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Research article

Exploring relationship between ecosystem services and socioeconomic development in the East Kolkata and Haiderpur wetlands of India

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Abstract: The world's most productive ecosystems at the interface between aquatic and terrestrial environments are known as Wetlands. They are unique concerning their structure and functions and are regarded as the cultural heritage of humanity. As per reports, India comprises over 7 lakh wetlands, of which only 75 have been designated Ramsar sites. These wetlands naturally help to mitigate climate change, maintain hydrological cycles, and reduce the carbon footprint. In fact, wetlands provide opportunities for fisheries, agriculture, energy resources, recreation, and tourism, which directly benefit the livelihoods of local communities. For instance, the East Kolkata Wetland recycles and reuses the city's sewage water through longstanding aquaculture and agriculture practices. At the same time, it supports employment and revenue generation through aquaculture products. Similarly, our exploration at Haiderpur wetland in Muzaffarnagar, Uttar Pradesh, witnessed the socio-economic potential through *Trapa natans* (water caltrop) cultivation. Though wetlands offer several direct and indirect ecosystem services, more than 35% of wetlands have been degraded or lost since 1970. According to the Ramsar convention reports, wetlands disappear three times faster than forests. Therefore, it is a prerequisite to protect the vulnerable wetlands and disseminate information on the importance of local wetlands through case studies and create public awareness as envisioned by the 'Wetland Mitra,' a government initiative for wetlands conservation. Considering the above-mentioned facts, the present work was undertaken, which mainly focused on assessing the potential of selected wetlands in the context of ecosystem service and sustainable livelihoods.

Keywords: India - Wetlands - Ramsar sites - Ecosystem service - Livelihoods.

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INTRODUCTION

Wetlands are among the most critical and interlinked ecosystems with human livelihood and well-being (Mccartney *et al.* 2015). It is the world's most unique and productive environment, providing numerous ecosystem services. Wetlands act as distinct ecotones where the land is covered by either salt or freshwater or somewhere between two biomes, permanently supporting aquatic and terrestrial species. Various wetlands like marshes, swamps, open water bodies, mangroves and tidal flats, and salt marshes provide niche habitats for several threatened species (Davidson *et al.* 2005) Assessing the potential of wetlands in each country by involving public voluntaries and scientific societies is vital for the conservation and sustainable use of resources as envisioned by the Kunming-Montreal Global Biodiversity Framework 2022. Further, it provides deep insight into wetlands' supply and demand ratio and their ecology, biodiversity, and livelihoods (Duku *et al.* 2022). However, ever-increasing biodiversity loss and degradation of wetland habitats due to the change in land use and urbanization urge conservation policies for the protection of wetlands characteristics worldwide.

In 1971, The United Nations Educational, Scientific and Cultural Organization (UNESCO) established an

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intergovernmental environmental treaty on wetlands at Ramsar, Iran. Ramsar Convention defines wetlands as "*areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meters*" (Ramsar Convention Secretariat 2010). Presently, over 170 nations are signatories to the Ramsar Convention, including India. This convention aims to develop and maintain an international network of wetlands, facilitating national action plans and bringing in international cooperation to conserve wetlands. It also forms the framework for preserving the ecological character of wetlands and directing the wise use of their resources. Signatory countries are designating the 'Wetlands of International Importance' by following the guidelines of Ramsar site-specific criteria categorized into Group 'A' and Group' B' (The Ramsar Sites Criteria 1971). The sites that contain representative, rare, or unique near-natural wetlands in any biogeographic region are designated as 'Ramsar sites' under Group 'A' criteria. Identification of 'sites of international importance' for conserving biological diversity relies on specific criteria based on the occurrence of threatened species. The 'Ramsar sites' of Group 'B' criteria include vulnerable, endangered, or critically endangered species and ecological communities which provide refuge for water birds, fishes, and other taxa during adverse conditions.

The Cobourg Peninsula in Australia was selected as the world's first Ramsar Site in 1974. The largest Ramsar Sites identified are Rio Negro, Ngiri-Tumba-Maindombe, and Queen Maud Gulf from Brazil, the Democratic Republic of Congo, and Canada, respectively. As of 2023, 172 Contracting Parties (Signatory countries) designated 2,492 Wetlands of International Importance, covering 256,637,813 hectares of the earth's surface (www.ramsar.org). World Wetlands Day is celebrated yearly as a global awareness campaign on 2nd February to highlight the value of wetlands and commemorate the anniversary of the Convention on Wetlands. The Conference of the Contracting Parties (COP) meeting is conducted every three years for contracting parties to discuss policy-making, adopt decisions (resolutions and recommendations) to administer the convention's work and improve how they can implement their objectives.

