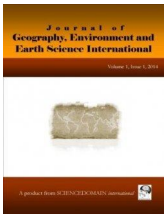

Journal of Geography, Environment and Earth Science International

16(4): 1-24, 2018; Article no.JGEESI.43229
ISSN: 2454-7352

Threats and Opportunities of Ecosystem Services: A Geographical Study of Purbasthali Oxbow Lake

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Authors' contributions

This work was carried out in collaboration with all three authors. The authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JGEESI/2018/43229
Editor(s):
(1) Anthony R. Lupo, Professor, Department of Soil, Environmental and Atmospheric Science, University of Missouri, Columbia, USA.
Reviewers:
(1) John C. Thomas, University of Michigan, USA.
(2) Moitree Taran, Tripura University, India.
Complete Peer review History: http://www.sciencedomain.org/review-history/25853

Original Research Article

Received 28th May 2018
Accepted 6th August 2018
Published 11th August 2018

ABSTRACT

Natural wetlands are most productive and most threatened ecosystems on the Earth's surface. They provide various ecosystem services beneficial for the local environment and economy. The Purbasthali Oxbow Lake, a palaeochannel of the Bhagirathi, is considered as the case for investigation. This paper attempts to examine the instrumental forces responsible for the deterioration of the ecosystem and the possible measures to be adopted for sustainable utilisation of the ecosystem services by using SWOT analysis. Reduction of surface area and increasing turbid zones has been identified by GIS environment. Ecosystem services like flood control, groundwater recharge, the habitat of biota along with the direct use of the oxbow lake by nearby people in eleven ways have been identified. Human intervention in forms of agricultural expansion, the establishment of brick kilns, illegal trapping and hunting of birds pose serious threats to the health of the lake ecosystem. Present Strength and Weakness and probable Opportunities and Threats associated with the ecosystem services have been identified and sustainable alternatives have been formulated for future development of the area. It can be concluded that despite the various threats posed by the human population, the wetland still has the potentialities to extend various future benefits to the nearby social groups.

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Keywords: Ecosystem services; palaeochannel; sustainable utilization; SWOT analysis; wetland.

1. INTRODUCTION

Wetlands are the transitional zones between terrestrial and aquatic ecosystems [1] where water plays prime role to shape the environment and the allied plant and animal life [2] and it has been estimated to cover from 5.3 million km^2 [3] to 12.8 million km^2 [4] on the Earth's surface. They offer several ecosystem services i.e. the natural assets [5] produced by the environment and utilized by the human society [6,7,8,9,10] and provide natural habitat for a number of unique communities of diverse flora and fauna such as birds, mammals, fish, amphibians, insects etc [11,12,13] especially to rare, endangered and threatened species [14,15]. Thus wetlands are often considered as 'Ecological Hotspot' [16,17] or 'Biological Supermarkets' [18,19] of the earth.

The wetlands, in spite of the high value of ecosystem services, have been degraded, reclaimed and filled in to support agriculture, urbanization, industrialization and other development works throughout the world [20,21]. As a result, almost half of the global wetlands have been lost in the last century [22,6] and many of the remaining wetlands are facing degradation due to anthropogenic interferences [23,24]. Notwithstanding various international agreements and national policies, area and status of wetlands continue to decline [25,26,27]. Till the early 1970s, wetlands have been remained unacknowledged, discarded and ignored as ecosystems [28]. For ages, its ecological services are often undervalued [25] and they have been viewed as valueless wastelands associated with disease, difficulty and danger [29]. It is also believed that wetlands may be reclaimed to fulfill various human needs. Development has eliminated coastal wetlands at a rate of 1% per year [30] whereas, inland wetlands are disappearing at a faster rate than coastal ones [31]. Protection and restoration of wetlands are essential for future sustainability as the wetlands could be an effective agent to mitigate global climate change and supply clean water and food to feed the increasing world population [1] Encroachment to wetland habitat, unsustainable harvesting of resources, industrial pollution, poisoning, agricultural runoff and siltation as well as introduction of invasive plants and weeds often put wetland biodiversity in danger [32,33,34].

Freshwater wetlands of India support almost 20% of her biological diversity [35]. West Bengal is endowed with very bio-diverse wetlands in India [36]. The wetlands of lower the Gangetic plain, including the present Purbasthali wetland, are facing serious threats of conversion, areal reduction and degradation in quality and quantity of water in consequence of development works [37]. A number of wetlands of the region are now under increasing anthropogenic stresses though they have been declared as wetland sanctuaries [38]. This work is an attempt to examine the types of ecosystem services granted by the Purbashali wetland and to probe into the ways the human interventions have become a serious threat to this aquatic ecosystem. The SWOT model has been adopted to test the significances of the mitigation strategies suitable for future development of this wetland and the human communities living around it.

2. MATERIALS AND METHODS

2.1 The Area under Study

The Purbasathali wetland (locally known as *Chupi Beel*), is situated in the moribund tract of the deltaic region [39] at the boundary between Nadia and Purba Barddhaman Districts of West Bengal ($23^0 25' 54''$N to 23^0 $27' 54''$ N and $88^0 19' 45''$ E to $88^0 21' 54''$ E) covering a total water area of 2.19 km^2 (2017). Morphologically, the 'inland wetland' is an abandoned channel (geographically termed as oxbow lake due to its crescent shape) of the River Bhagirathi on its right bank. This Gangetic Alluvial Plain wetland [40] is considered as 'Permanent Freshwater Lake' ('O' category) [41]. This 'open-type' lake is still connected with the River Bhagirathi at its southern portion through a narrow channel that allows free mixing of stagnant and flowing water. Thus the lake has acquired the characteristics of both lacustrine and riverine ecosystems [42].

