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Assessment of scope for fish biodiversity conservation in relation to environmental variables at Surajpur Lake, an urban wetland of the Upper Gangetic Plain, Northern India

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ABSTRACT

Surajpur Lake is a prominent wetland site in Upper Gangetic Plain in India known for its rich avifaunal and aquatic biodiversity. The present study was carried out to describe the fish diversity in relation to major hydrological and meteorological parameters in spatio-temporal scales from March 2010 to February 2013. Fish samples were collected together with water quality parameters from three sampling blocks of the Surajpur Lake along with three years of meteorological data. The data were analysed using PAST (version 2.15) software. One-way analysis of variance (ANOVA) was used to compare the data among the blocks and months. The relative abundance and composition of fishes were estimated by catch per unit effort (CPUE) independently for each site and month of sampling. Pearson Product Moment Correlation and Principal Component Analysis (PCA) were performed to check the relationship of fish abundance with environmental variables. During the study period, a total of 185 fishes belonging to 15 species and 10 families were recorded. The fish abundance for each sampling block sharply reduced from November to January and gradually increased from February to May, which suggests that fish fauna of the lake prefer pre-monsoon and post-monsoon period. On the basis of catching/sighting frequency, 7 species were categorised as rare, 2 frequent, 2 common, 3 occasional and one (the banded gaurami *Trichogaster fasciata*) highly abundant, suggesting less sightings of few species and frequent sightings of one species. The relative abundance of fishes in terms of CPUE was highest during the month of May. The Shannon diversity recorded 2.20 among individuals, 1.82 among species and CPUE, 1.57 in block C, 1.22 in block A and 1.05 in block B. The ANOVA indicated that there was no significant ($p>0.05$) difference in physico-chemical parameters of water quality among the different blocks and months, whereas meteorological parameters showed significant difference among the months. Correlation and PCA analysis illustrated that environmental variables *viz*., air temperature, rainfall, humidity, wind speed, water temperature, turbidity and phosphate showed positive relationship whereas pH, dissolved oxygen, total hardness, total alkalinity, chloride, nitrate and iron showed negative correlation with fish communities. Overall, our findings suggest that water temperature and rainfall are the main influential factors for fish species distribution in the Surajpur Lake. Results of the present study could be effectively used for proper management as well as for conservation of piscifauna and aquatic biodiversity of Surajpur wetland.

Keywords: Catch per unit effort, Environmental parameters, Fish diversity, Principal component analysis, Surajpur Lake

Introduction

In recent years, it has been realised that the fish and freshwaters are the most vulnerable resources in nature that have been heavily impacted by human usage and regulation (Sarkar *et al.,* 2015). The Gangetic Plain is one such important biogeographic zones having vast potential of aquatic bioresources and offers considerable scope for inland fisheries development and aquaculture, characterised by fine alluvium and clay-rich swamps, fertile soil and high water retention capacity (Manral *et al.,* 2013). The Gangetic Plains are scattered with several natural freshwater wetlands which support all life forms through extensive food webs and biodiversity (Mitsch and Gosselink, 1989). The landscape has the highest human density in India of 800-1200 people per km^2, which has resulted in a high level of anthropogenic impact on natural ecosystems. Urban wetlands such as these have been the lifeline of most cities of India and provide multiple values such as food and water security for suburban and city dwellers (Castelle *et al.,* 1994). Various anthropogenic activities *viz*., urbanisation, hydropower generation, mega developmental projects, agriculture and pollution directly or indirectly change the physical and chemical characteristics in the landscape. The Surajpur wetland is one such urban wetlands located in Upper Gangetic Plain biogeographic zone and provides us with an opportunity to conserve and preserve the native flora, fauna and biodiversity amidst a densely populated urban area.