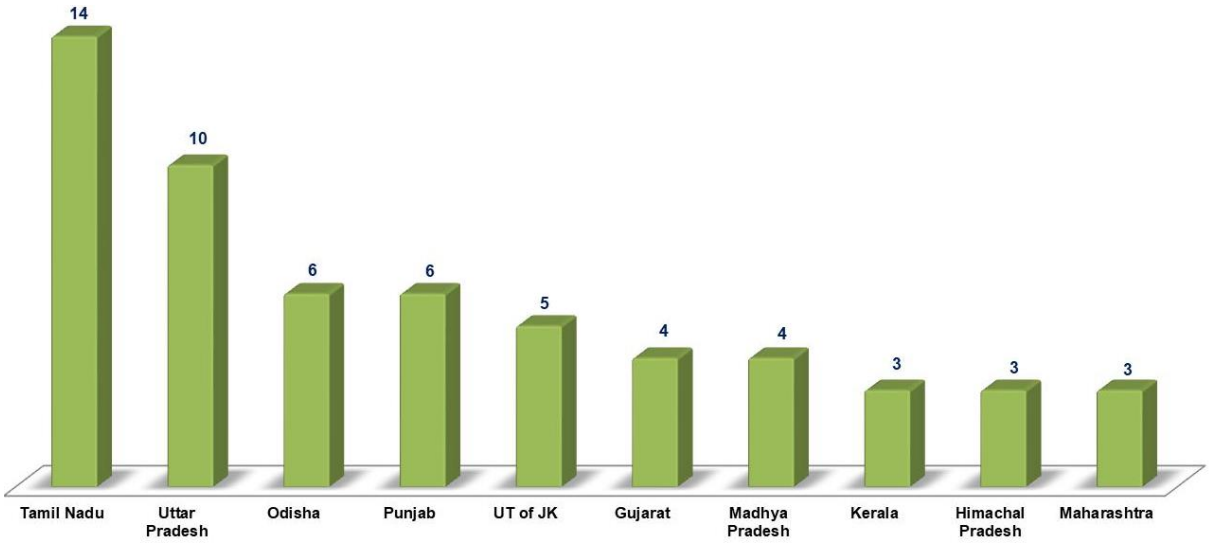


Figure 1. Top wetlands of India.

India is one of the prime countries associated with the inter-governmental treaty for preserving the ecological character of wetlands to benefit livelihoods. Ecological character is the combination of ecosystem components, processes, benefits, and services that describe the wetland at any given point in time. So far, 75 wetlands have been designated as Wetlands of International Importance (Ramsar Sites), covering 15.98 million hectares of wetlands (approx. 4.8% of its geographical area) (Yadav & Goyal 2022). Tamil Nadu designated the maximum Ramsar sites (14), followed by Uttar Pradesh (Fig. 1). The Chilika Lake in Orissa and Keoladeo National Park in Rajasthan were designated as the first Ramsar Sites of India in 1981. The largest Ramsar Site identified was the Sundarbans Wetland, one of the most extensive mangrove forests in the world and encompassed rich biodiversity occurring in the delta region between the Rivers Ganges and Brahmaputra (Fig. 2).

The Government of India is implementing a comprehensive and multi-pronged approach to conserving wetlands. For instance, the 100 Wetlands Rejuvenation Programme under the 169 transformative ideas has been up-scaled into all districts with a target of reaching 1,000 wetlands. The National Plan for Conservation of Aquatic Ecosystems (NPCA) framework has standardised the preparation of brief documents, rapid ecosystem

health assessment, the constitution of Wetland Mitra, and preparation of integrated wetlands management as a four-pronged approach (http://moef.gov.in) (MoEF & CC 2023). The Wetland Mitra campaign (Friends of Wetlands), a Conservation Initiative, gained more popularity among youths in India. The best practice of this activity is to inspire the communities to take direct action for wetland conservation and to change behaviour and practices at individual level & community levels.