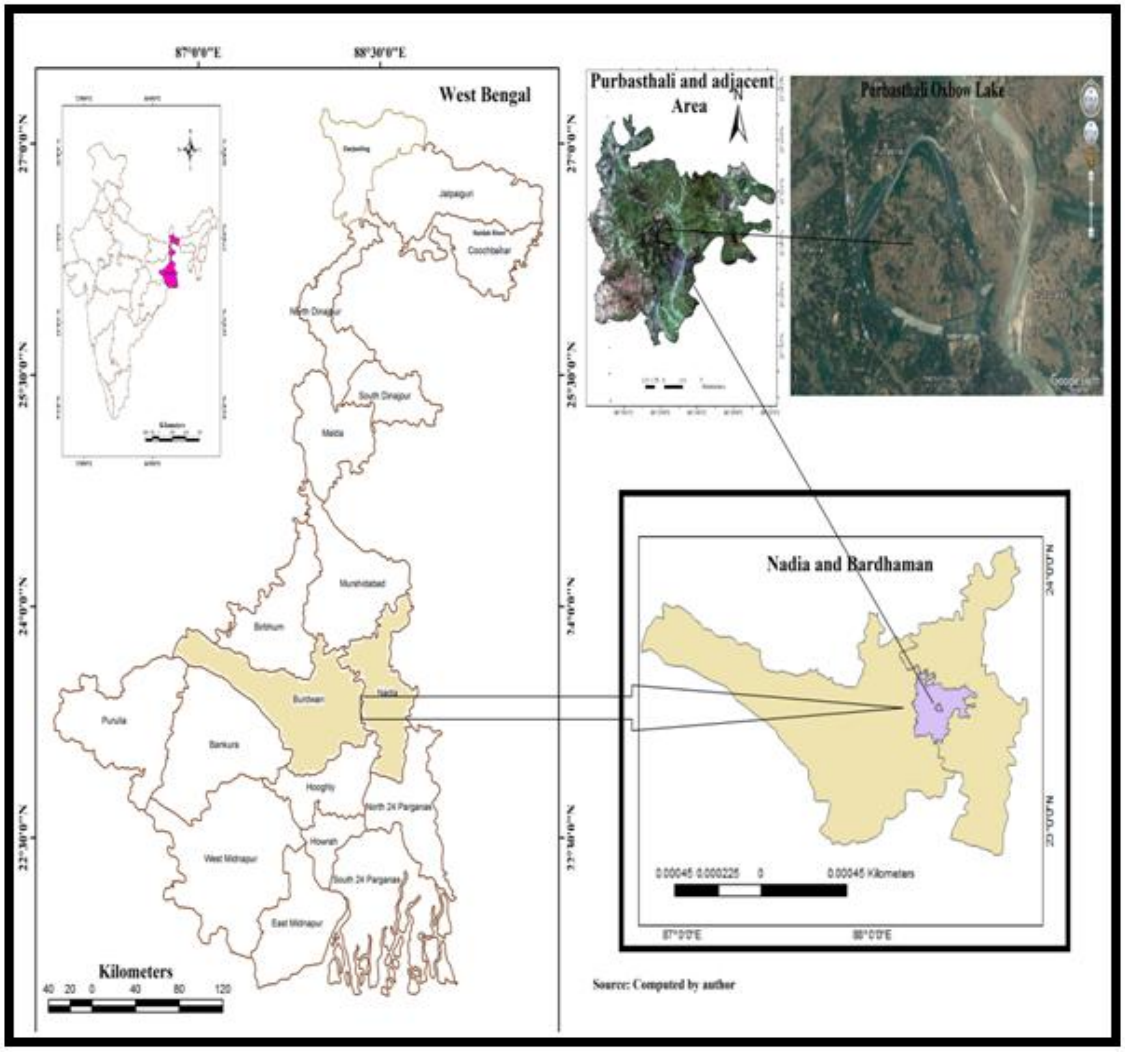
2.2 Methods and Techniques

Both Primary and Secondary data have been used to fulfill the objectives. A brief account of biota has been enlisted from the West Bengal

Biodiversity Board. In order to assess the health of the wetland and its impact on the biodiversity, special attention has been paid to the avifauna of the lake as bird's population is considered as a sensitive bioindicator of the health of both terrestrial and aquatic ecosystem [43,44,45,46, 47] and avifaunal density helps to understand the abundance of various species of other organisms [48]. Detailed information on avifaunal community regarding order, family, species and population (Year: 2013, 2014, 2016, 2017 and 2018) have been collected from The *Junglees*, a Non- Government Organization that has chronologically monitored and recorded the avifauna, especially the migratory birds over the years. The authors have actively participated in bird counting through Point Count method with the team of The *Junglees* in January 2017 and 2018. In addition, various journals and research articles have intensively been reviewed to justify the context of the study.

Relative Diversity Index (RDi) has been calculated to assess the species richness in accordance with the order and family of the birds using the formula [49]:

RDi = (Number of bird species in a family/Total number of species) × 100



Map 1. The study area

SOI toposheet No.79A (scale 1:250000) of 1927, 79A /6 (scale 1:50000) of 1968 and US Army Corps of Engineers' toposheet (NF45-2 series U502, scale 1:250000) of 1954 and Landsat 5-MSS (resolution 80m) of 1978, Landsat 5- MSS (resolution 70m) of 1980, Landsat 5- TM (resolution 30m) of 1989 and Landsat 5- TM (resolution 30m) of 1991 have been used to identify the shifting of Bhagirathi River and formation of the Purbasthali wetland during 1927 to 1991. In addition, Landsat 5- TM (30m resolution) of 1991, Landsat 5- TM (30m resolution) of 2000 and Landsat 7 OLI (30m resolution) of 2017 have been used to calculate the areal shrinkage and turbidity zones of the lake during 1991 to 2017.

Normalized Difference Turbidity Index (NDTI) [50] has been computed to show the temporal changes in turbidity with the help of the following formula:

NDTI = (Red band - Green band) / (Red band + Green band)

The result of NDTI has been classified as low (Mean – SD), Moderate (Mean + SD) and High (> Mean + SD) [51] turbidity zones along with their percentage value for analysing the variation of cloudiness of water.

A SWOT model, introduced by Albert Humphrey [52], is instrumental to visualize the strengths and weaknesses of a system as well as the future opportunities and threats [53,54,55]. The SWOT analysis has been done to identify the Strength, Weakness, Opportunities and Threats of the concerned ecosystem of the study unit. SWOT is an abbreviated form of its prime four components: strengths (S), weaknesses (W), opportunities (O) and threats (T) [56,57,58,59]. It is the sum of the internal (Strength and Weakness) and external factors (Opportunities and Threats) [60] for formulating alternative strategies, called strategic factors [61]. The strengths should be used to obtain the opportunities and restrict the harmful effects of future threats by understanding the weaknesses [62]. Hence, the approach proves beneficial for prompting worthy alternatives, useful in grouping key management issues [63].

On contrary, primary data have been acquired through field investigation and direct interaction with the stakeholders during September to February of 2016-17 and 2017-18 with a semi-structured questionnaire. Five adjacent villages namely *Indrakpur, Chupi, Kashthashali, Purbasthali* and *Ramchandrapur* have been surveyed and the respondents are chosen by Purposive Random Sampling Techniques (with 10 % sampling) in this context. The detailed identity of the selected villages with the encountered respondent numbers is given below (Table 1).

3. EVOLUTIONARY HISTORY OF THE PURBASTHALI OXBOW LAKE

The Lower Gangetic Plain in West Bengal is characterized with several natural freshwater wetlands due to the low gradient of the region, high discharge during monsoon and meandering nature of the River Bhagirathi [42]. Morphogenetically, the Purbasthali wetland is an oxbow lake of River Bhagirathi. The lake has been formed during 1989-1991 [64] as a consequence of the gradual shifting of the river course coupled with the simultaneous erosion-accretion processes. Historically, the alluvial channel of the River Bhagirathi in the lower Gangetic plain has reorganized its course for several times owing to various causes like an increase in volume of water and sediment load, tectonic movement, anthropogenic interferences etc. [65] and still it has not achieved a stable state. The River is most dynamic and oscillating in between Katwa (confluence point of River Ajoy) and Nabadwip (confluence point of River Jalangi) [39,66]. The construction of the Farakka Barrage has significantly increased the discharge that leads to regaining the energy of the Bhagirathi River that results into rapid bank erosion in the lower stretch of the river [67,68]. The changing volume of discharge has caused the creation of several unstable meander loops of the River [69,70,71], as four oxbow lakes have been shaped at an average time interval of 9-10 years after the post-Farakka phase [66].

The evolutionary history of the Purbasthali oxbow lake may be divided into four consecutive phases [37] (Table 2). During the stipulated period (1927-1991), the River has eroded primarily the left bank at an exponential rate along with infilling of sediments in the right bank that ultimately delinked the meander loop from the course of the River Bhagirathi and the wetland has formed in the right bank (Fig. 1). Thus a lotic ecosystem has been changed into a lentic ecosystem along with the transformation of a dynamic water mass into a static and stagnant water body [37].