Indian fish fauna represents about 8.9% of known fish species of the world comprising about 2500 species of which 930 are freshwater inhabitants and 1570 are marine species. Concretely, Jayaram (2012) listed a total of 852 freshwater fishes under 272 different genera, 71 families and 16 orders, including both primary and secondary freshwater fishes from India, Bangladesh, Myanmar, Nepal, Pakistan and Sri Lanka. Further Menon (1999) listed a total of 446 primary freshwater species (under 33 families and 11 orders) from the Indian region. Among Asian countries, India possesses the highest number of endemic freshwater finfish species (27.8%) followed by China, Indonesia and Myanmar. The Uttar Pradesh region alone reveals a total of 124 fish species contributing 14.11% to India's freshwater fish diversity (Sarkar *et al.,* 2015). Although, survey of fish fauna in the rivers of Uttar Pradesh have been made by several authors (Sarkar *et al.,* 2007, 2012, 2015; Nautiyal *et al.,* 2013), the number of studies of diversity and habitat characteristics in urban wetland are still scarce to address the conservation and sustainable management of fisheries. In this context, the present study was conducted to describe the fish diversity in the Surajpur wetland in relation to major hydrological and meteorological parameters in order to assist with implementing appropriate management policies and regulations hitherto unreported.

Materials and methods

The present study was carried out for a period of three years from March 2010 to February 2013 to explore the fish fauna of Surajpur Lake (28°31.425'N; 77°29.714'E) in relation to hydrological and meteorological parameters. The area is a reserve forest spread over 308 ha including 60 ha of natural perennial wetland (Bura *et al.,* 2013) (Fig. 1). The major source of water is the rainfall; however, the other sources of water recharge are Hawaliya Drain which is attached to Hindon River and Tilapta Canal. The wetland area was divided into three blocks (A, B and C) on the basis of dominant aquatic vegetation and water spread to facilitate complete horizontal sampling of the area (Fig. 2). Fish sampling was done using cast net (10x10 mm mesh size with 3 m radius) and occasionally gill nets (mesh size 16x16 mm) (Hossain *et al.,* 2012) on monthly basis from 08.00 to 13.00 hrs during the study period (Patra and Datta, 2010). Weight, length and breadth of each fish caught in the net were measured. One individual of each fish species was collected and preserved in 10% formaldehyde solution (Kline, 2001) in

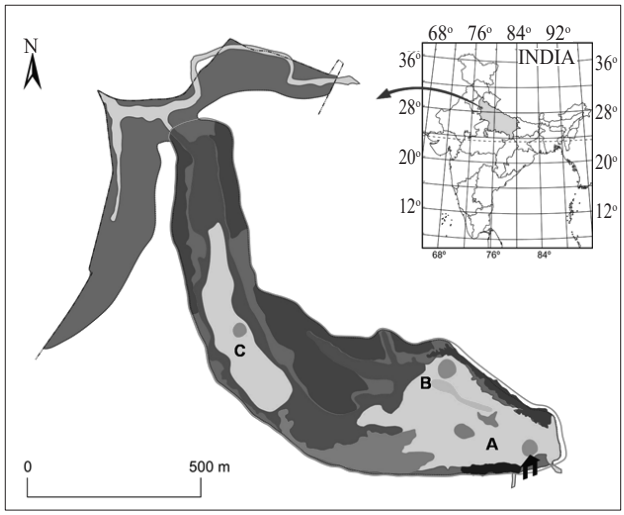
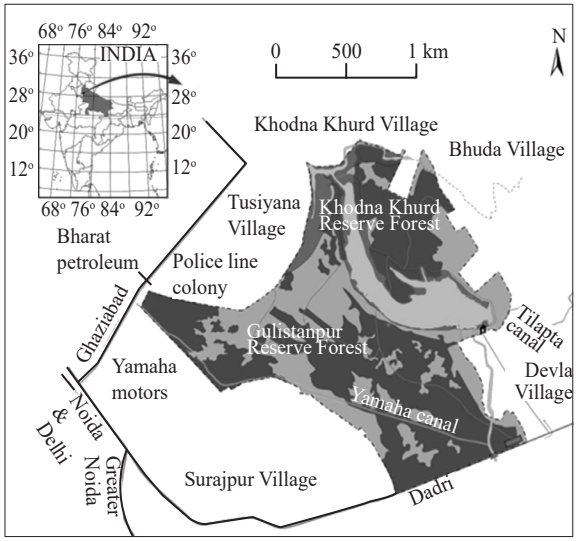