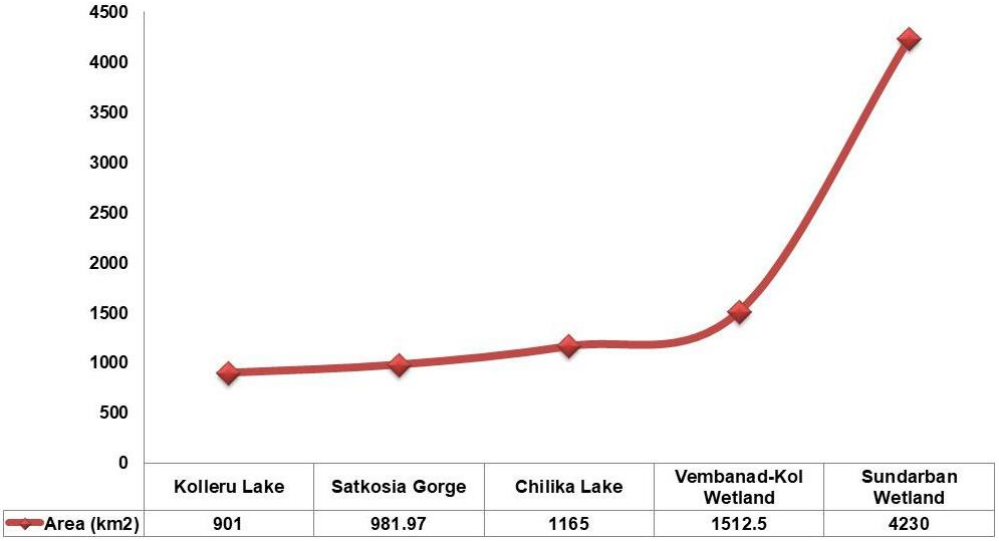


Figure 2. The largest Ramsar Sites of India.

Despite immense biodiversity, ecosystem services, and values, most wetland ecosystems rapidly disappear due to anthropogenic pressures and habitat degradation (Bassia *et al.* 2014, Newton *et al.* 2020). In response, the Government of India follows several strategies to conserve wetlands ranging from Ramsar Sites, wetlands of national importance, and urban and rural ponds. The Ministry of Environment, Forest and Climate Change (MoEF & CC) has launched the "Save Wetlands Campaign" under the Mission 'Sahbhagita' during the World Wetlands Day celebrations 2023. The objectives of this mission are to (a) Make wetland conservation a people's movement, (b) Inspire, infuse pride and ownership amongst stakeholders to adopt sustainable lifestyles for healthy wetlands and promote the wise use of wetlands, (c) Demonstrate and establish India's leadership in Wetland Conservation through the Lifestyle for Environment (LiFE for Wetlands) (d) Enhance biodiversity and carbon stock (e) Enhance ecotourism opportunities and income generation for local communities and (d) Empower all Ramsar sites of India to be managed better and effectively making them models of wise-use. Our study aimed to disseminate the significance and ecological benefits of wetlands in India. The current study discusses the potential of wetlands based on ecosystem services and sustainable use of resources from the East Kolkata and Haiderpur wetlands of India.

MATERIAL AND METHODS

The present study provides a comprehensive account on the ecology, biodiversity, sustainable use of resources for aquaculture, agriculture practices, recreation and tourism opportunities in East Kolkata and Haiderpur wetlands. Field survey of East Kolkata and Haiderpur wetland has been undertaken in the 2019 and 2022–2023, respectively. Field survey data along with literatures pertaining to ecosystem services and socio-economics of the wetland were compiled. Information on the utilization of aquatic, semi-aquatic, marshy and woody angiosperms was collected from the local villagers based on open-ended questions. Digital photographs along with GPS location for the plants were captured with Nikon D700 DSLR Camera. Data on habit, habitat, locality, elevation, associated plants, distribution pattern, abundance, phenology and local uses were recorded in the field notebook.

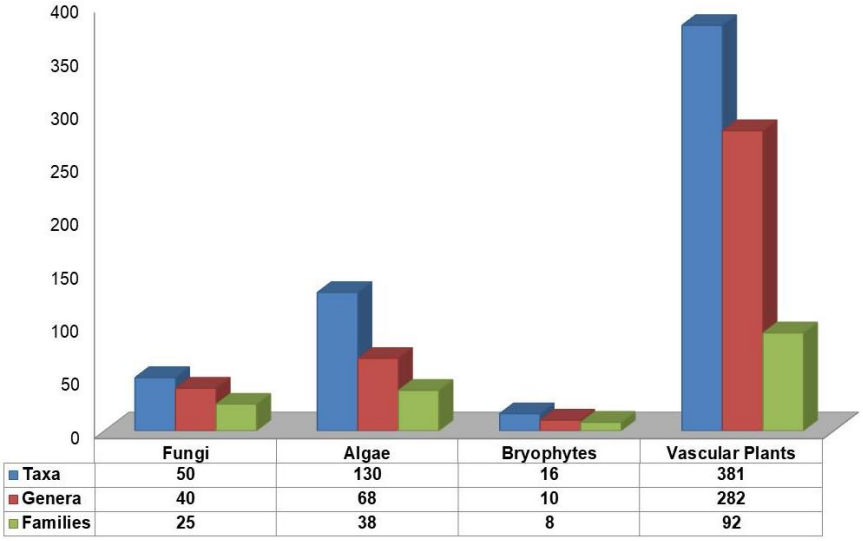
RESULTS AND DISCUSSION

Glimpse of East Kolkata Wetland

The East Kolkata Wetlands (EKW) is one of the largest, oldest, and most man-made wetlands on the globe, lying on the eastern fringes of Kolkata, West Bengal, in India. It covers an area of about 12,500 ha with species-rich diversity in a series of brackish wetlands connected to the freshwater and marine environments of the Gangetic Delta and the Bay of Bengal (Chakraborty *et al.* 2023). Water networks of the Gangetic Delta form massive inter-distributary channels consisting of intertidal marshes, salt meadows (wastewater treatment),