4. THE ECOSYSTEM SERVICES OF THE WETLAND

Wetlands not only affect the hydraulics of the river connected to it but serve the economy and culture of the human society in various ways [42, 72]. Despite covering only 6% of the Earth's surface [73,74], wetlands provide 40% of global ecosystem services with universal importance [30]. 'Ecosystem services' incorporate the natural services and benefits of human society, derived from the ecosystems [75,76]. These can broadly be classified into provisioning, regulating, cultural and supporting services [77,78]. Several scholars have identified various ecosystem services of the wetlands that have resulted from multi-faceted physical-biological interactions [79] such as surface water detention, stream flow maintenance, nutrient transformation, coastal protection (from storm waves, erosion and cyclones), shoreline stabilization, regulation of local and global climate, climate change and stability, sustaining unique biota and biodiversity, regulating atmospheric gases, sediment control, water supply and water quality improvement, flood abatement, carbon sequestration, purification of environment, landscape virtues etc [80,81,82,83,84,85,86,87, 88,89,90,91,92,93]. Wetlands are thus logically termed as 'the Earth's kidneys' [15]. Wetlands play an important role in the global carbon cycle containing about 12% of the global carbon pool, [94,95,96] or 30% of all organic carbon storage [97].

4.1 Flood Mitigation

Freshwater wetlands like oxbow lakes are instrumental in combating flood events [98]. Wetlands are surface depressions that act like a sponge and retain the excess water during wet periods that reduce the frequency and magnitude of floods [78]. The Purbasthali Oxbow Lake traps the excess monsoonal water during rainy season in this part of the deltaic lowland area and reduces the chances of flooding. As a consequence, the average depth of this horseshoe-shaped wetland has increased from 8ft in winter to 12 ft in monsoon [42]. More than 75% respondents from five selected villages have opined that the frequency and magnitude of the floods in the area have been reduced after the formation of the lake (Fig. 2).

Table 1. Administrative Identity of the selected villages with sample size

Village	Geographical Co-ordinates	C.D. Block	District	No. of Households (2011)	Sample Size (10%)
Indrakpur	$23^0$27′04″N $88^0$20′43″E	Nabadwip	Nadia	464	47
Kashthashali	$23^0$27′45″ N $88^0$21′02″E	Purbasthali II	Purba Barddhaman	1032	104
Chupi	$23^0$28′11″ N $88^0$20′43″E			1596	160
Purbasthali	$23^0$27′26″ N $88^0$19′41″E			1040	104
Ramchandrapur	$23^0$25′52″ N $88^0$21′37″E	Purbasthali I		59	6

Table 2. Different Phases of Formation of Purbasthali Oxbow Lake, 1927-2017

Phase	Time Period	Features
Phase-I	1927-1968	Meander loop was almost stable (1927-1954). Bank line shifted eastward at an accelerated rate (1954-1968).
Phase-II	1968-1978	Direction of bank line migration changed to south-eastward. Northern neck was active.
Phase-III	1978-1989	Direction of bank line migration changed southward. Completion of oxbow shaped lake (1980-89). The distance between two necks has been decreased.
Phase-IV	1989-1991	Detachment occurred and the oxbow lake formed.

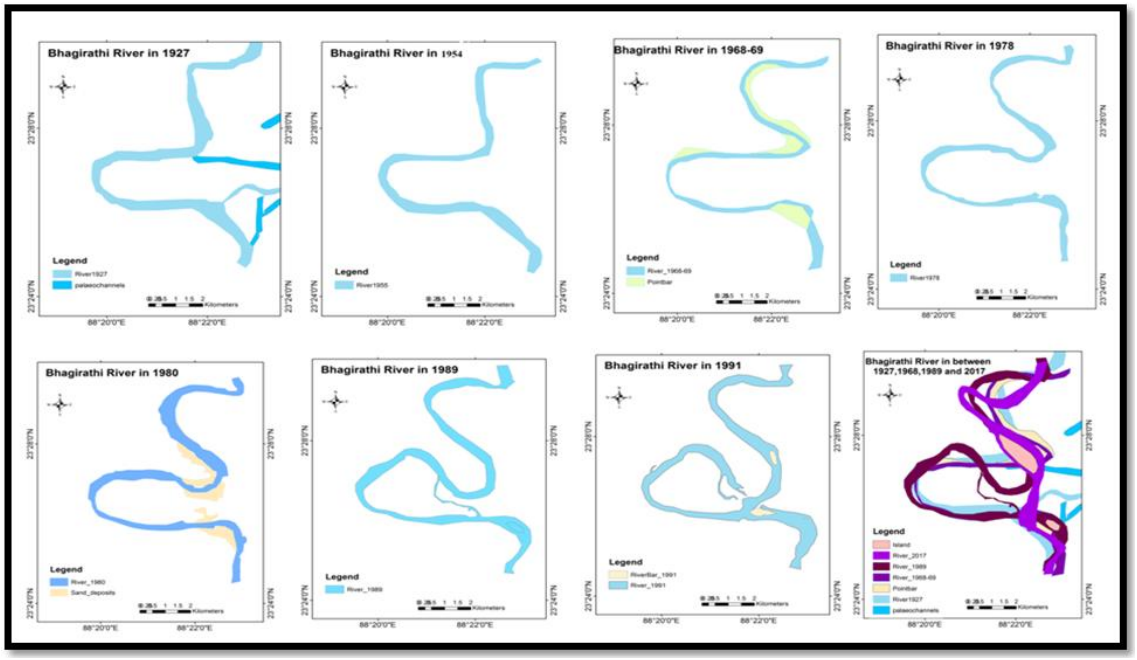


Fig. 1. Different Stages of Formation of Purbasthali Oxbow Lake, 1927-2017

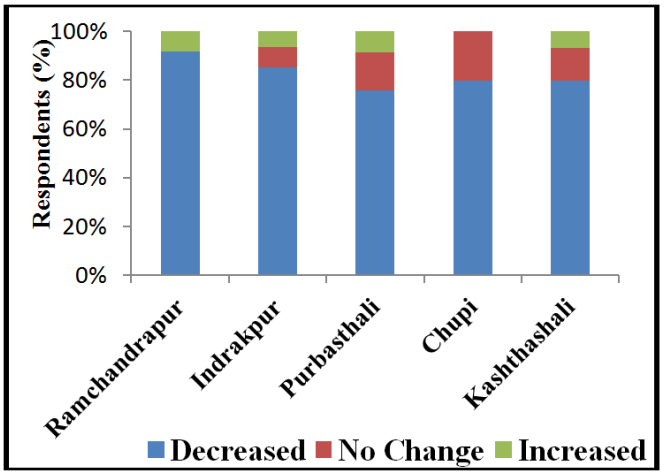


Fig. 2. People's perception of flood events

4.2 Role in Ground Water Recharge

It has been proved that wetlands have the capability of recharging ground water. During inundation of the floodplain wetlands, water moves downwards to the underlying aquifer to recharge the ground [99]. *Lohachar, Srirampur, Patuli, Samudragarh, Krishnanagar II* and *Nabadwip* located near the Bhagirathi show variability in depth of groundwater. Among the places, *Nabadwip* and *Krishnanagar II* show less fluctuation in ground water during monsoon, pre-monsoon and post-monsoon seasons (Fig. 3). It is evident that the Purbasthali Oxbow Lake at *Nabadwip* helps in ground water recharge throughout the year.

4.3 Habitat of Flora and Fauna

Oxbow lakes generally bear a favourable and supportive environment for the growth and sustenance of water and hygrophilous flora, a rich source of biomass that forms the base of the food pyramid of the ecosystem [100]. The connection with the river makes the environment of an oxbow lake suitable for growth of fauna

and flora [11,12]. Naturally, the Purbashtali oxbow lake also hosts diverse plant and animal species. Nearly 39 species of flora have been found in the lake and its adjoining areas. Among the floral species, 21 species have been found in bank areas i.e. the zone of human encroachment. Whereas, 9 species have grown in open water and another nine species live in the edge areas. Ganesan and Khan [42] have identified 14 different species of macrophytes and classified them into four categories i.e. free floating, rooted submerged, free submerged and emergent (Table 3). They have also highlighted that abundance of zooplankton species in the Purbasthali Lake is noticeably higher than other wetlands of this region due to the availability of various aquatic plants and relatively clean water.