Fig. 2. Map showing the three sampling blocks (A, B and C) in Surajpur wetland



Key
- Wetland boundary
- Protected area boundary
- Metal road
- Main gate
- Canal-perennial
- Cannal-seasonal
- Nature trail
- Matchan
- Watch tower
- Visitor zone
- Range office (Dadri) Forest nursery
- Bridge

Habitat	Wetland	Woodland	Grassland	Marshland
Area (Ha)	32	152	96	28
Percentage (%)	10.39	49.35	31.16	9.09

Fig. 1. Map showing various habitats of Surajpur Lake

plastic jars for laboratory study. In the laboratory, samples were sorted and identified to species level following Talwar and Jhingran (1991), Jhingran (1991), Heda (2009), Jayaram (2012) and also confirmed by fish fauna experts and local fishermen. The frequency of each species was calculated based on the number of occasions the species was collected during the sampling period, following the standard catch frequency chart (Common: 91-100%, Abundant: 81-90%, Frequent: 61-80%, Occasional: 31-59%, Sporadic: 15-30%, Rare: 05-14% and Extremely rare: <05%) presented by Tamang *et al.* (2007) The hydrological parameters were analysed subsequently with each fish sampling. A total of 11 hydrological parameters were used for analysis of water quality at each sampling site including physico-chemical parameters. The most changeable and sensitive physical parameters *i.e.,* water temperature, water depth, pH, transparency (turbidity) and dissolved oxygen (DO) were measured *in-situ* and the other chemical parameters (total hardness as CaCO3, total alkalinity as CaCO3, chloride, nitrate, phosphate, total Iron) were analysed in the laboratory (Chari, 2002; Nasir, 2010; Hossain *et al.,* 2012). Estimation of various water quality parameters were done as per standard procedures reported in Golterman *et al*. (1978) and APHA (2006). Meteorological data for four atmospheric parameters (air temperature, rainfall, humidity and wind velocity) were collected from secondary sources *viz.,* Indian Meteorological Department, Meteorological Centre, Delhi (http://imd.gov.in/) and Weather History for New Delhi, India, Weather Underground (http://wunderground.com).

Data analysis was performed using PAST software (Version 3.08) (Hammer *et al.,* 2001). Species diversity was assessed using alpha diversity indices *viz*., Shannon, Simpson, Margalef and Equitability indices in both spatial and temporal spectrum. One-way analysis of variance (ANOVA) was used to check the significance of difference between the blocks and months. Quantification of fish assemblage and relative abundance was done following catch per unit effort (CPUE) independently for each site and month of sampling (Petrere *et al.,* 2010). CPUE was calculated by dividing total number of individuals caught with time spent and number of attempts. Pearson Product Moment Correlation and Principal Component Analysis (PCA) were performed to check the relationship of fish abundance with environmental variables (Lugo *et al.,* 2013).

Results and discussion

Fisheries abundance and diversity

A total of 185 individuals were identified comprising of 15 species belonging to 10 families (Table 1). The maximum recorded abundance was of banded gaurami *Trichogaster fasciata* with 65 individuals and the lowest recorded abundance was for the stinging catfish *Heteropneustes fossilis* and bighead carp *Hypophthalmichthys nobilis*, both species with only one individual found. With respect to month-wise abundance, maximum of five species were recorded in May with maximum number of individuals (n=62) (Table 3). No species were recorded in August and September, although this is likely because of the fact that the area was flooded and the fishes were more spatially

