Dependence on Ecosystem Goods and Services: A Case Study on East Kolkata Wetlands, West Bengal, India

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Nitai Kundu and Anita Chakraborty

Abstract

The age-old practice of utilizing wastewater into fishpond in the East Kolkata Wetlands (EKW), India, is a unique example of resource recovery. The wetlands, providing a range of ecosystem services, form the base of ecological security of the entire region and livelihoods of the dependent communities. Being a dynamic ecosystem, the wetland is subject to influence from various natural as well as human factors. Integrated management of this ecosystem is crucial for maintaining the rich productivity of the wetland ecosystem as well as achieving wise use of resources. The present chapter is an effort to present broadly the ecological-economic linkages of the wetland uses with emphasis on the economics of aquaculture, horticulture, and agriculture under the waste recycling practices.

Keywords

Aquaculture • *Bheries* • Biodiversity • Horticulture • Macrophytes • Wetland

N. Kundu (✉)
Institute of Environmental Studies and Wetland Management, Kolkata, India
e-mail: npk1967@yahoo.co.in

A. Chakraborty
Centre for Environmental Management and Participatory Development,
HB-150, Saila Bhawan, Sector-III, Salt Lake City, Kolkata 700106, India

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20.1 Introduction

A natural ecosystem delivers a range of benefits for people, known as ecosystem services. The concept of ecosystem goods and services allows for identification of the various benefits that human derive from functioning ecosystems such as wetlands. The concept provides the example of human-centered exploitation of resources, which has emerged as the motivation to conserve and maintain ecosystem, and it is a relatively new approach. Historically strong arguments had been put forth for conservation justifying on ethical reasons or intrinsic value of nature's organisms, populations, species, and ecosystem (Turner and Daily 2008), and many people also support the fact the species ought to exist and have the right to exist (Barnosky et al. 2011).

Wetland ecosystem, including rivers, lakes, marshes, rice fields, and coastal areas, provides many ecosystem services that contribute to human well-being and poverty alleviation (MEA 2005). From an economic point of view, ecosystems can broadly be seen as part of our natural capital and the flow of ecosystem services the "interest" on the capital that society receives (Costanza and Daly 1992). Two of the most recognized wetland ecosystem services affecting human well-being are fish supply and water availability. India, owing to wide variations in rainfall, hydrology, physiography, geomorphology, and climate, has a rich diversity of inland wetlands. As per the National Wetland Atlas (SAC 2011), of the 15.26 million ha area under wetlands in the country, inland wetlands constitute 69.22% (10.56 million ha). The country's inland fisheries are of particular importance as they are the primary source of animal protein to which rural communities have access (MEA 2005). Another positive example of wetlands is the case of East Kolkata Wetlands (EKW), West Bengal, India, where untreated wastewater[1] from the city is used in fishpond for the purpose of fisheries.

The EKW is a complex and dynamic system providing a wide range of goods (food, water, fuel wood, fodder, etc.) and services (water supply, air purification, natural recycling of waste, etc.) and an example of wise use of wetlands. Farming vegetables, rice, and fish around the city of Kolkata, in the EKW, benefits local people and urban population of Kolkata in several ways:

- By generation of employment through (1) direct employment for thousands of men and women in catching fish, weeding, and cultivating vegetables and as casual laborers and (2) payment in kind for work undertaken on farms, e.g., weed clearing or carrying fish to market
- By indirect employment in supply and distribution networks, e.g., fish seed traders and market vendors

[1] This untreated water, mostly Kolkata city's domestic sewage, through the canals is first collected in primary ponds with heavy growth of macrophytes. The wastewater allowed to stand for considerable period of time is diverted to aquaculture ponds and then agricultural fields for further use. Agriculturalists and aquaculturists believe the whole process help in natural purification of the gray water and its sustainable use.

– Supplying affordable and fresh fish and vegetables to markets serving poor communities
– Through waste reuse, mitigating environmental degradation and reducing health risks
– The overall improvement in environmental quality due to the existence of peri-urban farming and water bodies

The EKW, located on the eastern fringes of Kolkata city, spread over an area of 12,500 ha is perhaps the largest sewage-fed fishponds. These wetlands form a part of the extensive inter-distributary wetland system in the Gangetic delta. The EKW sustains the world's largest and perhaps the oldest integrated resource recovery practice based on a combination of agriculture (including horticulture) and aquaculture. This provides livelihood support to a large, economically underprivileged population of around 20,000 families that depend upon the various wetland products, primarily fish and vegetables for sustenance (WISA 2008). Based on its immense ecological and sociocultural importance and on the recommendation of the Government of India, Ramsar Convention declared EKW as a wetland of international importance in the year 2002. This has drawn attention of international community to these wetlands. Further, "The East Kolkata Wetlands (Conservation and Management) Act, 2006" was a major statutory commitment to preserve the wetlands for current and future generation. This act makes provision for the conservation and management of the EKW and presents a schedule of landholdings within EKW specifying their character and mode of use. The current chapter is an effort to present broadly the ecological-economic linkages of this wetland with special emphasis on aquaculture, horticulture, and agriculture in the wetland complex under the waste recycling practices.[2]

The wetland system currently produces over 15,000 MT fish per annum from its 264 aquaculture ponds, locally called *bheries*. Additionally, nearly 150 tons of vegetable are produced daily. Thus, it is prudent to say that EKW serves as the backbone of food security of the Kolkata city. Further, it sets a typical example of harnessing natural resource in a wetland ecosystem for aquaculture and agriculture

[2] The resource recovery system in EKW follows a scientific approach wherein huge amount of sewage is treated through pisciculture. The wetlands act as waste-stabilizing ponds, while the slow-moving canal system functions as anaerobic and facultative ponds. The removal mechanisms for biochemical oxygen demand (BOD), nitrogen, and phosphorus are the settling of nutrients followed by their incorporation/uptake into algal biomass which is consumed by fishes getting incorporated into fish biomass. According to the aquaculturists, the cumulative efficiency in reducing the BOD of the sewage wastewater in these ponds is above 80% and that in reducing the coliform bacteria is about 99.99% on an average. The solar radiation is also reported about 250 langleys/day, adequate for photosynthesis. In fact, the sewage-fed fishery ponds in EKW act as solar reactors, trapping solar energy by thickly growing plankton, which is consumed by the planktivorous fishes. The plankton plays significant role in degrading the organic matter in the wastewater. The fishes, grazing on the planktons, maintain proper balance of the plankton population in the pond and convert the nutrients in the wastewater into consumable form (fish biomass) for humans. This complex ecological process is made use by the fish farmers of the EKW to produce fish at production cost unmatched in any other freshwater fishponds of this country.

(including horticulture) ensuring community participation and their traditional knowledge in waste recycling. This wetland system is also a testimony of a best practice of drawing local communities into conservation and management. Thus, it stands as one of the 17 case studies of wise use of wetlands by the Ramsar Convention (Bunting et al. 2011).