The lake hosts for 129 species of fauna (Invertebrates 27 species and Vertebrates 102 species). The wetland harbours diverse species of Vertebrate fauna such as avian, amphibian and piscean. The common fish species are Common carp (*Cyprinus carpio),* Silver carp (*Hypopthalmicthys molitrix*), Grass carp (C*tenopharyngodon idella*), *Tilapia (Oreochromis mossambica), Catla* (*Catla catla*), *Chanda* (*Chanda ranga,*), *Magur* (*Clarius batrachus*), *Koi* (*Anabas testudineus*) etc. whereas, the common amphibian species found in the wetland are Green pond frog *(Rana hexadactyla),* Indian bullfrog *(Rana tigrina)* and South Indian bullfrog (*Rana crassa)* etc. [42]. The wetland provides natural habitat for resident as well as migratory birds of various species [101,102]. A total number of 74 avian species that belong to 18 families and 9 orders have been identified during the survey in January 2017 (Primary Survey, 2017). Among those avian species, 48.65 % are resident and 51.35% are migratory in nature. More than 60% (61.33%) of the birds live in the water edge areas, 26.67% in open water and only 10.67% have nested in the nearby large trees around the wetland. The common bird species are Lesser Whistling Duck (*Dendrocygna javanica*), Red Crested Pochard (*Netta rufina*), Little Grebe (*Tachybaptus ruficollis*) , Little Egrets (*Egretta garzetta*), Cattle Egret (*Bubulcus ibis*), Asian Open Billed Stork (*Anastomus oscitans*), White Breasted Water Hen (*Amaurornis phoenicurus*), Common Coot (*Fulica atra*), Indian Pond Heron (*Ardeola grayii*) and Night Heron (*Nycticorax nycticorax*) etc. Two vulnerable species and five near-threatened species, as per IUCN's Red Data Book, have been recorded during the survey. Common Pochard and Lesser Adjutant of Anseriformes Orders are two vulnerable bird species whereas Black Headed Ibis of Pelecaniformes Order, Ferruginous Pochard of Anseriformes Order, River Lapwing, Great stone Plover and River Tern of Charadriiformes Order are the near threatened species observed here during the survey.

The calculated Relative Diversity Index shows that the avian species richness is highest for the order Charadriiformes (33.33%) followed by Pelecaniformes (16.67%), Whereas, Anatidae (18.92%) is the most dominant avian family in the study area followed by Charadriidae (14.86%), Ardeidae (12.16%) and Scolopacidae (12.16%) (Table 4).

4.4 Socio-economic Services

Wetlands, along with its ecological services, provide important diverse socio-economic and cultural benefits and services to the human society around the world [103]. Several human communities, especially the rural communities across the world, profoundly depend on wetlands for their daily sustenance by harvesting a variety of natural products [104,105,106,107] and their lifestyle has often been changed with the alteration of the natural body [108]. It plays a vital role in socio-economic development of the people living nearby as a storehouse of resources like fish, shellfish, fodder, fuel wood, thatching materials etc. and a contributor of aesthetics and recreational value [109,110] and thus local people are most dependent on wetland for their sustenance [111,112]. The people dependent on wetland adjacent to five villages namely, *Purbasthali, Kashthashali, Chupi, Indrakpur* and *Ramchandrapur* have used the wetland to satisfy their socio-economic and spiritual needs. Nearly 84% of the respondent households use the lake water for worshipping, followed by irrigation (50.07%), bathing (52.43%), washing of cloths and utensils (43.98%) and cattle bathing (35.83%) (Fig. 4).

On contrary, nearly 35.57% of the households use the water for agriculture and 30.84% use it as a fishing pool. Besides, the lake water is used for cooking (34.41%), jute retting (22.20%) and collection of aquatic plants as fodder (23.07%). Nearly, 35.83% of the people have been engaged in the boat services as boats play a crucial role in transport and communication (especially for the villagers of *Indrakpur* as it is located at the centre and surrounded by water in all sides) and help tourist service in winter (the season of migratory birds).

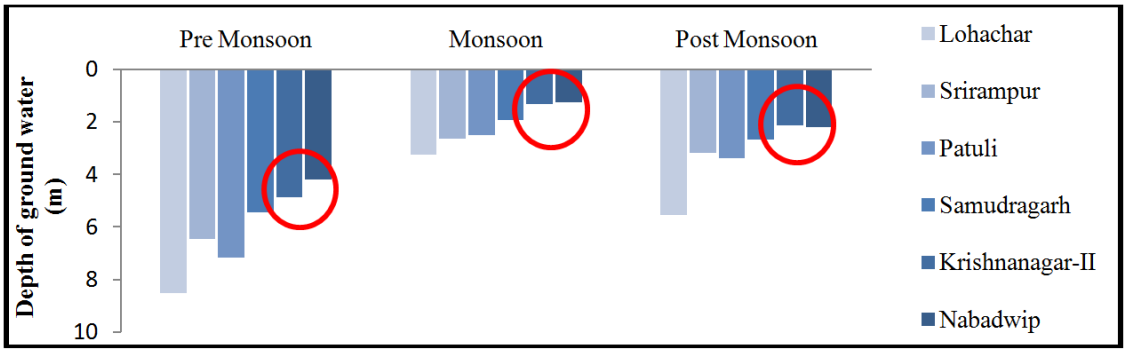


Fig. 3. Fluctuation of depth of ground in different seasons
Source: Mandal, 2017

Table 3. List of Macrophytic taxa recorded in Purbasthali Oxbow Lake

Categories	Family	Species
Free Floating	Aroidaea	*Pistia* sp
	Lemnaceae	*Lemna* sp
		Spirodella sp
	Onagraceae	*Trapa bispinosa*
	Pontederiaceae	*Eicchornia crassipes*
	Salviniaceae	*Azolla pinnata*
Rooted Submerged	Characeae	*Chara branchypus*
	Hydrochorideae	*Hydrilla verticillata*
		Vallisneria spiralis
	Naiadaceae	*Potamogeton crispus*
Free Submerged	Ceratophyllaceae	*Ceratophyllum demersum*
Emergent	Cyperaceae	*Scirpus articulates*
	Typhaceae	*Typha angustata*
	Convolvulaceae	*Ipomia aquatic*

Source: Ganesan and Khan, 2008

5. INTERRUPTIONS TO THE ECOSYSTEM SERVICES

The wetlands have been altered and degraded, both in quantity and quality by the interventions of human society throughout the world [113, 107]. Turner [114] has classified the main threats to wetlands into five categories (Fig. 5).

Brinson and Malvarez [115] and Zedler and Kercher [30] have classified the disturbances and alterations of wetlands as follows: (*a*) geomorphic and hydrologic (water diversions and dams, disconnection of floodplains from flood flows, filling, dirking, sedimentation and draining); (*b*) nutrients and contaminants (eutrophication, salinization, loading with toxic materials); (*c*) harvests, extinctions, and invasions (grazing, harvests of plants and animals, exotic species), and (*d*) climate change (global warming, increased storm intensity and frequency).

For the Purbasthali wetland, four types of interventions i.e. agricultural encroachment, pollution, brick kilns and hunting of birds have interrupted the wetland ecosystem.