Table 1. List of fishes recorded from Surajpur Lake during the study period

Family	Name			Abundance Status	IUCN status
	Scientific	Common/ English	Local		
Balitoridae	*Nemacheilus anguilla*	Black lined loach	Baatta	R	LC
Amphipnoidae	*Monopterus cuchia*	Cuchia cuchia	Bam	R	NE
Cyprinidae	*Hypophthalmichthys nobilis*	Bighead carp	Biggread	R	DD
Cyprinidae	*Laubuka laubuca*	Indian glass barb	Chilwa	A	NE
Anabantidae	*Anabas testudineus*	Climbing perch	Kawai	R	DD
Osphronemidae	*Trichogaster fasciata*	Banded gourami	Kharda	F	NE
Siluridae	*Wallagao attu*	Boel	Lauch/Barari	R	NT
Clariidae	*Clarias batrachus*	Magur	Mangur	O	LC
Cyprinidae	*Puntius sopohore*	Spot-fin swamp barb	Putti	C	LC
Cyprinidae	*Puntius chola*	Chola barb	Putti	C	LC
Cyprinidae	*Labeo rohita*	Rohu	Rohu	R	LC
Chaniidae	*Channa striata*	Striped snakehead	Shol	O	NE
Chaniidae	*Channa punctata*	Spotted snakehead	Shol	O	NE
Heteropneustidae	*Heteropneustes fossilis*	Stinging catfish	Singhi	F	LC
Bagridae	*Mystus bleekeri*	Day's mystus	Tengna	R	LC

Abundance Status : A - Abundant, F - Frequent, C - Common, O - Occasional, R - Rare
IUCN Status: NT - Near Threatened, LC - Least Concern, NE - Not Evaluated, DD - Data Deficient

dispersed. The monthly abundance for each sampling zone sharply reduced from November to January and gradually increased from February to May (Fig. 3). Block-wise, the maximum recorded abundance was found in block C (7 species and 98 individuals) followed by block A (5 species and 65 individuals) and block B (5 species and 22 individuals) (Table 2 and Fig. 4). On the basis of catching/sighting frequency, 7 species were categorised as rare, 2 as frequent, 2 common, 3 occasional and one abundant. However, no significant difference ($p>0.05$) was observed in fish diversity between different blocks and months (Table 1) which means different blocks bear resemblance with each other.

The quantification of fish assemblage was performed in terms of catch per unit effort (CPUE) and the maximum CPUE (8.27) was recorded in May 2011 while minimum CPUE (0.13) was observed in October 2011 and February 2012, excluding August and September 2011 as no species

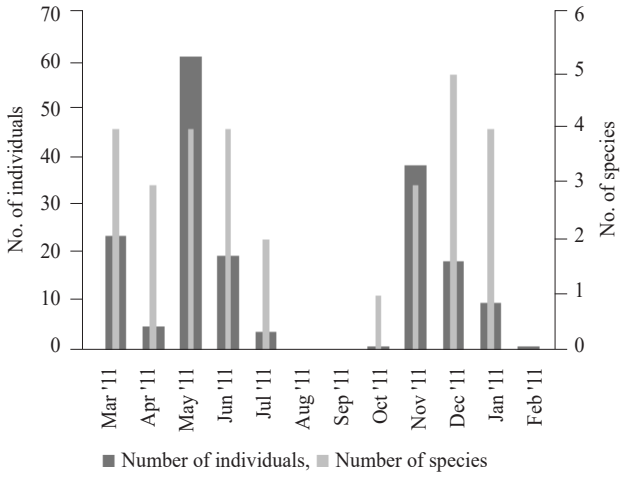


Fig. 3. Number of species and individuals recorded during the sampling months

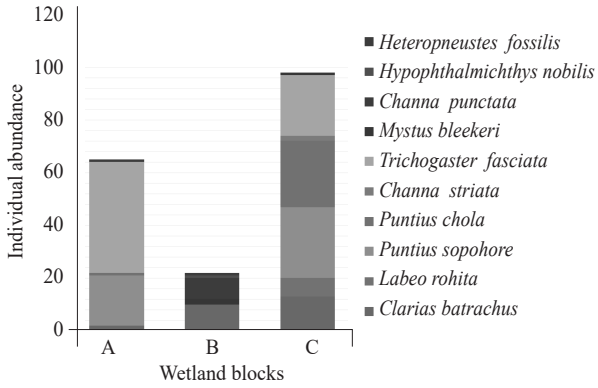


Fig. 4. Abundance of individuals in the sampled blocks during the study period

were recorded due to flooding events (Table 3; Fig. 5). Maximum number of fishes and their assemblage (CPUE) were recorded in May, because in summer season the area becomes dry, retains very little water and therefore, all fishes were caught in the net while sampling whereas, in monsoon, the area becomes flooded and fishes becomes more spatially dispersed and no fishes were caught in the net.