The genesis of the EKW is strongly connected with the development of the city, changing river courses and waste management of Kolkata. The city of Kolkata was historically a part of the mangrove and forestland of the Sundarban delta system. The rivers in this deltaic region were characterized by distinctive drainage pattern, massive swamps, and numerous wetlands. Earlier, the wetland complex in the eastern fringes of Kolkata was called salt lake (Sengupta 1980). Presently this wetland complex is also a part of EKW, which also represents the remnant beds of mighty tidal Bidyadhari River and its spill areas. Loss of tidal ingress from Sundarban delta and continuous runoff from the catchment facilitated the conversion and dilution of the salinity of the wetland complex rendering it into a freshwater wetland complex in due course of time (Kundu et al. 2008).

During the late eighteenth century, there was disruption of the connecting rivers, tributaries, estuaries, and network of channels connecting the Bidyadhari River. Damodar River, principally contributing to the upland discharge to the Jamuna-Bidyadhari, changed its course in due course (meandering character of river). Thus, in the absence of the upland water and clogging of the interconnected channels, the Bidyadhari became dependent for water solely on rainfall in its drainage basin. The situation was further aggravated with increase in tidal silt ingress, inadequate discharge to flush the silt, and construction of bridges and channels in the area. This event apparently transformed the ecosystem into marshes and swamps of varying sizes that subsequently changed into ponds for both fish and paddy cultivations.

Over the time, Kolkata grew into a large urban and trade center with no proper sewerage and solid waste management systems. This unplanned approach often resulted in drainage congestion and subsequent health impacts. The entire waste was initially dumped into the Hooghly River, a practice that was abandoned due to frequent outbreaks of malaria during 1700–1800 (Kundu et al. 2012). On the recommendation of a duly constituted committee, all the city wastes were transferred to salt lakes as the city has natural eastward slope. The wetlands were nearly 8.5 ft below the highest point of the city, and it was strongly suggested to construct a series of sewers and pumping stations toward the salt lake. In 1864, a portion of the salt lakes was also acquired for dumping solid waste. The first attempt of freshwater aquaculture was made in year 1918 (Kundu et al. 2012). Subsequent development of the wastewater channels in the city and rapid growth of the settlements ensured more sewerage directly promoting adoption of waste-fed aquaculture in the lakes. The wetland system presently has 264 *bheries* (WISA 2008). The solid waste dumping areas on the western fringe of the wetland complex were fully converted to horticulture since 1876. Application of sewage was sequenced skillfully based on detention time needed to improve the water quality appropriate for aquaculture activity (Kundu et al. 2012).

20.1.1 Dependence of the City on the Services Provided by the EKW

Complex ecosystems lying between river and coastal systems are fundamental to the well-being of society as a whole (Sayer et al. 2013). Conventionally, ecosystem services have been described as “the benefits of nature to households, communities, and economies” (Boyd and Banzhaf 2006). The Millennium Ecosystem Assessment (MEA 2005) defined them as provisioning, regulating, cultural, and supporting services and examined how changes in ecosystem services influence human well-being. Human well-being in this context is assumed to have multiple components, including security that encompasses secure access to natural and other resources, personal safety, and security from natural and human-made disasters. EKW is the best existing example, which provides a range of goods and services (Fig. 20.1) that contribute to human well-being and poverty alleviation. Communities living near wetlands are highly dependent on these services and are directly harmed by their degradation.

The economic activities that have mushroomed across the wetland complex is literally converting urban waste into wealth. Hence, this vast wetland has earned the title of Waste Recycling Region (WRR) in India (Kundu et al. 2012). These economic activities, of which agriculture, horticulture, and fisheries (Fig. 20.2 land use and cover) are the most important, have provided employment to thousands of people who live in the EKW region and its outskirts.

For understanding the ecological-economic linkages of EKW, a socioeconomic survey was conducted in the wetland complex. Primary data was collected through a sample survey of 10% of the total households residing in and around the EKW engaged in aquaculture, horticulture, and agriculture conducted from March 2011 to August 2014. Through stratified random sampling, 202 households were interviewed using a socioeconomic survey questionnaire. The investigation of Mukherjee