5.1 Expansion of Agriculture: Shrinkage of the Area under Wetland

Agricultural expansion is the prime cause of reclamation of wetlands that results to areal loss. Agriculture is the prime source of livelihood in the region located in the alluvial tract characterized by fertile alluvial soil capable of producing huge amount of crops [38]. Drainage for agriculture is instrumental to wetland loss, and as of 1985, it was estimated that 26% of the global wetland area had been drained out for intensive agriculture [116].

Table 4. Family and Species Richness of Water Birds, 2017

Order	No. of Family	Rdi	Family	No. of species	Rdi
Podicipediformes	1	5.56	Podicipedidae	1	1.35
Pelecaniformes	3	16.67	Phalacrocoracidae	3	4.05
			Ardeidae	9	12.16
			Threskiornithidae	3	4.05
Ciconformes	1	5.56	Ciconidae	2	2.70
Anseriformes	1	5.56	Anatidae	14	18.92
Gruiformes	1	5.56	Rallidae	5	6.76
Charadriifofmes	6	33.33	Jacanidae	2	2.70
			Charadriidae	11	14.86
			Scolopacidae	9	12.16
			Rostratulidae	1	1.35
			Burhinidae	1	1.35
			Laridae	2	2.70
Passeriformes	2	11.11	Hirundinidae	1	1.35
			Motacillidae	3	4.05
Coraciiformes	1	5.56	Alcedinidae	4	5.41
Accipitriformes	2	11.11	Accipitridae	2	2.70
			Pandionidae	1	1.35
	18			74	

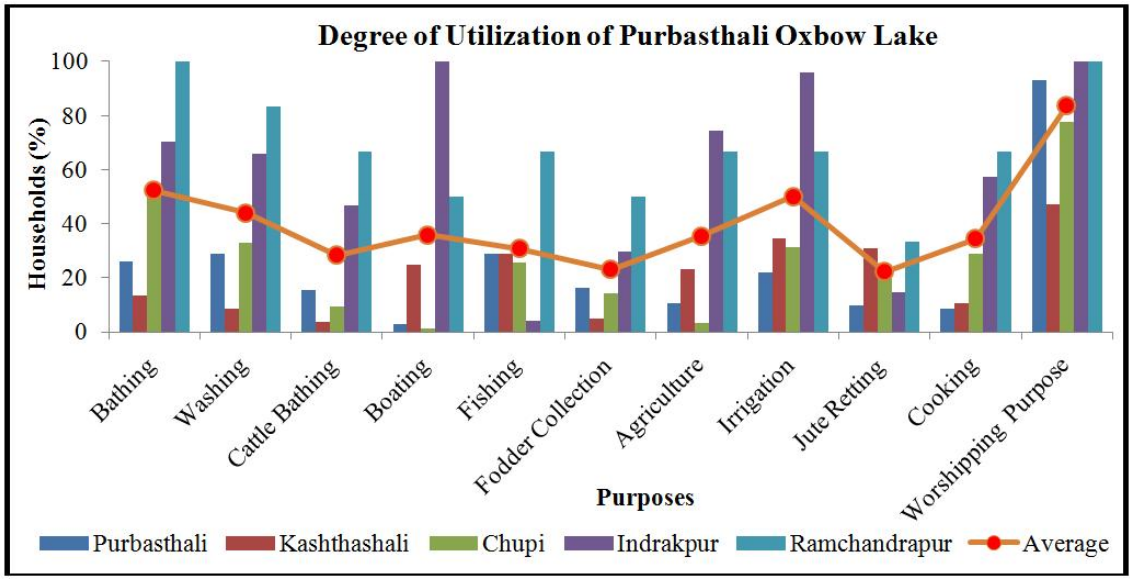


Fig. 4. Utilization of lake water in various purposes

In spite of favourable conditions and potentialities, neither large-scale fishing activities nor any other industries have been developed in the region and maximum share of the nearby population still are engaged in agricultural activity. The agricultural activities have been extended to the bank areas through reclamation and infilling. The bank area is often used as the seedbed, which has caused reduction in the water surface of the wetland. It has been observed that the open water area has been gradually shrank from 3.44 km^2 in 1991 to 2.19 km^2 in 2017 owing to the expansion of agricultural lands in the study area (Fig. 6).

Das et al. [28] have pointed out that not only by the siltation process, more often the in-filling of wetlands is intentional where there is a conflict in the land-use pattern for various kinds of

commercial development and recreation. Direct interaction with the stakeholders has revealed that the villagers of the *Indrakpur* desired to fill up the lake to extend the agricultural land. Whereas, the people of other four villages desired to keep the lake free. The adjacent people seek to find new fertile land for agriculture and they favour to convert the water area of the wetland into agricultural land. The infilling of the wetland for agricultural extension has accelerated the rate of siltation along with soil erosion, pollution, waste discharge and excessive algal growth that have increased the turbidity (cloudiness) of the water. The magnitude of turbidity has been increased with the increasing amount of total suspended solids in the water. The calculated Normalized Difference Turbidity Index (NDTI) clearly shows a continuous decrease of low turbidity areas (Table 5). On contrary, rise in moderate turbidity zone has attested the increasing rate of siltation that has reduced the depth, the water holding capacity and the navigability (in some parts) of the lake (Fig. 7). Water turbidity has affected the ecosystem as it is composed of inorganic and organic components with high concentrations of viruses, protozoa, and bacteria that have increased the possibility for waterborne diseases [51].

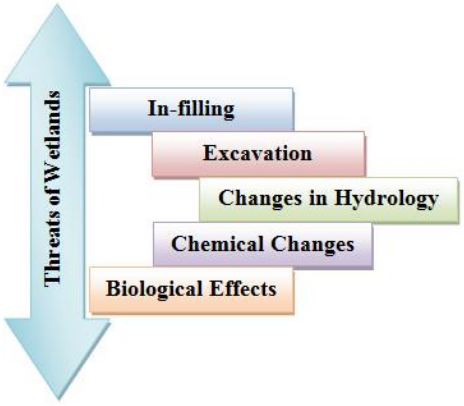


Fig. 5. Threats of wetlands after Turner, 1988

5.2 Pollution

Different types of land use along the bank of the oxbow lake have influenced the water uses as well as the water quality [117]. Wetlands are efficient in trapping pollutants and decomposing the wastes (Das et al. 2010). Recent years have witnessed a growing rate of environmental pollution caused by anthropogenic activities [100]. As wetlands are the sinks of nutrients and pollutants that accumulate in wetlands, these lead to the deterioration of the quality of water [118]. Ganesan and Khan [42] have found that the water is moderately polluted during the monsoon and pre-monsoon months caused by surface-run-offs and domestic wastes. Now, the ambient water, soil and water quality of the lake have been deteriorated by the various ongoing economic activities that pose threats to the sustainability of the lake and its resources.

Expansion of agriculture in bank areas with increasing use of chemical fertilizer and pesticides washed out from the adjacent cultivated land contaminates the water [29]. Thus, the increment of nutrient content in lake's water leads to eutrophication that often threatens the wetland with allowing aggressive growth of some plants and also has displaced some native species [30]. The excessive algal growth has reduced the navigability of some parts of the lake. The primary survey has revealed that 22.20% households of the surrounding villages use the water for jute retting that has caused further deterioration of the water quality [29]. Draining out of wastewater, disposal of household waste, tourist activities and multi-purpose uses of the lake have caused pollution of the lake water. The laboratory analysis of the twenty collected water sample from different points of the lake has recorded the average pH value of 8.9 (average), which is greater than the natural pH level (7.00) of neutral water. So the water is alkaline in nature (Primary Survey, 2018).