Various alpha diversity indices were estimated across the study period. The Shannon diversity estimated was 2.20 among individuals, 1.82 among species and CPUE, 1.57 in block C, 1.22 in block A and 1.05 in block B. Similarly, Simpson Evenness followed the same pattern to Shannon. Margalef diversity recorded a maximum of 2.95 among CPUE and a minimum of 0.97 among block B. Equitability index recorded maximum of 0.95 among individuals and minimum of 0.86 among block A (Table 4).

Environmental parameters

Physico-chemical parameters recorded in different blocks during different months are shown in Fig. 6. Water

Table 2. Fish assemblage in different blocks of Surajpur Lake

Species	Wetland blocks			Total no. of individuals
	A	B	C	
Clarias batrachus	2	10	13	25
Labeo rohita	0	0	7	7
Puntius sopohore	19	0	27	46
Puntius chola	1	0	25	26
Channa striata	0	0	2	2
Trichogaster fasciata	42	0	23	65
Mystus bleekeri	0	2	1	3
Channa punctata	1	8	0	9
Hypophthalmichthys nobilis	0	1	0	1
Heteropneustes fossilis	0	1	0	1
Total no. of individuals	65	22	98	185
Total no. of species	5	5	7	

Table 3. Monthly fish abundance recorded (March 2011-February 2012) in the study area

Months	No. of individuals	No. species	No. of attempts	Time (min) spent per catch	CPUE
Mar 2011	24	4	15	2	3.20
Apr "	5	3	15	2	0.67
May "	62	4	15	2	8.27
Jun "	20	4	15	2	2.67
Jul "	4	2	15	2	0.53
Aug "	0	0	15	2	0.00
Sep "	0	0	15	2	0.00
Oct "	1	1	15	2	0.13
Nov "	39	3	15	2	5.20
Dec "	19	5	15	2	2.53
Jan 2012	10	4	15	2	1.33
Feb "	1	1	15	2	0.13

