (food) and woody debris (habitat structures) into channel • Purge invasive introduced species from aquatic riparian communities • Disburse seeds and fruits of riparian plant • Drive lateral movement of river channel, forming new habitats (secondary channels and oxbow lakes) • Provide plant seedlings with prolonged access to soil moisture.

10. Pollutions in Indian Rivers

Nearly 80% of India's water bodies are polluted due to: (Samudrani, 2016; Board, 2018)
- Untreated Sewage (largest contributor)
- Industrial Effluents
- Agricultural Chemicals
- Religious Activities
- Plastic Waste
- Oil Leakage
- Unregulated Urbanization

Consequences include:
- Waterborne diseases (cholera, typhoid, diarrhea)
- Groundwater contamination
- Loss of aquatic life
- Reduced agricultural productivity
- Ecosystem collapse

11. Biodiversity in Indian Rivers

India hosts one of the world's richest freshwater biodiversity's: (Anonymous, 2012; Team, 2012)
- 650+ freshwater fish species
- Critical habitats in Eastern Himalayas and Western Ghats
- Home to endangered species like river dolphins, gharials, turtles

Major threats: Dams and hydropower, Pollution, Habitat fragmentation, Sand mining and overfishing.

12. Case study 1: River Ganga

The Ganga Basin supports 540 million people and rich biodiversity. However, hydropower projects, embankments, rapid urbanization, and industrial discharge severely impact ecological integrity. (Joshi, 1994; Team, 2012).

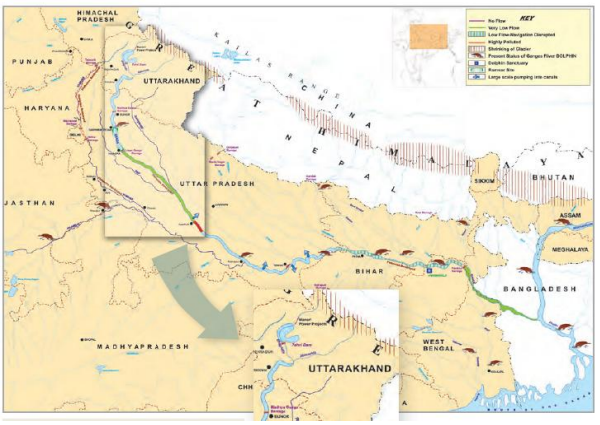

Figure 2: Flow of Ganga from Origin to End Point ((NIH), 2020)

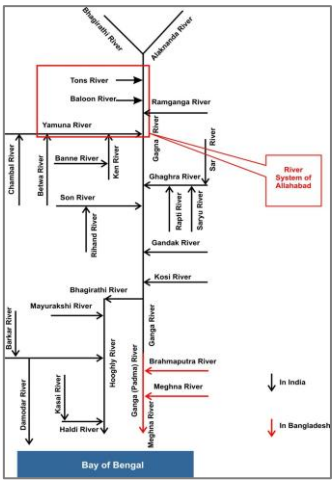

Figure 3: System of River Ganga ((NIH), 2020; Shakti, National River Conservation Plan Reports, 2020)

12.1 Environmental Flows

The Ganga is divided into three segments:

Table 2: Segment Stretch of River Ganga (IUCN, 2010; Shakti, 2020)

	Stretch	Distance Covers	Places Covered
A.	Upper Ganga	≈ 294 km	Gaumukh to Haridwar
B.	Middle Ganga	≈ 1082 km	Haridwar to Varanasi
C.	Lower Ganga	≈ 1134 km	Varanasi to Ganga Sagar

12.2 Pollution

- Over 3 billion liters/day of untreated sewage enter the river. (Samudrani, 2016; Team, 2012)
- WWF pilot projects using **bioremediation** showed 75% pollution reduction and 95% bacteria removal. (Team, 2012)

12.3 Biodiversity

The Ganga River dolphin population dropped from 6000 (1982) to 2000 (2005). (Joshi, 1994; Team, 2012) Conservation programs have increased local populations through habitat restoration, gharial reintroduction, and turtle hatcheries.

13. Case Study 2: River Yamuna

Yamuna is divided into five segments: Himalayan, Upper Delhi, Eutrophicated, Diluted. (Board, 2018; Team, 2012)

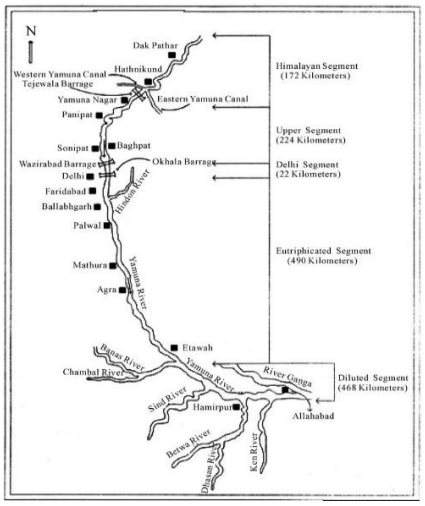

Figure 4: Segments of River Yamuna (Team, 2012; Board, 2018)

13.1 Environmental Flow

Yamuna's mean annual flow: **13.9 TMCM**
Water abstraction before Delhi: **9.5 TMCM**
Result: river runs dry in many stretches → ecological collapse. (Shakti, National River Conservation Plan Reports, 2020)

13.2 Pollution

Yamuna's Delhi segment is among India's most polluted: 3296 MLD sewage inflow, industrial waste, plastic, religious waste, agricultural chemicals, severe fish depletion and complete disappearance of river dolphins (Board, 2018; Team, 2012)

14. Management and Development Strategies

14.1 Sustainable Water Management

Environmental flow assessments and integration of e-flows in Ganga Basin Plan. (Shakti, National River Conservation Plan Reports, 2020)

14.2 Climate Adaptation

Climate-resilient agriculture and 20% increase in water-crop productivity through pilot programs. (Team, 2012)

14.3 Pollution Abatement

1200 MLD sewage is treated biologically (Kanpur, Allahabad) and 20–30% water footprint reduction in industries. (Board, 2018)

14.4 Water & Energy Co-Management

5–10% energy savings in cities and 30–40% savings in agriculture. (Shakti, National River Conservation Plan Reports, 2020)

Biodiversity Conservation
Gharials reintroduced 550, dolphin populations stabilizing and community-led conservation of turtle habitats. (Team, 2012)

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