5.3 Development of Brick Kilns

Development of a number of brick kiln units has deteriorated the air, water and soil quality of the area in various ways. Being a booming industry with the immense potentiality of employment generation [119], the brick kiln units have adversely affected the physical environment as well as the health of the biotic communities of the lake including the nearby human being. It has posed immense disturbance to damage the eco-system [120], reduce soil fertility and productivity by extraction of top alluvial layer, reduction of atmospheric visibility, drying up of the groundwater sources and deterioration of land quality [121].

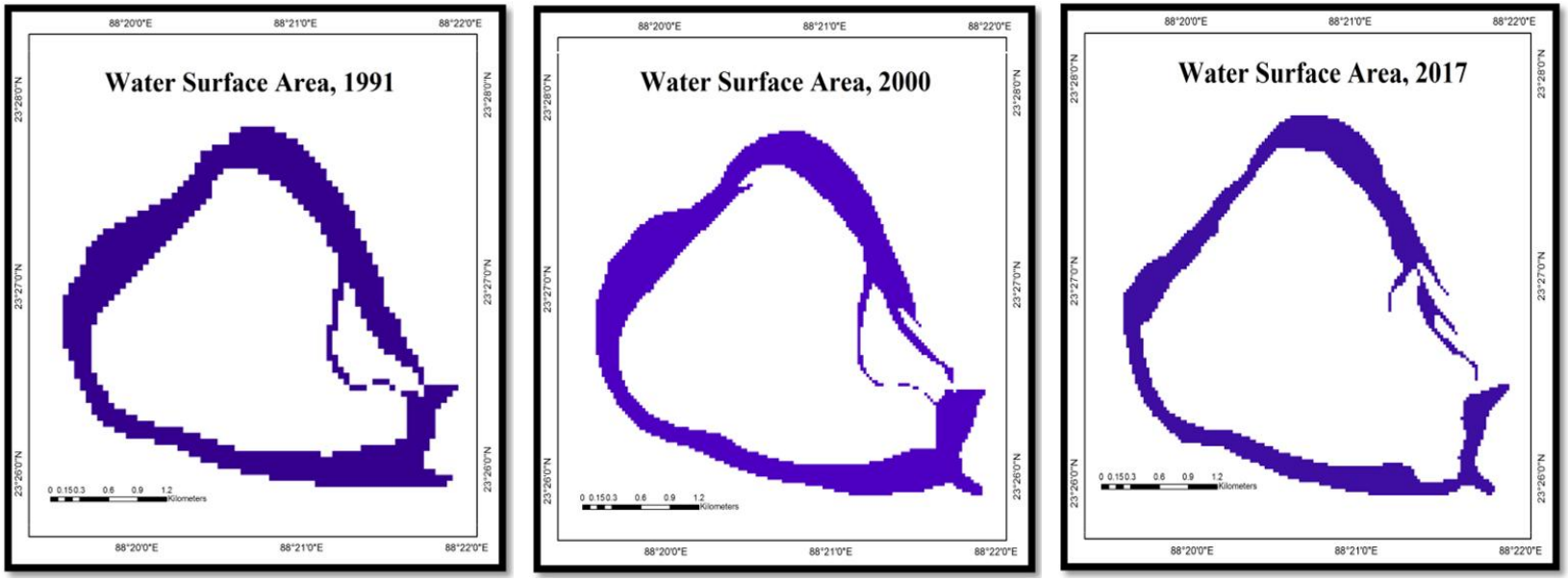


Fig. 6. Reduction in Areal of Purbasthali Oxbow Lake, 1991-2017

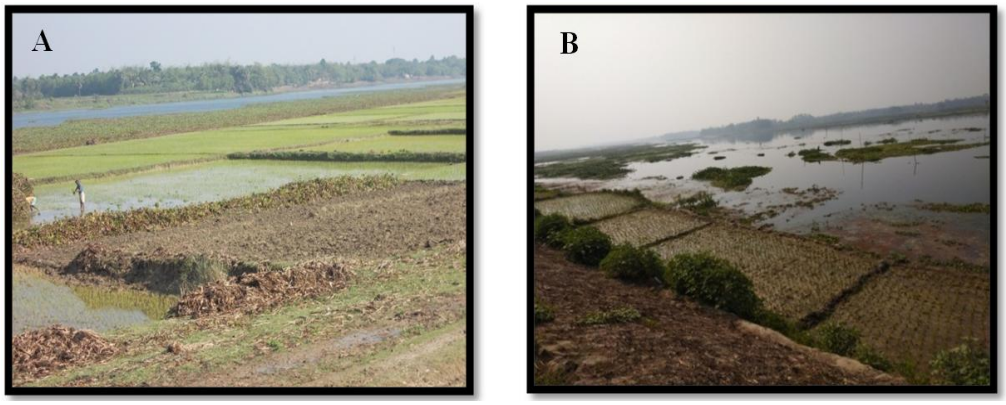


Plate 1. Agriculture on and around the bank
A. Agricultural expansion towards the lake; B. Use of bank area as seed bed

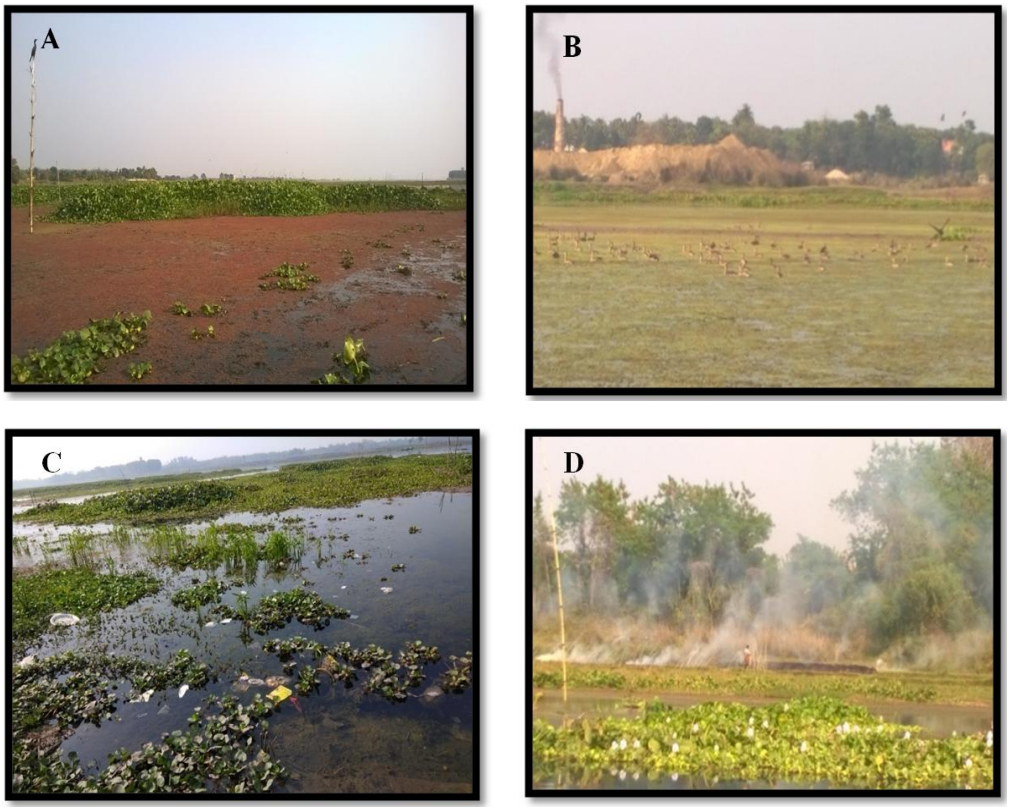


Plate 2. Different Types of Pollution and its Sources in and around the Lake
A. Eutrophication; B. Pollution from Brick Kiln; C. Disposal of waste in the lake
D. Burning of Waste at the bank: Deteriorate the air quality makes unhealthy for birds