settling ponds (Bheries and Jheels), fish farms and sewage canals, oxidation basins, dumping grounds, green zone, and cultivable lands (Chaudhuri *et al.* 2012). The freshwater ecosystem is a mosaic of landforms, including water-dominated areas such as fish farms and land-centric usages for agriculture, horticulture, and settlements. This wetland has a unique characteristic in its wise use of resources in producing a wide range of goods and services and a sustainable and eco-friendly wastewater treatment system. On these bases, the EKW has been designated as a 'wetland of international importance' (Ramsar Site No. 1208) under article 8 by the Ramsar Convention on Wetlands on 19th August 2002. The wetland ecosystem plays a significant role in securing Kolkata's ecological and economic security. Here, we discussed the potential of ecosystem services in terms of ecology, biodiversity, waste recycling, aquaculture, agriculture practices, and tourism. Further, biological resources rendered by this wetland for more than centuries and their sustainable usage are assessed to gain more insights into the remarkable wetland.

Ecology & Biodiversity of EKW



	Fungi	Algae	Bryophytes	Vascular Plants
Taxa	50	130	16	381
Genera	40	68	10	282
Families	25	38	8	92

Figure 3. Plant species diversity of East Kolkata Wetlands, West Bengal, India.

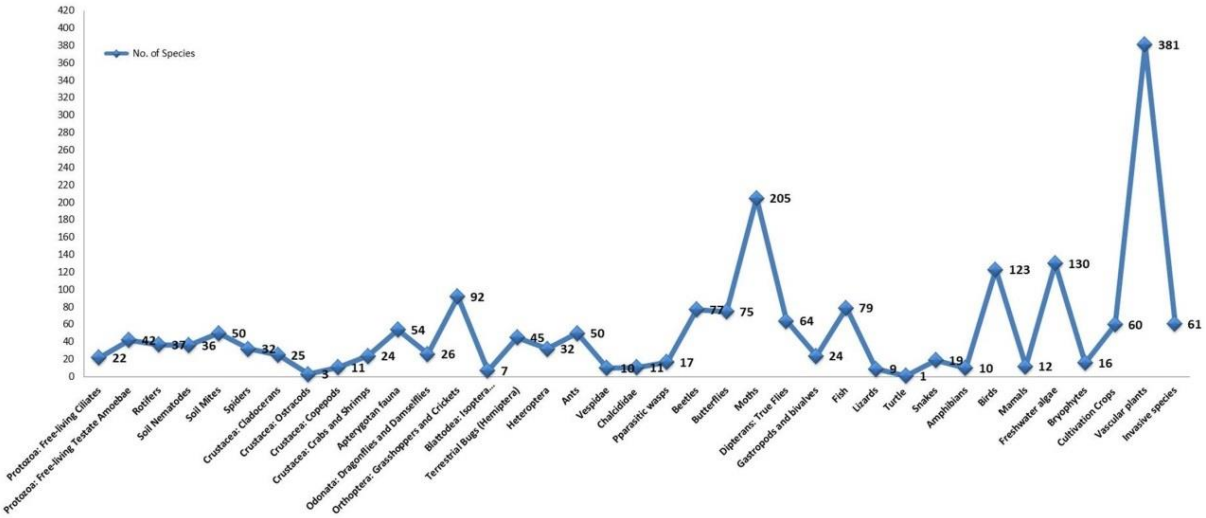


Figure 4. Animal species diversity of East Kolkata Wetlands, West Bengal, India.

Wetlands are an essential base of our planet's food web and are considered 'super biological systems' for producing food in high volumes to support a significant level of biodiversity (Emerton 2016). The EKW is an example of a highly productive wetland that acts as a paradise for many biological species and resources that help maintain ecological stability. The hot and humid climate and an average rainfall of 1600 mm from mid-June to October make the area rich in species diversity. The species inhabiting the wetland ecosystem plays major environmental role such as productivity and food chain, bio-geochemical cycling, water purification, and reducing carbon footprint. Evaluation of species diversity and distributions are the central focus of ecology which promotes future conservation initiatives (Keddy 2010). The food web of EKW supports myriad species of plants, fungi, birds, fish, amphibians, shellfish, and insects. Micro and macro observation experts during the