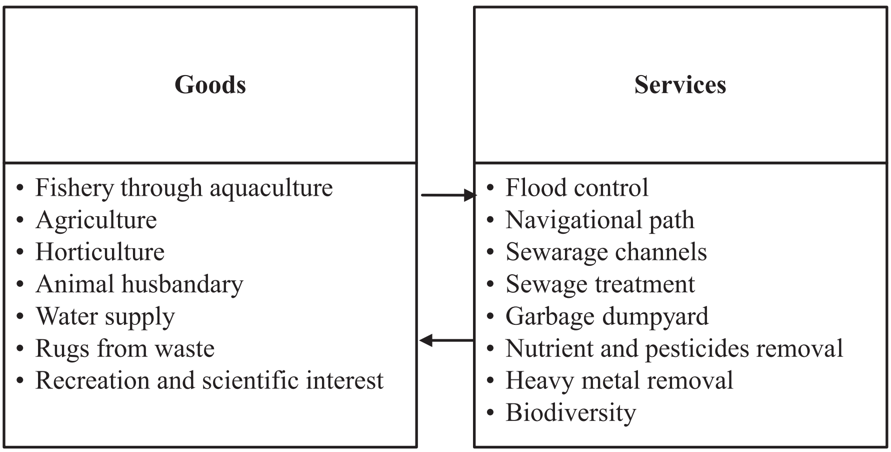

Fig. 20.1 Wetland goods and services provided by the EKW

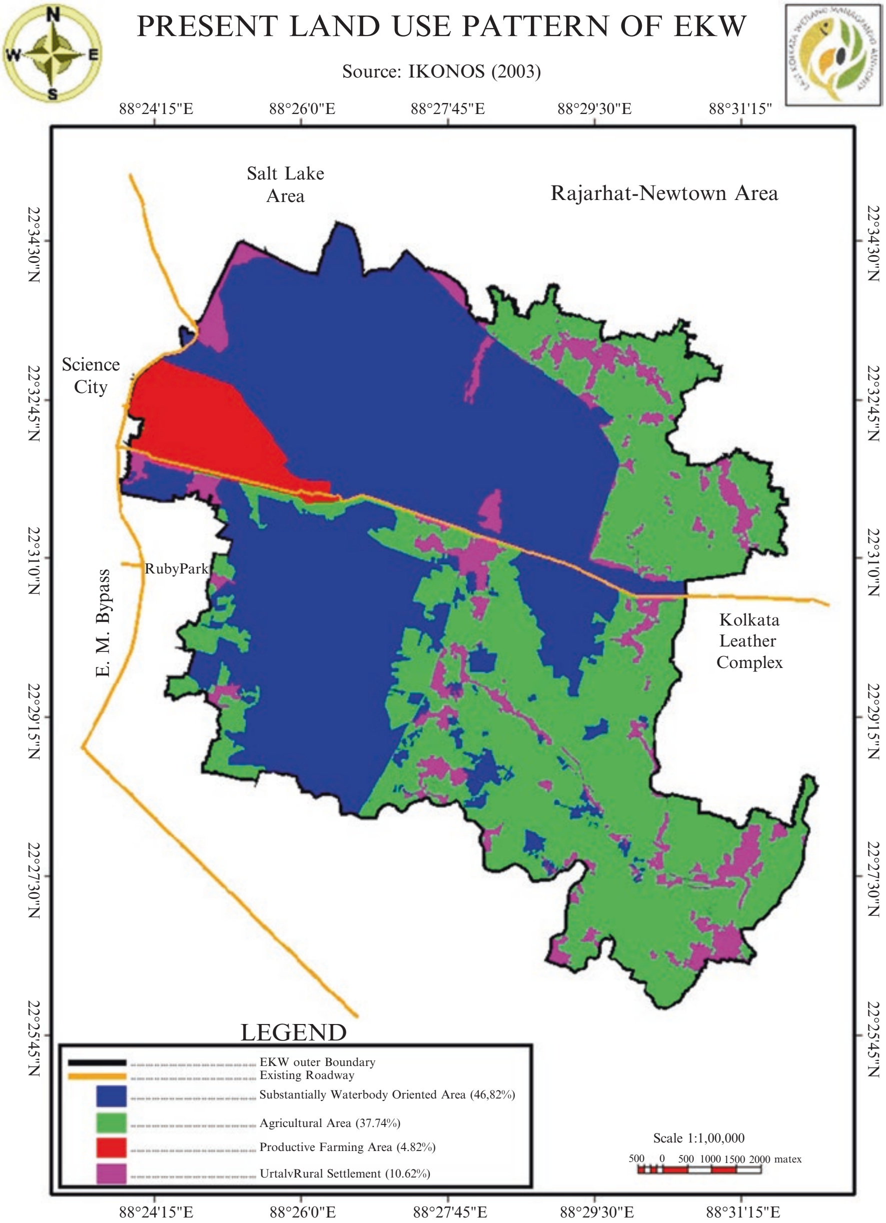

Fig. 20.2 Land use and land cover of East Kolkata Wetlands (Source: CEMPD 2013)

(1996) was used as baseline for aquaculture operation, updated accordingly based on the sample survey. Data was collected to reflect household level demographic profile, economic profile, resource use, ecosystem services, and perception toward management planning. Participatory appraisals were also conducted in 10% of the household to assess community rights and capacity for integrated management. Specific data for eight different areas of landholding for aquaculture ponds were analyzed for economics of aquaculture operation, while the data for agriculture and horticulture were examined for the net profit and issues associated with the operation. There was high reluctance among the stakeholders in sharing information on the gross economic benefit from the culture and cultivation practices although they were more willing to share information on issues related with the operation. A narrative of the range of ecosystem goods and services from this wetland complex is given in the subsequent sections.

20.1.1.1 Agriculture

Agriculture, within the eastern margins of the wetlands and to the south of the dry weather flow (DWF) channels, accounts for 38% of the land use. Paddy is the major crop cultivated thrice in a year. The monsoon crop (locally called *boro*) and winter crop (locally called *aman*) are the major two crops in a year, while the third crop (locally called *aus*) cultivated during summer constitutes the rest. Individually, average yield is highest in *boro* paddy (5 MT ha^{-1}), followed by *aman* (3 MT ha^{-1}) and *aus* (2.5 MT ha^{-1}) (WISA 2008). Assured water and fertile land ensured good harvest on investment, which principally governs the land use practices and conversion. In 1980s, about 2200 ha of ponds have been converted to paddy cultivation. Water for paddy cultivation is principally derived from the effluent from the fish farms. However, recently a trend of decline in sewage inflow and consequent higher dependence on monsoon and pumped water for cultivation is emerging very strong, which require strong interventions and management initiatives.

20.1.1.2 Horticulture

Kolkata generates roughly 3520 MT of garbage (solid waste) a day (Ali 2016), which is collected and dumped at designated sites (*Dhapa*) in the wetlands. The garbage-filled areas are extensively used to raise a variety of vegetables. The area surrounding *Dhapa* in peri-urban Kolkata is a center for vegetable cultivation. The area at present produces 15,000 MT vegetables per annum. Almost 15 varieties of vegetable are grown and sold in local and city markets, supporting small and marginal farmers and providing employment to thousands of poor people in the region. The production meets nearly 20% of the vegetable requirement of the Kolkata city. Of the total area under *Dhapa* (i.e., waste dump yard where vegetables are farmed), 55% area is used for double-cropping, while the rest is used for three crops in a year. The community practicing horticulture in these areas believes that the wastewater from the fishponds provides essential nutrients for the crops and ensures good harvest at the end. Availability of water, nutrient (from city garbage), and good urban market made horticulture as a household activity in the area. Farmers even rent small plots for raising vegetables. These plots are designed with alternate bands of garbage-filled lands and long trench-like ponds for cultivation. Water from the main sewage channels, secondary feeder channels, and freshwater wetlands are used to irrigate the vegetable plots.

20.1.1.3 Aquaculture

Sewage-fed fisheries are practiced mainly in the urban-facing areas of the wetland complex where huge quantity of sewage is ensured. The practice contributes 2% of the inland fish production and 65% of the total sewage-fed fisheries production of the state. Fish from the EKW meets a large share of demand of freshwater fish in Kolkata and adjacent areas. Apart from aquaculture, a large number of people are engaged in supply chain activities like transport, retailing, and processing. About 264 functional (sewage-fed) fishponds, occupying an area of 2858.65 ha, are major means of fish production (CRG 1997). Of this, private-owned *bheries* account for 93%, and farms managed by cooperatives 6%. Ponds managed by the state government are less than 1%. However, despite such a promising future, the effective area under aquaculture is declining rapidly. The major conversion was during 1992–2003 when a considerable part (6117.92–5852.14 ha) of water bodies was filled for agriculture and settlements. At present, the total area under the aquaculture practice is about 12,500 ha only (EKWMA and WI 2010).

20.1.1.4 Animal Husbandry

The EKW with fertile land and swamps supports animal life significantly. The inhabitants of the region have cashed in on the opportunity and set up piggeries, goat farms, duck, and ornamental fish rearing along with food fish cultivation. Such activities require low investment on equipment and infrastructure, and the products have good demand in urban market. Products like pork and ornamental fishes are also exported.

20.1.1.5 Water Supply

The EKW predominantly serves as a source of water for agriculture, horticulture, aquaculture and livestock, and for the use of communities residing within the wetland complex. Water use within the wetland is predominantly governed by the needs of aquaculture, agriculture, and horticulture. There exist no guided water allocation practices in EKW. The outflow from the wetland complex depends on the inflow to the wetlands, which is largely governed by the sewage generated from the Kolkata Municipal Corporation (KMC). An assessment carried by *Jalabhumi Bachao* Committee indicates that on an average 230 MLD with significant reduction during the monsoon is allocated for the agriculture. Ghosh (2005) indicates the overall sewage use by agriculture to be 400 MLD. No assessments are available on the uptake of effluents by the fish farms. The overall demand for the fisheries was estimated at 420 MLD (WISA 2008). Allocation of water supply is done by opening and closing the sluice gates. The operation is principally governed based on mutual consent on demands by farmers and aquaculturists for their respective activities.

20.1.1.6 Rag Picking

The *Dhapa* in EKW was initially conceived as garbage-dumping ground. Eventually, it has emerged as a concentrated one-point hold for huge rags of the city as well. Currently the city generates around 3063 MT of solid waste per day of which 563 MT is industrial waste and 2500 MT of garbage. Ragpickers scout these wastes for objects that can be re-recycled. Mostly these pickers represent major unregistered slums of Kolkata (Kundu 2003). Many areas in Kolkata lack public sanitation services, and ragpickers are the only means of solid waste disposal. A large part of the poorest section of the society depends on ragpicking for their livelihood. They collect about 10% of the total solid waste generated by the city, thereby reducing the enormous burden of waste management on the municipal corporation.