Table 5. Variations in Turbidity Area, 1991-2017

Turbidity Zones	Area (%)		
	1991	2000	2017
Low Turbidity	14.51	4.17	3.96
Moderate Turbidity	68.56	80.71	78.71

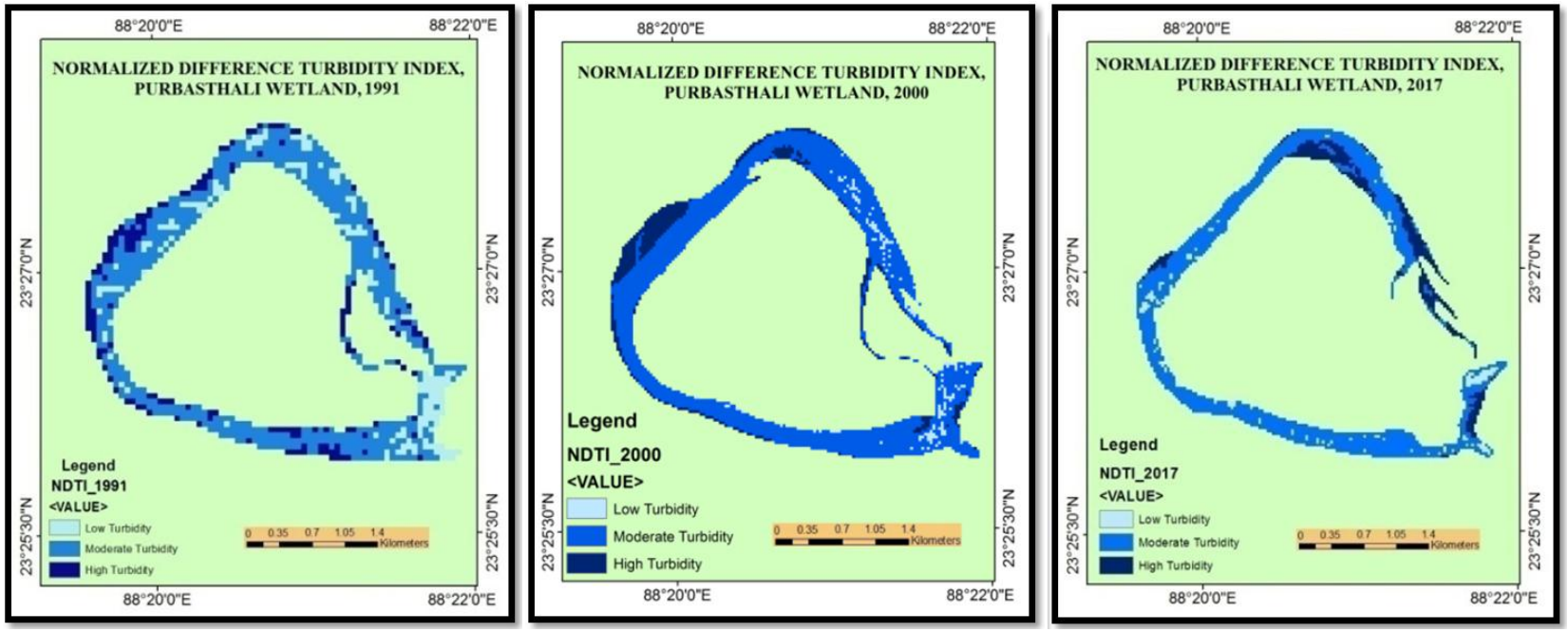


Fig. 7. Temporal Variations of Turbidity Zones

Brick fields are mostly established on the banks of the river and fertile agricultural land as it needs clayey, silty, and good textured loamy soil to make bricks [121]. The fertile alluvial tract of the Gangetic plain provides a favourable condition for the development of brickfields. Four brick kilns have been developed along the bank areas of the Purbasthali Oxbow Lake depending upon the thick alluvial deposits of the river Bhagirathi in the region (Fig. 8). Development of such brick kilns now exhibits an additional threat on the biodiversity of the oxbow lake. The establishment of such brick kilns has affected the physico-chemical parameters of the water of the lake effective upon the biotic resources. In addition, as brick kiln industries accelerate land erosion, increase temperature of the adjacent areas, produce high volume of flying ash, they have affected the agricultural productivity of the surrounding fertile tracts too [119].

5.4 Illegal Hunting and Trapping of Birds

Various studies have elaborated the affects of hunting and trapping of water birds [122,123, 124,125]. Flegg [126] has found that irrespective of the effect of changing natural factors, (like climate), changes in bird populations and their distribution has also been influenced by the impact of other than natural factors. Hunting can potentially influence the demographic parameters such as population size, age composition, sex-ratio, behaviour, distribution, movement and future reproduction of natural populations of birds [127,128,129,130,131]. Hunting of water birds have now become extensive throughout the Northern Hemisphere and may have a considerable impact on population and distribution of some species [122,132]. Hunting has exerted considerable pressure on wildlife that leads to population decline and thus it has become instrumental to biodiversity loss [133]. Hunting has become an important mortality factor for many migratory and resident bird species in Europe [134]. Numerous studies [135,136,137] have found that hunting and trapping of several bird species (such as Skylark, Lapwing, Curlew, Black tailed Godwit, Taiga Bean Goose, Garganey, Pintail, Snipe, Quail or Turtle Dove etc) has reduced their population to an alarming number in past few decades and has accelerated the decline of a number of species with hostile conservation status [134]. Benítez-López et al. [133] have estimated that birds' population has declined by more than 50% in hunted areas compared to the restricted areas across the tropics especially the areas of greater accessibility to urban areas. At present, illegal hunting of the migratory birds has become a live threat to the avian fauna of the lake. In absence of proper monitoring system of the migratory birds, hunting and trapping activities have been increased in past few years. Some of the local people have also been engaged in trapping of the birds for additional earnings. The impact of illegal hunting and trapping on the migratory bird species has been clearly witnessed in the area. But, due to the inadequacy of proper record, it is hard to quantify the magnitude of the loss of migratory birds by such activities. The issue has been highlighted in the local esteemed dailies [138] but has failed to gain proper attention of the authorities. Recently, the Forest Department of West Bengal has launched intense public awareness campaign in association with several Non-Government Organizations to protect the migratory birds from the greed of hunters [139].

6. IMPACT OF HUMAN INTERVENTION ON BIOTIC COMMUNITY

Worldwide loss and degradation of wetlands certainly have affected the birds' population [24]. Multipurpose use of the lake by local people has resulted in the degradation of the lacustrine ecosystem. Extension of agricultural activity in the transitional areas by clearing out the indigenous plants has affected the floral diversity as well as destroyed the natural habitat and the ecological niche of the avian fauna, especially of the waders. Flooding in each year augments the soil fertility of the transitional zones (the bank area) of the wetland. Thus human communities always look for the bank area for better agricultural practices. At the same time, the wader species prefer to live in bank areas and wade in this transitional zone of wetland in search of food. Thus the ecotone region of the lake has become a zone of conflict between the human society and the biotic communities of the lake ecosystem. The natural habitats of the avian species are being eliminated at an alarming rate globally due to extended human intervention [140,141,142]. Ganguly [101] has recorded a gradual decrease in the population of 14 migratory bird species in the Purbasthali Lake from 2004 to 2010.