field studies documented 50, 130, 16, and 381 taxa of Fungi, Algae, Bryophytes, pteridophytes, and angiosperms, respectively (Chandra *et al.* 2020) (Fig. 3). Fungi such as Pseudogilled macrofungi, Crust Macrofungi, Toothed Macrofungi, Jelly Macrofungi, Stinkhorn, Carbon and cushion macrofungi were documented. Studies on Algae found that the Chlorophyceae (25 genera, 13 families) and Cyanophyceae (21 genera, 11 families) were predominant in freshwaters. Interestingly, seven liverworts and nine mosses were reported at different localities of East Kolkata Wetlands. Vascular plants of 381 taxa belonging to 371 angiosperms, one gymnosperm, and nine taxa of pteridophytes from 282 genera and 92 families were also recorded (Chandra *et al.* 2020). Besides, the wetland is home to several other faunas, including 123 different birds, 79 fishes, 19 reptiles, 12 mammals, 202 insects and ten amphibian species, 50 ants, 75 butterflies, and 205 moths (Ekwma & Wisa 2021) (Fig. 4).

A traditional way of recycling the natural waste in EKW

EKW wetland is one of India's rarest examples of natural waste recycling, environmental protection, and management practices. The local farmers adopted a complex ecological process by mastering the largest multi-functional resource retrieval model on the Wetlands. The area of 12,500 ha wide, expanding over 37 mouzas (24 districts) with 11,085 water bodies, has been serving as natural sewage treatment plants for over a century (Chandra *et al.* 2020). Waste recycling involves three major inter-linked resources recovery systems (i) sewage fed fishes (254), (ii) paddy cultivation by utilizing fish pond effluents, and (iii) cultivation of vegetables using organic waste as fertilizer (Banerjee & Dey 2017). Every day, over 900 MLD of pre-settled sewage from the Kolkata Metropolitan region is channelized to 260 shallow fish ponds through a series of locally excavated secondary and tertiary canals. The nutrient-rich effluent from the city passes through this series of channels and gets progressively cleaned and redirected to the algal ponds. Instantaneously, algae are used as a feed source for 17 different species of fish cultured as part of Pisciculture practice in these ponds. At last, the Nitrogen and phosphorus-rich water produced during the process is used as a fertilizer to irrigate the adjacent agricultural lands.

These unique management practices offered the farmers a way to use wastewater wisely to address the scarcity of water resources and the supply of nutrients for agricultural practices. The flow of traditional knowledge is still preserved even today, which results in an outstanding agricultural practice witnessing the cultivation and harvesting of several crops and aquaculture as part of local livelihood. It is reported that around 50,000 MT of vegetables and 20,000 MT of fish are produced using this waste recycling system, and the wastewater is utilized to irrigate 4700 ha of paddy lands (Ekwma & Wisa 2021). The productive reuse of sewage in urban aquaculture using fish ponds ensures the disposal of solid organic waste and wastewater. This longstanding water purification and sewage waste recovery practice saves nearly 4,680 million INR annually, on 65% of the city's sewage treatment cost. Besides, wetlands also act as carbon sinks and absorb over 60% of carbon from wastewater, contributing to the reduced effect of Green House Gas emissions from the city. Similarly, urban aquaculture also offers monetary benefits such as increased tax revenue and subsidized waste management, non-renewable recovery of resources, and other functional and non-functional benefits from the wetland (Malinauskaite *et al.* 2017). The best practices of waste reuse guarantee public health and environmental protection as multi-faceted benefits to the people of Kolkata city.

Livelihood from Aquaculture & Agriculture Practices in EKW

The wetland biodiversity of EKW is responsible for socio-economic uplifting and has supported the employment of 1.5 lakh residents for more than decades (Bhattacharyya *et al.* 2008). Farmers practice the dual resource recovery system as a blending approach using aquaculture and agriculture set a model for other states of India for efficient resource recovery from the wetlands. The essential and actual benefits of urban aquaculture are food security, employment, and income generation. Roughly 74% of the local working community depends on agriculture and fish farming. In the case of fish farming, the city sewage is used for plankton growth, which acts as the leading food resource for fish cultivation. At least 30 tonnes of fish are supplied to the city market daily, and around 20,000 metric tons of fish are commercially produced yearly (Ekwma & Wisa 2021). Species like *Catla catla* (Catla), *Labeo rohita* (Rohu), *Cirrhinus mrigala* (Mrigal), *Labeo bata* (Bata), and *Labeo calbasu* (Calbasu) are commonly cultured in fish farms. The demand and supply of aqua products in urban markets are usually high compared to other rural areas. Fast and easy transportation and delivery of fresh products in the markets with less time are the major advantages to meeting the bulk demand in the urban markets. Assured demand for fish in urban markets is the critical factor for developing many aquaculture farms that directly support the livelihood of local communities in lower socio-economic strata.