20.1.1.7 Flood Control

The EKW acts as a natural depression between the Kolkata city and Kulti estuary. These depressions have enormous water-holding capacity. Under the natural settings, water-holding capacity enabled the wetlands to regulate the flow regimes and attenuate floods by storing peak monsoon flows as well as tidal flows. However, the landscape of the city has changed or specifically deviated due to the alteration in the natural drainage system for the need of urbanization resulting in frequent flooding. This happens due to the failure of planning process to consider the natural incline-based drainage patterns that formerly existed in the city (WWF 2011, 2013).

20.1.1.8 Hooghly River as the Oldest Navigational Gateway to the Ocean

Historically the entire eastern fringe falls within the water route for transportation of goods through the Hooghly River. Hooghly, a distributary of River Ganges, forms the western boundary of the city and provides filtered water to the city. It is also used as the navigation channel to the ocean. Initially the river and its vast wetland complex were the pathway to the ocean for unimpaired shipment of goods. Thus, it can be said as one of the major services provided by the river and its associated wetland complex during the British era. At present, the river is connected with the EKW via sewage channels only.

20.1.1.9 Sewage Channels

Hydrological regimes within the Kolkata and its sub-basins are through drainage and sewage channels, which connect both the urban and peri-urban Kolkata on the bank of Hooghly to the outfall systems of Kulti. Spread across 545 km^2, the basin flows are ultimately discharged to the two rivers Hooghly and Kulti through 1421 km long drainage system and interconnected network of drains and channels (Fig. 20.3). Four such channels are supporting the whole mechanism, which are briefly mentioned in the subsequent subsections.

20.1.1.9.1 The Dry Weather Flow (DWF) and Storm Weather Flow (SWF)

The Dry Weather Flow (DWF) and storm weather flow (SWF) are the most important channels in the East Kolkata Wetland Recycling Region (EKWRG). These

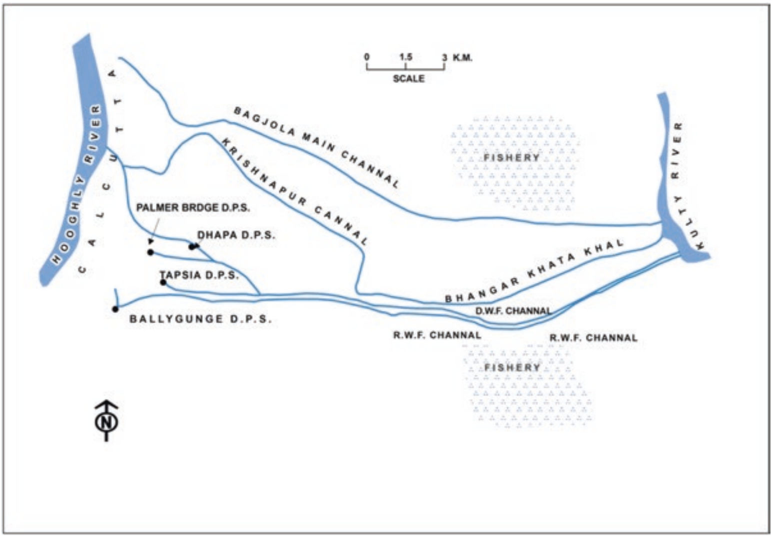

Fig. 20.3 Channel system in Kolkata city and East Kolkata Wetland (Source: CEMPD 2013)

channels ultimately debouch into the Kulti River about 30 km east from the Kolkata city. About 75% of Kolkata's wastewater passes through the SWF/DWF system. There are several points where the channels have interconnecting sluice gates. Currently large amount of Kolkata's DWF is channeled through the SWF.

20.1.1.9.2 The Baghbazar System

The Baghbazar System originates at the Chitpur lock in the Hooghly River about 2 km inland, splitting into circular canal (Beliaghata canal) and Krishnapur canal. The circular canal receives wastewater from unsewered areas of Beliaghata/ Manicktala basin and then moves south and eastward for about 12 km to meet the Krishnapur canal. The Krishnapur canal takes a northerly course around Salt Lake City reconnecting with the circular canal at first and then joining the Choreswar Khal resulting in the formation of the Bhangor Kata Khal. This canal continues eastward parallel to the DWF and SWF and empties into the Kulti River, just north of the Ghusighata outfall.

20.1.1.9.3 The Tolly's Nula/Nullah

Tolly's *Nullah* constructed in the 1770s was used for navigation between the Hooghly River and parts of Kolkata's immediate hinterland to the east. The canal originates in the Hooghly River just south of Vidyasagar *Setu* and follows the bed of Adi Ganga, an old distributary of the Ganga River. The main canal goes eastward for about 20 km where it meets the dead Bidyadhari River at Samukpota. Although Tolly's *Nullah* was originally meant for navigation, negligence and lack of proper maintenance have made the canal impassable. The current function of the canal is to drain Chowbaga basin and some of the Suburban basins in Kolkata. Since Tolly's Nullah was not planned to serve as a drainage canal, there are no treatment facilities yet in place to handle the wastewater leading to direct release of untreated wastewater into the Hooghly River.

20.1.1.10 Disposal of City Sewage

The city of Kolkata, situated in a deltaic plain, follows a general elevation from west (Hooghly River) to east (salt lakes and EKW). This topology allowed the drainage committee formed in 1857 to divert the whole city sewage into the wetland instead of the Hooghly River. At present, the drainage system of Kolkata falls under two main systems, they being the town and suburban systems. The town system covers the major part of the city, while the suburban system covers the newly expanded city at Beniapukur, Tiljala, and Beliaghata. The two systems meet at Topsia and ultimately fall in the Bidyadhari River.

20.1.1.11 Treatment of Sewage Through Fisheries

The EKW plays a vital role in sewage management. Management of sewage and garbage has adopted the principle of resource recovery. The wetlands act as "sink" for sewage and waste material from Kolkata that lacks any substitutable sewage treatment facility for its 4.5 million residents (Census of India 2011). About 3500 t of municipal waste and 68 million liters of raw sewage drain into the wetland system on a daily basis. The schematic representation of pathway of sewerage use under different land use practices is presented in Fig. 20.4.