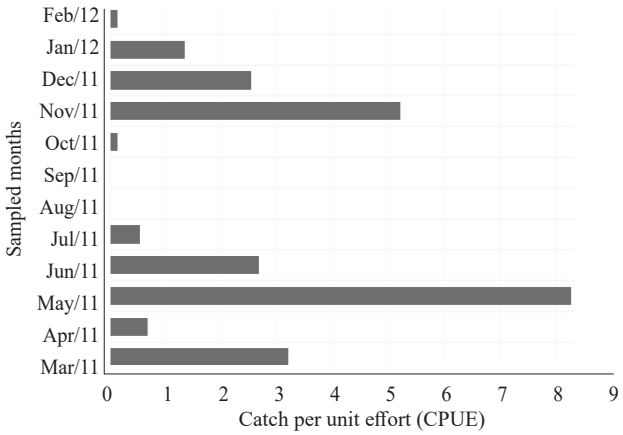


Fig. 5. Catch per unit effort (CPUE) during the sampling months

temperature recorded a maximum of 34°C in block B and block C during June and a minimum of 14°C in block B during December. Water depth recorded a maximum of 176 cm in block B during August and a minimum of 62 cm in block A during June. The monthly average water depth recorded maximum in August (168 cm) and minimum in June (62 cm). Average pH values did not fluctuate much across the months and blocks with values ranging from 5.67 (July) to 7.00 (March and October). Highest transparency of 61.5 cm was recorded in block C during August, whereas minimum value observed was 9 cm in block B during June and the average value fluctuated between 14.67 (March) to 51.83 cm (August and September). Dissolved oxygen concentration in water recorded a maximum of 21.6 mg l^{-1} in block B during April and not recorded in block A during August and block B during August and September and the average DO value was maximum (20.93 mg l^{-1}) in January and minimum (1.40 mg l^{-1}) in August. Total hardness as $CaCO_3$ recorded a maximum value of 336 mg l^{-1} in block A during April and minimum of 112 mg l^{-1} in block A, B and C during August and average values ranged from 112 (August) to 198.67 mg l^{-1} (February). Total alkalinity fluctuated across the blocks and months and average value ranged from 53.33 to 400.00 mg l^{-1} (February to November). The average chloride level observed was highest during April (147.33 mg l^{-1}) and least in August (25.33 mg l^{-1}) and average nitrate value ranged from 1.00 (March, April and June to October) to 18.67 mg l^{-1} (February and November). Average phosphate value did not fluctuate much across the study period and recorded minimum value in May (0.23 mg l^{-1}) and maximum in June, August and November (0.80 mg l^{-1}). Average total iron concentration recorded minimum in September and October (0.67 mg l^{-1}) and maximum in January and December (3.00 mg l^{-1}). No significant ($p>0.05$) difference was found in the physico-chemical parameters of water among the different blocks and months during the study period.

Trend of meteorological data during the three years study period is shown in Fig. 7. Air temperature ranged from 34.20°C in June to 12.75°C in January. Maximum rainfall of 278.47 mm was recorded during August, whereas minimum of 2.57 mm during December. In case of humidity, a maximum of 83.10% was recorded during August and a minimum of 30.30% was observed during May. Wind speed fluctuated between 2.37 mph during November to 7.54 mph during July. Significant difference ($p<0.05$) was observed among meteorological parameters between months ($F= 3.93$; $p= 0.01$).

Pearson product moment correlation was used to isolate environmental variables strongly associated with the fish ordination axis scores. Forward selection PCA was used to select a combination of environmental variables that explained most of the variation observed in the fish species matrix (Fig. 8). Air temperature, rainfall, humidity, wind speed, water temperature, turbidity and phosphate

Table 4. Alpha diversity indices recorded during March 2011-February 2012 in Surajpur Lake

	Species	Individuals	CPUE	Block A	Block B	Block C
Shannon_H	1.828	2.202	1.827	1.223	1.053	1.575
Margalef_R	1.724	2.621	2.956	1.198	0.9705	1.963
Simpson_E	0.8	0.8824	0.7998	0.6277	0.5909	0.7078
Equitability_J	0.7941	0.9561	0.7935	0.6823	0.7599	0.6842