The degradation of organic substances in sewage by the natural microbial population and fish ponds plays a significant role in wastewater recycling (Sarkar *et al.* 2014, Mukherjee *et al.* 2022). The wastewater drained from the city gets purified in a series of channels and directed to the production of substantial edible and non-edible resources such as food, fodder, fuel, vegetables, pulses, oils, paper-pulp, thatching material, and medicine supporting cottage-level industries. Local people are involved in vegetable cultivation as a household activity in small plots for their household sustenance and income. Approximately 150 tonnes of vegetables are produced daily from small-scale horticultural fields irrigated with wastewater. Nearly 60 plant species are cultivated under agricultural practices (Chandra *et al.* 2020). Some of them are *Abelmoshus esculentus* (Bhindi), *Amaranthus* spp. (Lalsag, Kanta Note, Note), *Amorphophallus paeoniifolius* (Ol), *Bacopa monnieri* (Bramhi), *Capsicum annuum* (Lanka), *Carissa carandas* (Karamcha), *Curcuma longa* (Hould), *Lycopersicon esculentum* (Tomato), *Momordica charantia* (Uchhe), *Solanum melongena* (Begun) and *Trapa natans* (Pani fal). During the post-monsoon period, 16,000 tonnes of winter paddy varieties are harvested, and the average annual yield of the 'boro paddy' variety reached 5 tonnes ha-1 and 'amon' by 3 tonnes ha-1 (Bhattacharya *et al.* 2012).

Recreation & Tourism Opportunities of EKW

In the broader aspects of ecosystem services, wetland also offers several recreation benefits, thereby increasing the state economy. Recreational facilities such as guided boat rides, landscape gardens, boardwalks, and nature trails are influential in shaping the ecosystem values and livelihood diversification of communities (Ekwma & Wisa 2021). The available guided boat rides in the Kolkata Heritage River Cruise that run from Kolkata to Gangasagar through the picturesque Hoogly River offers tourist to enjoy the view of famous historical landmarks such as the Eastern Railways Headquarters, Vidyasagar Setu, Eden Gardens, and city markets from the water. A guided boat ride at Nalban Bhery, a part of the wetland, attracts several nature lovers. The government facilities recreation activities like panel displays, interactive maps, 3D models, dioramas, audiovisual rooms, viewing galleries, and play areas at the Centre north of Krishnapur Canal. Opportunities for making tourism a profitable industry at EKW are plenty because of the numerous temples, mosques, and churches that attract tourists worldwide and still conserve urban beauty.

Conspectus of Haiderpur Wetland

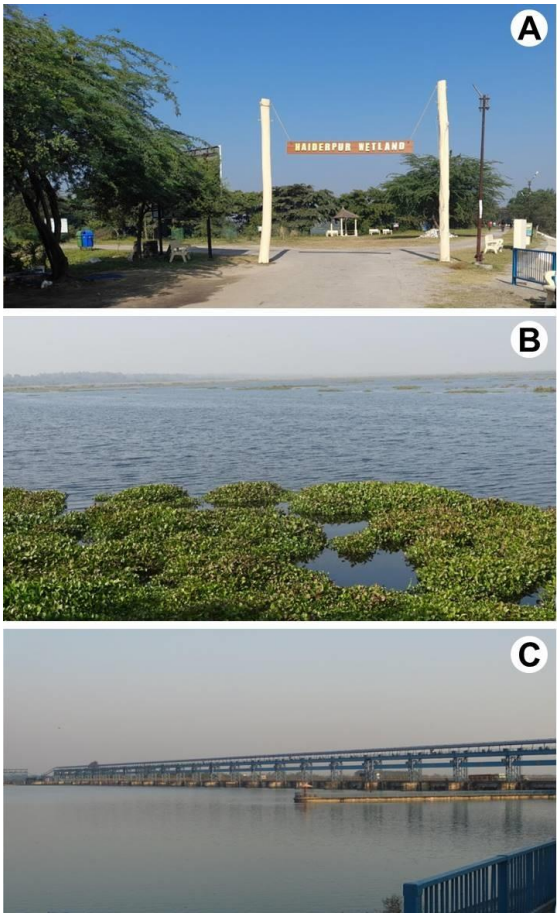


Figure 5. Overview of Haiderpur Wetland: **A**, Entrance of Haiderpur Wetland; **B**, Wet landscape occupied by Pontederia crassipes; **C**, A view of Bijnor Barrage.

Haiderpur is a freshwater, man-made, floodplain wetland of River Ganga near the Bijnor Barrage. This wetland came into existence after the construction of Madhya Ganga Barrage in 1984 (Fig. 5). The wetland area covers about 69.08 km^2 located within the Hastinapur Wildlife Sanctuary and is protected under the Wildlife Protection Act of 1972 (Ramsar Information Sheet 2021). The Sanctuary supports diverse vegetation such as tropical dry deciduous, tropical secondary scrub, and tropical grassland. The backwater received from River Ganga flows and retains in the deep upstream reservoir, shallow flooded land, stretches of river, perennial inundated patches, and areas between these patches are ecologically sensitive zones. It is essential to study the integration of river dynamics and its connectivity to the wet landscape to understand the spatiotemporal variability in the water-spread area (Singh *et al.* 2022). This wet landscape has remarkable vegetation that supports unique species-rich biodiversity in Haiderpur. Studies have reported numerous plants, including large trees, shrubs, herbs, and several species of grasses, reeds, and sedges along the mighty river. This diverse aquatic habitat thrives with life forms and provides a significant abode, especially for migratory water birds (Fig. 5).