Sewage-fed fisheries, which utilize such large volumes of sewage generated by the city, started functioning as early as 1883. In 1940, about 4682.22 ha of wetland area produced 0.14 t of fish per ha utilizing the municipal sewage. The

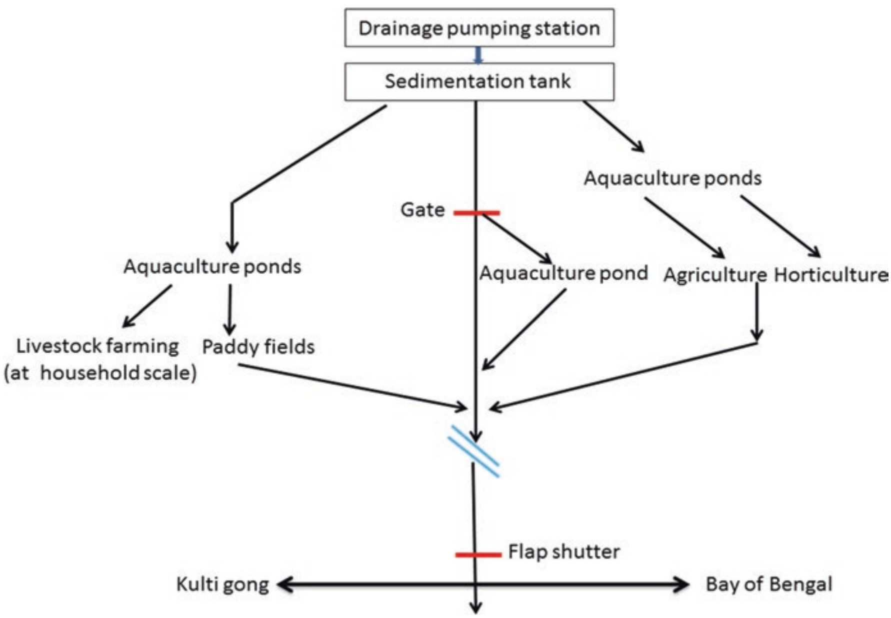

Fig. 20.4 Pathway of sewage being used for different purposes in EKW (Source: CEMPD 2013)

profit-generating potential of the wetlands in terms of aquaculture aroused interest in local farmers as well as local landlords who leased out most of the ponds to commercial managers. The conspicuous result was employment generation through production of fish and vegetables as well as a steady supply of food materials to the urban markets.

20.1.1.12 Disposal of Garbage

The city of Kolkata faces huge problem of disposal of garbage. A part of western region at EKW was acquired in 1864 for dumping the garbage with no concern for wetland conservation. Eventually with the indigenous farming practices, the land was converted into a horticulture ground. At the cost of marshy wetland, major cultivations like sewage-fed agriculture, garbage farming (i.e., growing crops on composted or decaying garbage), and sewage-fed aquaculture were developed. These farming systems eventually turned central to the livelihoods of many local poor people living in the surroundings (Bunting et al. 2001, 2002). The irrigation system for vegetable cultivation is fully dependent on the city sewage, currently producing about 150 tons of vegetables daily at the bargain of the solid waste. Noticeably no report or communication on the health hazard was known due to the practice, harvest, and consumption of the harvest. This makes this wetland globally one of the best examples of waste recycling model for adaptation and dissemination.

20.1.1.13 Nutrient and Pesticide Removal

The presence of *Actinobacteria* and *Firmicutes* indicates the prospect of nitrophenol, nitro-aromatic compound, and pesticide and herbicide degradation in the wetland as well as garbage-dumping ground that receives solid and liquid waste from the entire city (Chaudhuri and Thakur 2006). These microorganisms are also involved in decomposition and humus formation. These microbes are also involved in decomposition and humus formation. The *Proteobacteria* (gram-negative bacteria isolated during an investigation period of 12 months) present at the ECW indicates bioremediation of heavy metals from solid as well as liquid sources (Chaudhuri and Thakur 2006). They are involved in degradation and recycling of woody tissue of plants and biodegradation of oil-contaminated soil and toxic compounds. The presence of cyanobacteria specifies nitrogen fixation. The fact that only bacterial isolates were found does not mean that no Archaea or lower Eukarya are present. Compositional pattern of microbial population was seen to reach saturation on plotting the number of clones against the number of operational taxonomic units observed. Novel sequences falling within *Proteobacteria*, *Firmicutes*, and *Actinobacteria* indicate the probable presence of metal-accumulating (Klaus-Joerger et al. 2001), oil-degrading, antimicrobial compound-producing, as well as enzyme-producing bacteria (Georgalaki et al. 2002).

20.1.1.14 Heavy Metal Removal

Twenty bacterial isolates were found to grow in the presence of different concentrations of various heavy metals, *viz*., Al, Cu, Ni, Co, Fe, Cr, Pb, Ag, and Cd (Chaudhuri and Thakur 2006). The growth of the bacterial colony indicates that the EKW is home for useful bacteria, which effectively utilize heavy metals, helping in the immobilization from the sediment and water effectively.

20.1.1.15 Biodiversity

The wetland complex supports a wide range of both flora and fauna (Figs. 20.5 and 20.6) (IWMED 2004). Thirty species of phytoplankton were reported from the area. The vegetation comprises 55 species of aquatic macrophytes, 90 species of bank flora (including 41 species of herbs, 14 species of climbers), and 35 species of trees/shrubs (IWMED 2004). Moreover, in several parts of EKW, five species of fruit plants and ten species of ornamental plants are extensively cultivated by irrigating with sewage water (IWMED 2004). The wetland harbors 40 species of fishes (De et al. 1989), four species of amphibians (IWMED 2004), 19 species of reptiles (IWMED 2004), about 135 species of birds (Bhattacharya et al. 2008), and 16 species of mammals (IWMED 2004). Seventy-four species of butterflies (Chowdhury and Soren 2011), 10 species of benthos (Mallick 2009), and 17 species of zooplankton (Kundu et al. 2008) have also been recorded. The EKW supports rare mammals such as marsh mongoose (*Atilax paludinosus*), small Indian mongoose (*Herpestes auropunctatus*), Indian civet (*Viverra zibetha*), and the Indian mud turtle (*Lissemys punctata*) (WWF 2011). Bengal mongoose (*Herpestes palustris*) is an extinct mammal endemic to the EKWs (Mallick 2009).

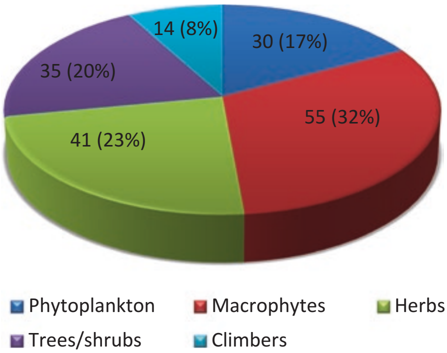

Fig. 20.5 Species (percentage in parenthesis) constituting the floral diversity of EKW

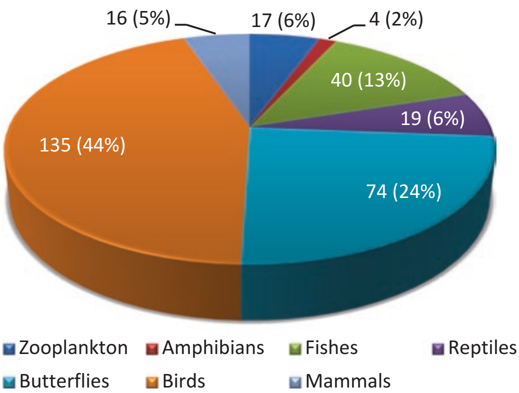

Fig. 20.6 Species (percentage in parenthesis) constituting faunal diversity of EKW

20.1.2 Valuation of East Kolkata Wetlands

The EKW compensate for an efficient, economical, and environment-friendly waste management and sewage treatment facility that the city of Kolkata lacks. The nutrients from the wastewater and human excreta enable the local villagers to practice wastewater-fed pisciculture and garbage-manured productive farming. Inhabitants of Kolkata get to enjoy the ecosystem services offered by the EKW without having to incur any cost. However, what makes the EKW stand out is the fact that it is a public good infringed with private ownerships. The flexibility of the lands, their use, and ownerships are facing major constraints due to the overarching Ramsar Convention and East Kolkata Wetlands (Conservation and Management) Act, 2006. Since a considerable portion of the land of the EKW is under private ownership, it imposes limited or no options to follow their own aspirations. The lands in EKW in fact are used by their owners for the purpose of facilitation of free public services to Kolkata citizens. This attests the principle of non-excludability as pertinent to both consumers and producers of the services. Traditional methodologies of public good pricing do not stand to be appropriate to resolve the predicament of evaluation of this unique public good.