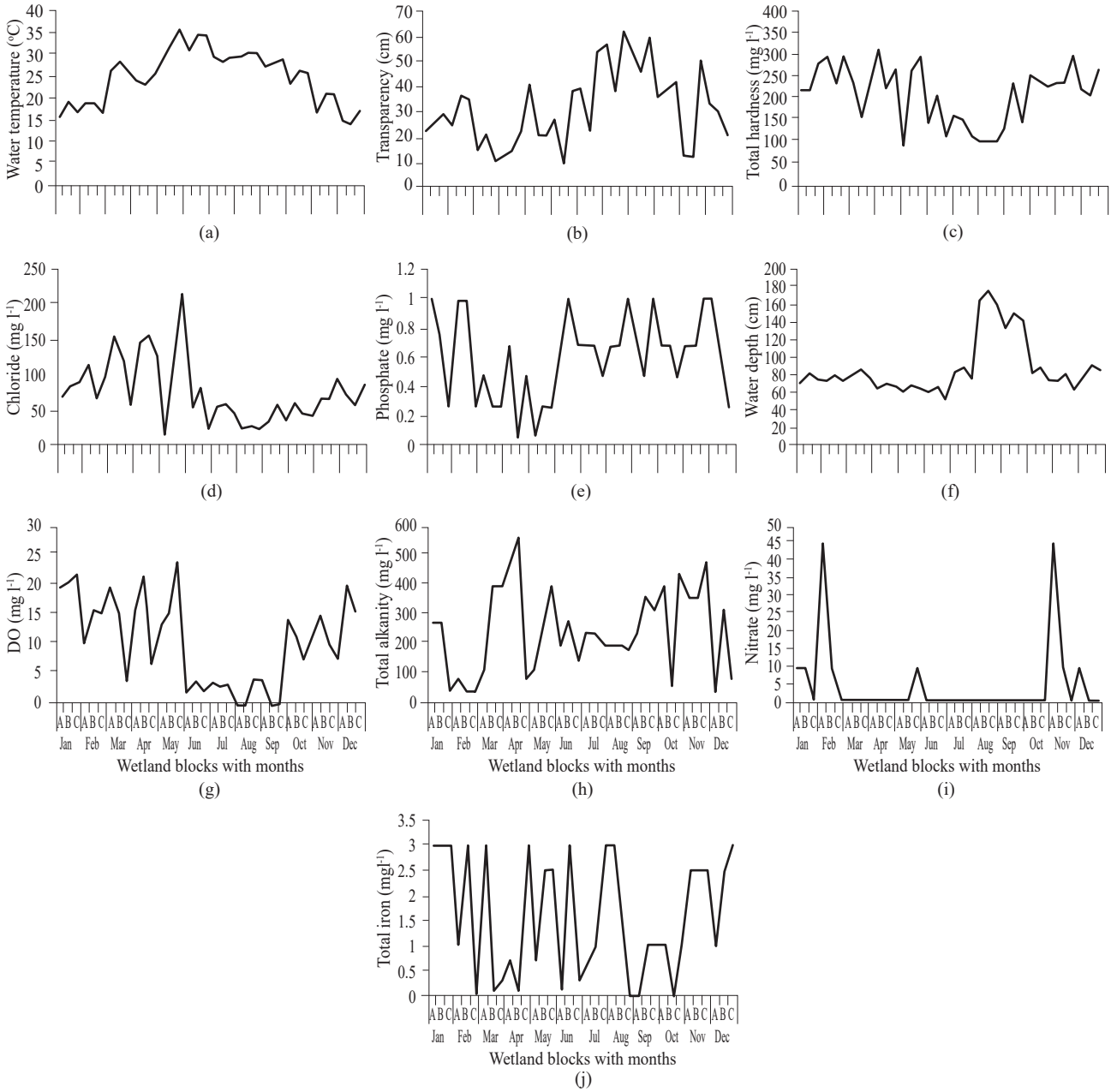


Fig. 6. Mothly variations in physico-chemical parameters of different blocks. a) Water temperature, b) Water depth, c) Transparency, d) Dissolved oxygen, e) Total hardness, f) Total alkalinity, g) Chloride, h) Nitrate, i) Phosphorus, j) Total iron

showed positive relationship whereas pH, dissolved oxygen, total hardness, total alkalinity, chloride, nitrate and iron showed a negative correlation with fish communities in PCA (Fig. 9). Positive correlation suggests that, with increase in dissolved oxygen and chloride, fish abundance increased, whereas an inverse relationship suggests that, with decrease in humidity, turbidity, phosphate, water depth and rainfall, fish abundance increased.