Fig. 8. Location of the brick kilns near the Purbasthali wetland

Source: Google image, 03.04.2018

The abundance of 20 bird species has been grouped into two on the basis of their habitat. The data of 10 most common birds found in open water and another 10 most common birds found in water edge areas in the year 2013, 2014, 2016, 2017 and 2018 have been selected to examine the variability of the birds according to their habitat location. The CV for the birds found in water edge areas (157.64%) is much higher than the birds live in open water (51.68%) (Table 6) that indicates the regularity of diving birds as they have received lesser disturbances from a human being compared to the birds live in bank areas. The invasion of human activity in the bank areas has played a crucial role in the higher variability of wader birds. Decrease in biological diversity, especially decline in migratory bird population and the productivity of fish and other fauna, are some of the obvious results of degradation of wetland associated with deterioration of water quality, sedimentation, shrinkage of areas etc. [143,144,145,146]. Water birds are inseparable from wetlands [147] and the density and diversity of the water birds (both resident and migratory) depend on the physico-chemical condition of water of the wetland [148]. As the abundance of avian fauna indicates the healthy status of the system and habitat of wetland, high variability of wader birds indicates that the Purbasthali Lake is getting degraded.

It can be concluded that these interventions seriously damage the lake ecosystem whether they are visible or invisible. The comprehensive effects of degradation on biota are feebly known, but it is clear that biodiversity has been definitely affected [149,150]. The magnitude of decline has been increased when disturbances are more frequent and work in combination [30].

Table 6. Trends and pattern of 20 common water birds at Purbasthali wetland

SL. no	Name	Birds found at Open Water					Mean
		2013	2014	2016	2017	2018	
1	Lesser Whistling Duck	4500	1452	3550	2921	3740	3232.6
2	Ferrigenous Pochard	3000	60	8	12	12	618.4
3	Gadwal	270	360	300	538	488	391.2
4	Red-Crested Pochard	10	380	240	307	302	247.8
5	Northern Pintail	350	68	30	74	32	110.8
6	Little Grebes	150	62	118	73	130	106.6
7	Cotton Pygmy Goose	50	71	110	110	145	97.2
8	Ruddy Shelduck	14	331	5	10	120	96
9	Little Cormorent	50	79	80	114	59	76.4
10	Garganey	25	56	22	50	160	62.6
						Mean	503.96
						SD	975.18
						CV (%)	51.68
SL. no	**Name**	**Birds found in Water Edge**					**Mean**
		2013	**2014**	**2016**	**2017**	**2018**	
1	Pheasant Tailed Jacana	250	38	120	31	145	116.8
2	Purple Swamphen	250	72	55	77	94	109.6
3	Indian Pond Heron	120	2	75	75	103	75
4	Common Sandpiper	50	16	65	3	38	34.4
5	Great Egret	35	13	20	5	25	19.6
6	Little Egret	35	13	180	15	87	66
7	Intermediate Egret	8	71	180	16	31	61.2
8	Bronzed-winged Jacana	50	35	50	28	55	43.6
9	Moorhen	25	4	72	71	34	41.2
10	Night Heron	2	2	7	5	7	4.6
						Mean	57.2
						SD	36.29
						CV (%)	157.64

Source: The Junglees; Computed by the authors

7. PROSPECTS OF THE WETLAND SERVICES

Changes in the status, composition and functions of the existing wetlands will certainly bring some obvious changes in the availability of wetland-related resources and services that will definitely enhance the vulnerability of biotic communities (including human) dependent on wetlands [151,8].

SWOT analysis is elaborated in the present context to examine the strengths and weaknesses of the area based on wetland and future opportunities and threats which may arise. Emphasis on the existing strengths may make the wetland ecosystem able to combat future threats and better use of the opportunities. The Strengths (S), Weaknesses (W), Opportunities (O) and Threats (T) are derived from field survey through direct interction with the respondents in which they were asked to put tick mark on some options given in each category. Various options for each group of S,W,O and T have been generated. SWOT matrix (Table 5) have resulted four strategic alternatives with an aim that the positive aspects (S and O) needs to be maximised and negative aspects (W and T) be minimised.

The four alternatives are as follows (Table 7):

Alternative 1- Ecotourism based on migratory birds

Alternative 2- Use of the wetland as commercial fishing ground

Alternative 3- Optimum number of birds, protection measures will reduce the hunting

Alternative 4- Agricultural advancement (regular replacement of excess silt will profit bank cultivation).

Table 7. SOWT Matrix

Internal Factor / External Factors	Strength (S)	Weakness (W)
	S1-.Migratory Birds S2- Enriched biodiversity S3- Easily accessible S4-Pleasant Climatic Condition S5- Socio-political stability	W1-Inundation during monsoon. W2- Absence of Industry/Less Infrastructural development W3- Less Socio-economic development W4- Reclamation of wetland W4- Siltation
Opportunities O1- Ecotourism by means of bird sanctuary O2- fishing O3- Opportunity of Agricultural Advancement	**Mitigation strategy from SO matrix** **Alternative 1-** Ecotourism based on migratory birds	**Mitigation strategy from WO matrix** **Alternative 2-**The wetland can be used as commercial fishing ground
Threats T1- Negligence of Govt. T2- Improper use of water and Pollution from bird watchers T3- Hunting T4- Bank Cultivation	**Mitigation strategies from ST matrix** **Alternative 3-** Optimum number of birds, protection measures will reduce the hunting	**Mitigation strategy from WT matrix** **Alternative 4-** Agricultural advancement (regular replacement of excess silt will profit bank cultivation)

The 4th alternative can further damage the lake ecosystem as already agricultural activities in and around the wetland have become threats and more over this is defensive strategy as it is generated through combination of weakness and threats and thus needs to be avoided. Alternative 1 and 3 stand for conservation of the wetland in a sustainable manner. Already, this place has witnessed arrival of enormous bird watcher during winter. Conservation policy of the wetland ecosystem and ecotourism will certainly enrich the local economy. Ecotourism in the area may encourage the development of tourism industry and associated sectors. Mass awareness will lessen the trend of hunting of migratory birds in near future. One shortcoming of this approach is the seasonality. As the migratory birds come only in winter (November to February) there should be another strategy for the development. In that case integration of Alternative 1 and 2 will be best possible combination for solution. Commercial fishing during monsoon, pre-monsoon and post-monsoon along with bird watching will help the local economy. Proper conservation policy can make the region one of India's best birds' sanctuaries.

8. CONCLUSION

It is clear from the overall discussion that human intervention has affected the physical health as well as the biotic resources of the ecosystem of the Purbasthali Lake. It has often been misused that has deteriorated of the water quality as well as reduced its economic, ecological, cultural and recreational values. The oxbow lakes should be managed in such a scientific and systematic way that it may become the paradise of biodiversity, ground water recharge zone, enriched fishing ground, source of irrigation and a resource pool for mankind. Degradation of the wetland affects the economy and well-being of wetland-dependent communities of the nearby villages along with significant loss of biodiversity. SWOT analysis has identified the best possible alternatives for the development of the region based on ecotourism. Involvement of local people in this regard will keep wetland ecosystem living by reducing the degree of intervention. Nevertheless, the protection and restoration of the Purbasthali oxbow lake are essential for its future sustainability and the overall well-being of the nearby societies.

ACKNOWLEDGEMENT

Authors have gratefully acknowledged the help extended by Mr. Raja Chatterjee, Secretary of 'The *Junglees'* (NGO) during the field observation. Besides, the cooperation of the local stakeholders is highly appreciated.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
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