20.1.2.1 Fisheries

Large areas of wetland are leased out to cooperatives and private proprietors for aquaculture. The leased wetlands usually range from 5 to 50 ha. Usually polyculture of eight different species (three species of carps, one species of minor carps, three species of exotic carps, and two species of cichlids) to table-size fishes is the main practice. Field surveys during 2003–2004 show 8500 people as directly engaged in sewage-fed fisheries. Of these about 90% are from local villages within the EKW, the others from adjoining areas of districts 24-Parganas (North) and 24-Parganas (South) and Midnapore, and sometimes from neighboring states of India. Culture practice provides opportunities for various types of skilled and unskilled labor including those engaged in security services, harvesting, loading, unloading, packing, and distribution of fish. Detailed economics of such aquaculture activities in eight representative wetlands are presented in Sects. 20.1.2.1.1, 20.1.2.1.2, 20.1.2.1.3, 20.1.2.1.4, and 20.1.2.1.5 below.

20.1.2.1.1 Inputs

Inputs can be either fixed or variable. Fixed inputs comprise land, initial investment in infrastructure (like huts, pipe channels, and embankment), and equipments (like boats, nets, bamboo, pumps) used in the operation. However, if the land is being leased out or under shareholding, the land costs become variable. There also exist maintenance costs and depreciation expenses on infrastructure and equipments. The variable costs include wages, fish fry-yearlings and fingerlings, pesticides, fish feed, fuel, and taxes.

20.1.2.1.2 Fixed Costs

Land costs are around INR 150,000 ha^{-1}. Land that is rented incurs a yearly variable cost of INR 3000 to INR 10,000 ha^{-1}. The variation in rent is driven by the harvest from the systems. In a shareholding system, between 25 and 50% of the profit goes to the owner, while in the large-sized wetlands' major portion, about 40% went to the owners.

Initial investment to set up aquaculture pond under the production process is difficult to estimate since the pond would have an existing structure left from the previous cycle. The amount usually varies between INR 100,000 and 500,000 for the initial setup of a pond of around 16 ha. These and other fixed costs for setting up the aquaculture operation in 16 ha of pond are presented in Table 20.1.

20.1.2.1.3 Variable Costs

Labor wages account for the major share of variable costs. There are 2.88 workers/ha on average in an aquaculture pond. Thus, 16 ha would have 46 workers, employed as harvesters, guards, carriers, managers, and skilled or unskilled labor. About 25% workers are considered permanent. Depending upon their skill, they get INR 500–1200 per month as well as other benefits such as lodging and medical treatments. It is stipulated that each temporary worker does only one kind of work and gets at least 6 months' work in a year and receives per day INR 166–400 and other benefits such as 250 g of food. Estimations of variable costs for 1993–1994 from eight sample ponds are given in Table 20.2. The data presented is compiled from the balance sheet maintained by an aquaculturist.

20.1.2.1.4 Scale Factor

Economics of scale are the cost advantages that enterprises obtain due to size, output, or scale of operation. The cost per unit output generally decreases with increasing scale as fixed costs are spread out over more units of output. The cost of taxes, pond preparation, weeds clearance, earthwork, and materials such as ropes and nails are scale dependent and increase proportionately with size. However, there are yearly variations in some of these components. On the other hand, certain items, although scale dependent, are used more at an increasing or decreasing rate as the scale increases. Boats are hardly required for very small setups, while their use increases proportionately with size. When the size of aquaculture pond goes above

Table 20.1 Fixed cost for setting up an aquaculture operation

Equipment	Price (INR)	Quantity (No.)	Total (INR)
Hut	2250	8	18,000
Net	5500	4	22,000
Boat	13,500	2	27,000
Bamboo	20,000	1	20,000
Diesel pump	8700	1	8700
Total			95,700

Source: Mukherjee (1996)

Table 20.2 Variable cost (INR) for aquaculture pond preparation and operation per annum

Size (area in ha)	4.8	8	16	24	40	48	80	96
Land lease, share of rent	24,000	25,000	37,000	60,000	598,097[a]	756,740[a]	350,000	250,000
Pond preparation, weed clearance, earth work	5000	10,000	1500	18,000	50,265	45,225	93,570	110,635
Pipelines, sewage distribution, water drainage	2000	2000	8000	10,000	26,623	26,520	43,720	45,792
Repair of office, boats, and purchase of ropes, pesticides	6990	14,175	31,000	17,500	49,918	51,005	82,007	108,055
Repair of nets	3000	4000	4000	6000	10,318	12,320	15,635	17,375
Bamboo	3250	5000	11,000	12500	29,440	25,440	54,500	66,400
Spawn, fry purchase	15,000	50,300	60,000	102,619	207,660	227,620	453,430	499,518
Supplementary feed	10,000	15,000	30,000	50,000	60,000	70,530	100,550	130,700
Energy	1950	3500	9000	18,000	35,000	49,142	91,902	100,750
Taxes	930	1550	Na	2000	6000	8130	15,000	16,450
Puja donations	4000	6500	5000	5000	6136	7985	9000	9370
Travel	Na	500	Na	Na	2000	2220	3000	3630
Wages	101,570	180,350	376,000	484,800	865,148	732,012	1,315,234	1,533,280
Total	177,690	317,875	607,500	786,419	1,348,508 (1,946,605)	1,258,149 (2,014,889)	2,627,548	2,896,925

Source: Mukherjee (1996)
All the variables are expressed in INR, if not mentioned otherwise
[a]40% share

32 ha, the number of boats required increases disproportionately. Per unit managerial and guard costs increase with scale, while the cost of skilled and unskilled permanent employees decreases with scale. Donations (in cash) for rituals are a common phenomenon being claimed from all the stakeholders and community residing near EKW. However, such charges paid on this particular ground do not increase much with size of the *bheries* in fish culture operation. Unit expenditure in energy increases with scale (Table 20.2). Apart from the scale factor, several other causal factors affect the costs. A narrative table (drawn from personal interview with an aquaculturist) on effect of causal factors on the variable cost affecting the overall operation of aquaculture is presented in Table 20.3.

In the present context, the cost was not inversely proportional to size**.** It simply indicates that the optimal size would be large. From the above table (Table 20.4), we can see that the total cost/ha does not move smoothly with size, but it is highest at 08 ha of *bhery* and lowest at 48 ha (Table 20.4). Considering the costs/ha, it is evident that both reduced unit costs and increased productivity are responsible for higher (per unit) profit. As profits per unit area are highest and labor costs per unit lowest for the 08 ha pond, this would be the ideal size for profitable aquaculture operation. With respect to maximizing employment, the 8 and 16 ha *bheries* appeared to be the most useful. It would also be better to have bigger fisheries held either on a partnership basis or by cooperatives.