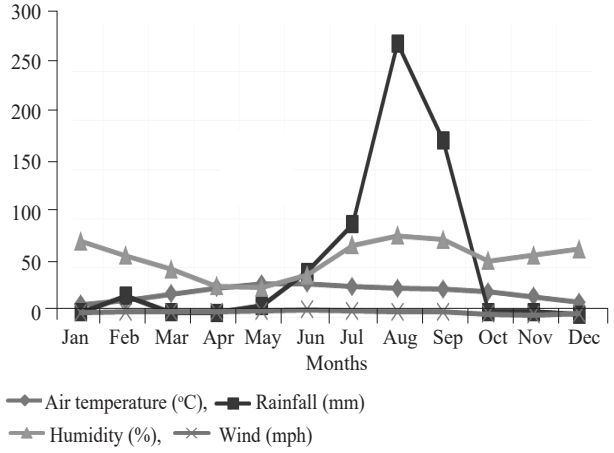


Fig. 7. Meteorological conditions of the study area during different months

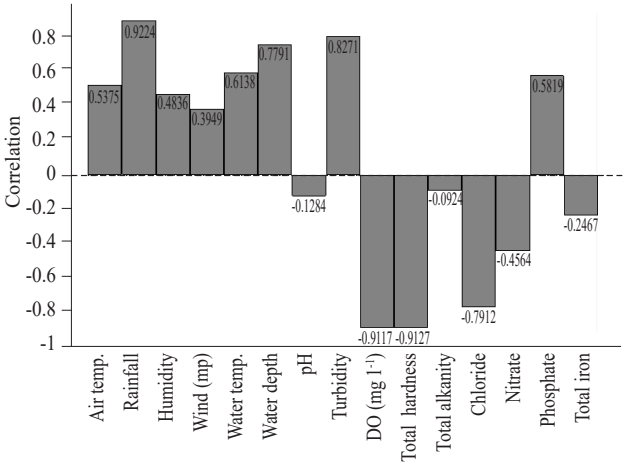


Fig. 9. Correlation among environmental parameters recorded during the study period

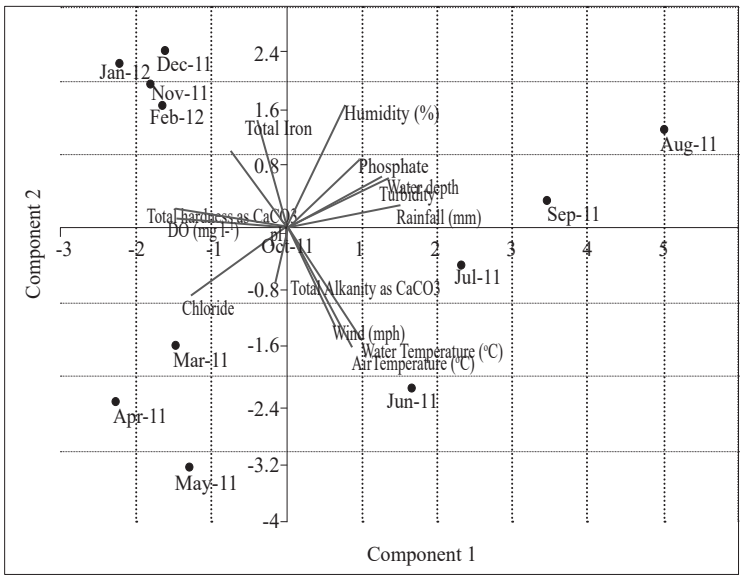


Fig. 8. PCA between environmental parameters and fish abundance

The effects of environmental parameters on the distribution patterns of aquatic organisms have been frequently studied (Ratz, 1996; Pombo *et al*., 2005; Childs *et al*., 2008, Lee and Brodziak, 2011). Most of these studies were based on extensive time series (several years), in contrast to our study which only analysed a database of 12 months. However, our results revealed a strong relation between catches and the physico-chemical variables studied.

The conservation status of fish species recorded during the study were assessed as per IUCN Red List category. One species was listed as Near Threatened (NT) *i.e.* boel *Wallago attu*, 7 species as Least Concern (LC), 2 species as Data Deficient (DD) and 4 species as Not Evaluated (NE) (Table 1). None of the species recorded has been listed in the Indian Wildlife (Protection) Act, 1972 (Table 1).

With the increasing fishing pressure globally, understanding the influence of environment on the survival and abundance of fishery resources is of vital importance, both from fisheries management as well as from environment point of view. Environmental factors and natural phenomena contribute to fluctuations in fish catch from year to year in an unpredictable manner, increasing the exposure of the fishery resources to the dangers of overexploitation and eventual collapse (Csirke, 1997).

The study showed that Surajpur wetland has immense potential to sustain the good fish biodiversity with favourable environmental parameters, which helps in the

improvement of the health of fish population. In addition to fish fauna, the area holds immense potential to sustain threatened flora, fauna and other biodiversity, as during the study period we also recorded 257 species of flora, 6 species of mammals, 186 species of birds, 13 species of herpeto-fauna and 52 species of butterflies from the study area (Ansari, 2016). This is the first scientific study in Surajpur wetland and the results would serve as baseline information to develop a comprehensive science based management plan for conservation of aquatic biodiversity of the area.

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