The site offers sustenance and shelter to more than 25,000 water birds and functions as a breeding site for threatened species like Black-Bellied Tern, Bronze-winged Jacana, Indian Grassbird, Indian Skimmer, Lesser-Whistling Duck, Steppe Eagle, and Sarus Crane. Animals such as wild cats, wild boar, spotted deer, leopards, pythons, cobras, and muggers are found in the fringes and the catchment areas of the wetland (Singh *et al.* 2018, Arya *et al.* 2020). This diverse habitat is crucial for the survival of niche-specific megaherbivores, swamp deer, and 15 globally threatened species, including the fish Gold Mahseer, Turtle, Dolphin, and fish-eating 'Gharial.' In addition, the wetland supports more than 1% of the greylag goose and bar-headed goose population. Haiderpur wetlands are endowed with several 'Vulnerable' species and play a significant role in preserving the ecological character and sustainable uses of resources. On 31st April 2021, this wetland was nominated as the 47th Ramsar Site in India and known to locals as the 'Barrage Wali Jheel' (Ramsar Information sheet 2021).

Livelihood from terrestrial flora and water caltrops

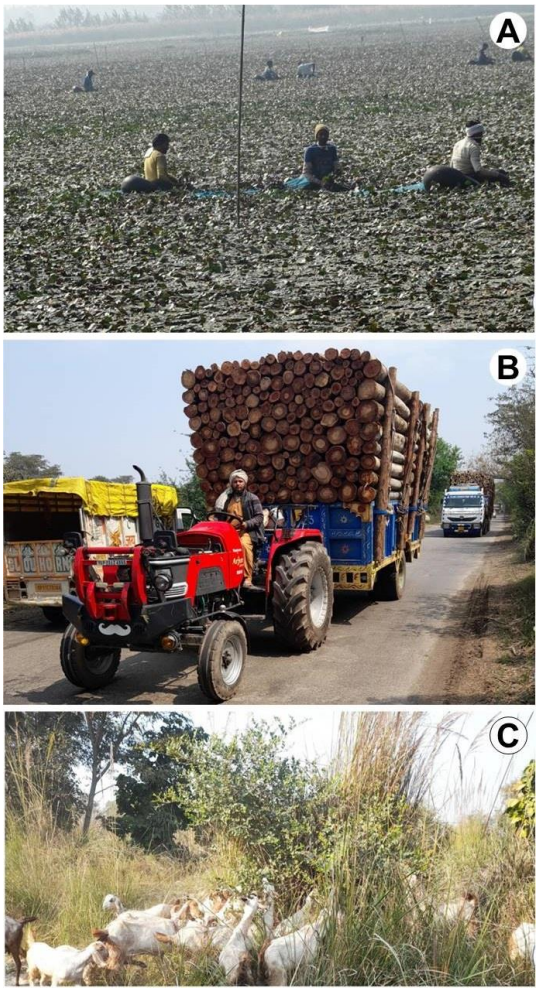


Figure 6. Potential of Haiderpur Wetland: **A**, Mass cultivation of water caltrop by farmers; **B**, Logged timber of *Populus* transported to local plywood industries; **C**, Grazing of livestock.

Haiderpur Wetland significantly supports the societal and economic growth of local communities. Our team members (O.N.M & S.S) during the field visits explored this magnificent self-sustained, backwater wetland between 2022 and 2023 (Fig. 5). The natural water reservoirs of this wetlands store a large quantity of water that was utilized for irrigation, aesthetic and cultivation purposes helps in maintaining the natural cycles and ecological diversity. This productive wetland is not only ecologically significant but also supports revenue for the local communities residing near the wetland through fisheries and water chestnut cultivation (Fig. 6). Although fishing is not practiced in large-scale farming as in EKW, it is part of a local lifestyle to meet the nutritional demand. We observed that the water resource retained in the shallow flooded land and perennial patches are essential for cultivating crops such as sugarcane, wheat, and vegetables. Agro-potential species such as eggplant, Lady's fingers, Onion, Potato, Tomato, Scarlet gourds, Cucumber, Watermelon, and Muskmelon are frequently cultivated by the people. On the other side, naturally grown grasses provide opportunities for localities to gain additional economic benefits through forage and thereby improving dairy production (Fig. 6). Perennial clumps with upright stems of Broom grass (*Thysanolaena latifolia* (Roxb. ex Hornem.) Honda) are used to make broomsticks that are commonly grown in semi-open areas, grasslands, and river banks. Narkat grass (*Arundo donax* L.) grows up to 10 m tall in heavy clay soil, and brackish estuaries possess a high degree of salt tolerance and are utilized for thatching huts and making baskets. The vast potential of these grasses is also seen in terms of soil protection, phytoremediation, energetics, and natural aesthetics. Furthermore, *farmers grow Populus and Eucalyptus trees commercially*, and the logged wood attracts veneers and plywood industries (Fig. 6).