20.1.2.1.5 Net Returns from the Aquaculture

Comparison of the returns to an owner under two different scenarios (i.e., if he/she sells fishery or kept the culture for longer period running it) is given below. Given that the fisheries cannot be sold for more than INR 15,000 ha^{-1} (on an average), long-term corporate interest would yield INR 3000 year^{-1}. Now running the fishery would yield a lease value on an average of around INR 650/year. Thus it is necessary for profit ha^{-1} to be more than INR 23,500/year to make the first scenario a preferred choice.

The profit figures are higher for all *bheries* that are >8 ha, and that would give the owner of bigger *bheries* a smaller incentive to sell. However, it also implies that for

Table 20.3 Effects of other causal factors on variable costs

Causal factor	Increases	Decreases
Supply of sewage to fisheries	Lease rate, productivity, output, cost of spawn, labor, boats, nets, materials, revenue	Expenditure on pipelines, fish feed, and fuel
Poaching	Expenditure on guards, guard huts	
Office/store structure	Repairing cost of mud structures, initial investment of brick and mortal buildings	
Nursery breeding		Spawn or fry purchases
Small *bheries*	Laborers per unit area	Bargaining strength
Large *bheries*		Per unit cost on labor and sewage

Table 20.4 Cost, productivity, revenue, and profit by size for sample fisheries

Size of pond (ha)	4.8	8	16	24	40	48	80	96
Cost (INR)/ha	59,230	63,580	60,750	52,430	53,940	41,930	52,550	48,280
Labor cost (INR)/ha	35,520	38,070	39,250	33,520	36,610	25,900	28,170	27,480
Labor cost (% of total)	57	57	62	62	64	58	50	53
Productivity (kg/ha)	4200	4800	5800	5500	6500	6000	5500	6000
Revenue	2200.50	4200	10,150	14,430.75	28,430.75	31,500	48,120.5	63,000
Profit	420.81	1050.13	4070.50	6570.33	14,950.24	18,910.85	21,840.95	34,030.08
Profit (INR) /ha	14,270	21,030	40,750	43,820	59,800	63,060	43,700	56,720

All the variables are expressed in INR, if not mentioned otherwise. Source: Mukherjee (1996) the owners of *bheries* <8 ha, it makes economic sense to sell them at the current price per ha. Thus, from the narrow perspective of personal net returns, the operation of these fisheries is not wholly justifiable, and that is why it is predicted that they will be wiped out unless production efficiency increases considerably, and the environmental and social benefits yielded by the fisheries are fully recognized.

20.1.2.2 Agriculture

The total agricultural area under the EKW is 4718.56 ha. Table 20.5 shows the variable costs incurred in cultivating paddy, the most widespread crop grown in the EKW. The profit depends on the size of the plot; the price of the output; the price of seed, tractor, and labor; the quality of the rice seed; the price of fertilizers and pesticides; and the use of sewage water. The profit ranges up to INR 17 kg^{-1} of rice with the average profit being INR 11. This high amount of profit earned attracts more farmers to shift to paddy cultivation in recent times.

20.1.2.3 Vegetable Cultivation

Vegetable production in the 1960s was estimated at 56,000 t $year^{-1}$. This particular practice in the EKW might have started due to the abundance of solid waste in the area. But at present, this sector is facing heavy market competition, reduction in solid waste accumulation, and climate uncertainties that largely affect the production. All land farmed by the participants is owned by the Kolkata Municipal Corporation (KMC). The farmers take the land on lease from either the KMC or an intermediary. Since lease is given for 1 year, farmers showed their unwillingness to take any kind of risk through investment in terms of both time and money for long-term benefit of the production system. This has resulted in poor quality of cultivation practices. The total area under productive farming in the EKW is 602.78 ha. The variable costs incurred in cabbage and cauliflower cultivation in the EKW are presented in Table 20.6. The cost of cultivation for cabbage is lower in large farms. The average yields of cabbage and cauliflower are 29 tons ha^{-1} and 15 tons ha^{-1}, respectively.

Table 20.5 Variable costs in paddy cultivation

Item	Price (INR ha^{-1})
Seed	26
Tractor	234
Main fertilizer	9.5
Supplementary fertilizer	6.5
Main pesticide	140.5
Supplementary pesticide	123
Labor	113
Total	652.5

Table 20.6 Variable costs in vegetable cultivation

	Price (INR/ha)	
Item	Cabbage	Cauliflower
Land preparation	1550	1450
Nursery/seedling	8110	7750
Irrigation	500	460
Manure + fertilizers	7250	7150
Plant protection	14,200	14,515
Hired human labor	13,330	1050
Land revenue and depreciation	640	560
Total cost	45,580	32,935

20.2 Issues Affecting the EKW

Changes in the land use within the EKW (Table 20.7), pressures from the metropolitan city as well as the growing human population are the major threats to this wetland complex. Despite their potential to provide multiple natural and social services, the wetlands are under various anthropogenic threats. As such, they need further study, effective maintenance, monitoring, and upgrading. An attempt to analyze the change through interpretation of Survey of India toposheets of 1959–1960 and remote sensing imageries 1989, 1999, and 2002 further indicates that the EKW are changing at a very fast rate. There has been also significant reduction in water spread area due to conversion for agriculture. Water being a critical factor in governing the ecological character and ecosystem services provided by the wetlands, such changes are required to be addressed immediately with appropriate interventions that enhance water spread areas.

Fragmentation of wetland habitats particularly by the dispersed human settlements within the east and southern parts of the wetlands associated with the higher elevation is an emerging potential threat of decreased siltation process (WISA 2008). Construction of the Eastern Metropolitan Bypass has made the EKW accessible, and Salt Lake City apparently provides additional social and economic infrastructures. Protection of the wetlands from developers and real estate agents is becoming increasingly difficult. The existing legal provisions and agencies have clearly been inefficient in preventing such encroachments. Constructions in the wetland areas can eventually hamper recharging of the groundwater and can increase the incidences of floods. Infrastructure development can cause fragmentation of EKW, which will increase social, ecological, and environmental imbalances in local areas. In addition, increased load of pollutants, siltation of ponds, poaching, unsustainable use of ground water, and loss of biodiversity are other major threats to EKW. An unprecedented problem in recent time is the presence of local *mafias* (goons) who are trying to control the fishponds. Moreover, as this is an urban area, there are more competing, conflicting interests and agencies than would be found in a village.

Table 20.7 Changing land use within EKW

Land use classes[a]	1986	1989	1992	1997	2003
Water bodies	6117.91	6117.67	6117.17	5943.82	5852.14
Agriculture	4469.28	4467.56	4470.15	4637.17	4718.56
Horticulture	593.79	594.12	593.23	597.86	602.78
Settlements	1319.02	1320.65	1319.45	1321.15	1326.52
Total	12,500	12,500	12,500	12,500	12,500

[a]All the values are in ha. Source: WISA (2008)

20.3 Opportunities

At present, the wetland complex is overarched by five national and three state regulatory legislations. Almost six authorities in the state are responsible for execution of the provisions and monitoring the wetland complex (Fig. 20.7) for compliance with the provisions. However, the policies and strategies lack integrated management approach. Planning approach often lacks coordination between different development and regulatory actions. Some of the major constraints on accessing the ecosystem goods and services from this wetland complex are:

1. Major gap in strategies to guide coordinated action linking the river basin with the coastal process.
2. Lack of involvement of marginalized communities.
3. Water allocation which do not consider ecological demands.
4. Ineffective institutional mechanism.
5. The economic evaluation of ecosystem goods and services had not been considered and incorporated in developmental plans and interventions by the EKW management authority.