The typical waterscape flora consisted of aquatic floating or submerged species of *Nymphaea* spp, *Pistia stratiotes* L, *Euryale ferox* Salisb, *Pontederia crassipes* Mart, *Ipomoea aquatica* Forssk, *Sagittaria sagittifolia* L, *Nelumbo nucifera* Gaertn, *Hygrophila auriculata* (Schumach.) Heine and *Trapa natans* L. Though wetland-based cultivation of water caltrops was reported from Bihar, Maharashtra, West Bengal, and Madhya Pradesh (Singh *et al.* 2018), our exploration near the Ganga Pushta, Gawari Gair, Ghuriapur Ahatmali region of Muzaffarnagar area reveals first observation on the commercial cultivation of the *T. natans* (Fig. 6). The cultivation of *T. natans* covers approx. 9 km^2 area of waterscape and farmers as migrants from the Bengal are involved in the cultivation as laborers. This lozenge, or diamond-shaped water caltrop, starts blooming from August to October, and nuts are harvested between October and December. Aquatic weeds are regulated at regular intervals to avoid crop-weed competition, and a yield of 4 tonnes/ha are achieved easily every year. The knobby edible nut is reddish black or pure green skin with crispy white flesh (soft tissue). The harvested nuts are transported to Bijnor and Muzaffarnagar markets through short commutes, Buffalo carts, and e-rikshaws. This seasonal freshwater edible nut has high demand in city markets and is further marketed to other districts through various outlets. Villagers form different communities selling these nuts for their daily income sources. The kernel has a sweet taste with a slight crunch eaten raw or boiled after skin separation. This seasonal nut is rich in water content, starch, protein, and carbohydrates and is an excellent source of crude fiber, vitamins B, Ca, K, Fe, and Zn (Arya *et al.* 2020).

Efforts on recreation and tourism

Infrastructure for eco-tourism activities such as nature trails, cycling, bird watching, viewpoints, watch towers, huts, and dolphin safari in the boat are developed in Haiderpur wetland. Likewise, livelihood opportunities were generated in nearby nine villages involving 6000 men working as Nature Guides & Boatmen. Local villagers have created nature shops to sell Laddu, agarbatti, candles, mats, and baskets.

CONCLUSION

The wetlands flora is capable of safeguarding the effects of climate change, thereby supporting the invaluable biodiversity of the country. It plays a vital role in species conservation, adaptation, resilience, and performing as the natural sink of carbon on the planet (Ramsar Convention Secretariat 2010, Campbell *et al.* 2022). Wetland networks also act as crucial corridors and stepping stones in allowing species to move toward more excellent areas to adapt to rising temperatures. However, it is estimated that 64% of the world's wetlands have already disappeared, which cautioned about the survival and status of threatened species. Significant losses of wetlands resulted from changes in land use to industrial, agricultural, and urban development's, which have caused hydrological alarms, pollution, and several other effects. Protecting wetlands from anthropogenic pressures helps to reduce greenhouse gases in the atmosphere.

The major apprehensions of wetlands are fragmentation and habitat degradation due to the dual effects of biotic and abiotic factors. Biotic pressures adversely affect the flora and fauna of wetlands. For example,

untreated industrial effluents and uncontrolled discharge of wastewater dramatically affect the survival of aquatic species due to water level fluctuations. Aquatic invasive species cause eutrophication in lakes and ponds (Adkar *et al.* 2014, Joshi *et al.* 2021), Unsustainable logging of timber and non-timber products affects the soil quality. Habitat destruction leads to the loss of fish and a decrease in Migratory birds.

Similarly, abiotic threats are the primary reason for the shrinkage of wetland areas due to encroachment. Habitat destruction and loss of biodiversity is results from urbanization, pollution, and pesticide used for farming. The wetlands are as rich as rainforests and coral reefs in terms of the number and variety of species. The economic benefits of the natural wetlands are much more significant than the ecosystem services provided by the whole society (Chen & Wong 2016). The wetland ecosystem services are irreplaceable since many funds are to be invested in water purification plants, dams, and other complex infrastructure. Local villagers conserved and sustainably used such sustainable wetlands based on traditional knowledge.

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