Apart from this, there exist many other site-specific constraints and threats associated with aquaculture. Siltation of canal and fishponds had emerged as a rapidly growing problem to the wetland complex resulting in decline in fish production. Chemical contamination constitutes a widespread threat and poses difficulties in marketing fish and agricultural products adding on to the magnitude to the problem.

However, it can be concluded that sewage-fed fisheries and garbage farms not only provide inexpensive and dependable agri-/aquacultural food products but also help to maintain an eco-friendly environment. However, the prevailing pisciculture practice in the EKW is hardly viable in the sense that it does not function optimally due to multiple problems. Increasing siltation in the channels and fishponds has subsequently reduced the quantity of sewage flowing to the fisheries and rendered many of the fishponds shallower that, in turn, have reduced fish production. While environmentalists are putting in efforts for preservation of the EKW, undue profit-seeking investors are increasing pressure for the right to develop areas for

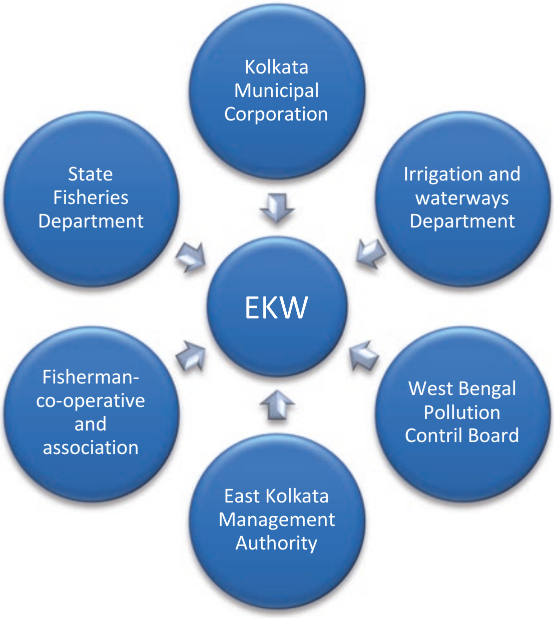

Fig. 20.7 Authorities in state government of West Bengal responsible for management of EKW

residential and other commercial purposes. The sewage-fed fisheries of the wetlands have been constrained due to inadequate management of water regimes, technology integration, weak marketing, post-marketing, and value addition opportunities. Management inefficiencies such as failure to operate sluice gates properly and to run the pumping systems, regulating the storm weather flow and the dry weather flow channels of the Kolkata drainage system in line with the requirements of farmers in East Kolkata, are gradually crushing the system. The current farm management systems are biased toward large private farmers and against the small- and medium-sized cooperatives. The existing aquaculture system needs to adopt upscale technologies to optimize fish production and related economies. The sewage-fed ponds should be dredged at regular intervals. There should be an efficient distribution system of sewage so that all the ponds in the EKW get adequate sewage to culture fishes.

The current institution, East Kolkata Management Authority (EKMA) under the chair of state chief secretary, had taken up these challenges. The said authority has initiated activities and intervention to mitigate the issues. The authority is already taking concerted efforts to implement the EKW (Conservation and Management) Act 2006. Various awareness generation activities were regularly taken up to make people aware of the values and functions of the wetland complex. Apart from this, desiltation of the clogged canal system had also been taken up under various projects. EKMA is also interested toward improving community livelihoods and quality of life with the help of several nongovernment organization and agencies.

However, despite serious problems to be tackled, the wetland complex still actively plays a vital role in managing the sewage from 4.5 million residents of the city of Kolkata. The management of 3,500 t of municipal waste and 68 million liters of raw sewage would not be possible, cost-effective, and sustainable without the integration of waste recycling-based EKW system in place. It has been estimated that an investment of INR 1.4 million would be required to build a conventional wastewater treatment facility to handle the sewage. It is to be emphasized that EKW has been providing a range of other ecosystem goods and services for decades. Hence, policymakers, planners, and stakeholders will have to make major policy decisions to determine how these wetlands will be used in the coming days in the face of growing threats.

20.4 Conclusion

The total area of EKW in the last 50 years has been reduced considerably and alarmingly. In another 25 years perhaps, these wetlands will become part of Kolkata's past despite the fact that these wetland complex accounts for numerous socioeconomic benefits such as employment generation, a moderately healthy rural society, secondary benefits to others (fish seller, net makers, boat makers), and the production of fish near the most important city of the net fish-importing state. Elimination of *bheries* would have grave consequences for the worker on one hand and the fish consumers on the other. It is difficult to imagine what would happen to Kolkata's flood, sewage, and garbage in the absence of this wetland complex. The failure in proper management of flood and sewage on the health and hazard cost cannot be measured by the market economy.

In spite of the importance of EKW in many ways, there has been shift in the land use within EKW. The area under fish farms has reduced from 7300 ha in 1945 to 5842 ha in 2003. Construction of fish farms bunds and roads within the fish farms have further reduced the effective area under water bodies to 2481 ha. The gradual reduction in water spread within the wetlands has reduced its capacity to recycle wastes and attenuate floods.

Decline in sewage and unregulated operation of the sewage canal has not only affected the productivity of agriculture and horticulture but also had grave impact on the people directly and indirectly depending on them. Management of hydrological regimes within EKW is biased toward flood management of Kolkata city without considering the flow requirements for the maintenance of ecological processes within the wetland system.

These had been also a rapid change in biodiversity associated with the wetlands due to changes in hydrological regimes and land use. The wetland, which in early twentieth century was teeming with large spectrum of brackish and freshwater fishes, now only supports cultivated freshwater fishes. The sewage-fed fisheries for which the wetland is known globally had been constrained due to the inadequate management of water regimes, technology integration, and value addition opportunities.

The current institutional arrangements are not effective in implementing the East Kolkata Wetlands (Conservation and Management) Act, 2006. The overall focus on patch management with mainly engineering measures and little awareness activity neglects the basic demand of interlinkages with hydrological processes and biodiversity. Involvement of multiple stakeholders with sectoral approaches limits adoption of a holistic management approach and strategy for the EKW.

Despite living within a highly resource-rich area, the communities living within EKW face higher levels of poverty. It is prudent to say that the wetland despite its multifaceted dynamism lacks integrated management approaches. Thus, for the sake of stakeholder welfare, the authorities in state government of West Bengal responsible for management of EKW should come up with an integrated management plan based on the principles of management zoning which will provide a basis for targeted interventions to achieve conservation and wise use of wetlands. The Ramsar framework for the wetland inventory assessment and monitoring, which is a multi-scalar approach, has already been adopted for sustainable management of EKW, but the interconnectivity in the management planning at different hierarchal levels needs to be ensured and maintained for the ecological and economic integrity of this wetland. Approaches with interdisciplinary, participatory, and integrated action planning process should be strictly followed in this wetland complex.

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