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Modelling Association of Waterfowl Conglomerations and Anthropogenic Multi-stressors at Najafgarh Jheel, Delhi, India

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ABSTRACT

Globally the inland urban freshwater wetland biodiversity is facing threat due to anthropogenic activities. Scientists worldwide understand the complex linkages between ecological impacts due to human induced pollution. Wetland systems are susceptible to changes in quality and quantity of water. The paper will focus on water quality based stressors and indicative changes in biodiversity including resident and wintering avifauna density. The avifauna is an indicator towards wetland and health of its ecosystem services. The present study provides an overview of a tropical inland wetland (Najafgarh Jheel) in Delhi, India which is exposed to multiple anthropogenic stressors. The wetland is a proposed bird sanctuary and is facing acute conservation issues due to expanding urbanization and extensive agriculture. We measure the data for number of birds at nine census transect points. The census was conducted once a month for a period of one year (2017), early morning 6 am- 9 am. To each census transect we associated eleven points for water quality parameters. The wetland is organically loaded with agricultural runoff and unregulated sewage drains deteriorating quality of water. Therefore, water quality is an immediate local stressor for the resident and wintering birds. The water quality parameters were partially correlated and further modelled with yearly bird density. The generalized linear mixed models depicted that DO, BOD and TDS have higher effect on conglomeration of birds. Further, CCA plot between wintering birds and water quality from two consecutive year data was plotted. The analysis depicts the inter-linkages of wintering birds with specific stressor. The combination of these multiple stressors has synergistic and antagonistic effects that are decisive for management and restoration of a lake. The current hypothesis based on understanding short term freshwater research, implication towards local management policy and baseline for long term comprehensive studies with holistic approaches. The concept of understanding short-term linkages using multivariate data analysis between water quality and bird density is relatively untested in urban tropical wetlands of India.

Key words: Urban Wetland, GLMM, Cluster Analysis, Wintering birds, Wetland Management, CCA

INTRODUCTION

The urban and semi urban freshwater wetland areas are experiencing rapid deterioration and recognized as hotspot of endangerment (Mittermeier et al. 2010). The biodiversity dependent on freshwater is declining at a steep rate of 37%, compared to the 27 % terrestrial species since 1970 (Loh et al. 2005, Garcia-Moreno et al. 2014). In India, the urban wetlands surface water expanse reduces by 35% during the post-monsoon season to the peak of summers (Bassi et al. 2015). The wetlands in India support one fifth of the known biodiversity with an equivalent of 1-5% of the geographic area (Seenivasan 2013). It has been estimated that India has between 1200 and 1300 species of migrating birds, accounting for approximately 24 percent of the country's total bird species (Agarwal 2011). The residual urban wetlands face to an excessive nutrient loading due to anthropogenic factors, related to an extensive urbanisation and altered land use. The capacity of the natural removal process of excessive nutrients through nitrification, sedimentation and uptake by macrophytes are limited and hinders the ecosystem services of the wetland causing eutrophication, degraded water quality and biodiversity loss (Verhoeven et al. 2006).

Delhi has the second largest population of bird species sightings above 450 species amongst capital cities of the world after Nairobi (Lalchandani 2012, Bassi et al. 2015). The waterfowl's species are primary indicators of wetland ecosystems services and health and has been estimated to decrease around the world for built-up and inland wetlands land covers (Sala et al. 2000). Moreover, out of 44 freshwater lakes existing in Delhi, only 21 have survived in the last decade and with a poor water quality, while the others have either permanently dried or encroached. It was observed that the lakes that survived were parts of protected areas by the government (Singh and Bhatnagar 2012). The Najafgarh Jheel (NJ), Delhi system has been a part of low-lying areas and Sahibi river tributary (now known as Najafgarh drain) being major source of water was dredged in 1983, due to which it split into 3 remnant lakes as of today. The NJ area is divided geographically by the Delhi-Haryana State borders with conflicts in management strategy. Holistic conservation demands a better understanding of biodiversity trends along with an integrated understanding of stressors and drivers. Waterfowl diversity dependence is mostly facultative or obligatory in a wetland and their congregations largely affected or dependent on factors pertaining to food availability, heterogenous microhabitats for breeding, roosting in addition to feeding and abiotic alterations (Jaksic 2004, Ma et al. 2010, Lagos et al. 2008). It has been observed that management of an urban wetland are planned taking into account biological models for quantifying the response of wildlife to specific changes in the environmental conditions (Matulich et al. 1982). The scientifically published information on NJ waterfowl abundance and water quality were limited (Verma and Bhat 2019). Studies around India have frequently concentrated on single stressors for bird density and abundance (Kumar and Rana 2020, Rustogi and Singh 2017). However, it has been quantified in recent studies that presence or absence of biodiversity at a specific geographic location could be due to more than one stressor or driver (Olden et al. 2010). Further, it was observed that studies on linkage of physiochemical parameters acting, as multi stressors towards waterfowl density for tropical wetlands of India are limited. In light of the foregoing, the purpose of this paper is to focus on interpreting the following aspects: 1) identifying the stressors affecting on the overall bird population density at NJ and 2) prospective relationships between physio-chemical parameters of water and wintering waterfowl assemblage.

METHODOLOGY

Study site

Najafgarh Jheel (NJ) is a wide wetland ecosystem, and a proposed bird sanctuary, situated in the national capital region (NCT) of Delhi, India (Fig. 1). The lake is located in the south-west district of Delhi with coordinates 28.499 N and 76.938 E. The 'jheel' or lake has been historically significant for waterfowl cited in the ornithology records by Ganguli (1975) until the Najafgarh drain was widened due to flooding in south-west Delhi (Vyas 2019, Banerjee and Pal 2017). This riverine lake known for large congregation of waterfowl and wintering bird lost its conservation status (Sinha 2018, Goswami 2017) due to numerous stresses from rapid urbanization, pumping water extraction for agriculture, direct sewage discharge, waste dumping along the drain stretch.

Water birds

Nine alternate 1 km line transects in a total of 18 km study area were conducted monthly for a period of January to December 2017. Occurrence of birds were assessed for abundance and diversity on sight basis using binoculars with magnification 7 × 50 and photographed with DSLR (Digital Single Lens Reflex Cameras) focal length 18-55mm and 55-130mm lens. The birds were identified using a field guide (Ali and Ali 1996, Norman 2014). The time of survey was 6:00 to 9:00 hours (Bibby et al. 2000, Sutherland et al. 2004). The data was collected for the number of birds in each transect for each species. The analysis was done on the total pure number of water birds found in each transect in all 12 consecutive months. The relative abundance (Lloyd and Ghelardi 1964) on the one-year data was also accounted to understand distribution and evenness of the bird species in NJ environment.

Environmental parameters

Nine alternate points from the above mentioned transects were chosen to collect water samples for testing a total of 11 parameters (Table 1). All parameters were tested using standard laboratory protocols provided by APHA (1989). The water temperature was measured *in situ* using a digital thermometer with operating range from -10 to +60°C. The water samples were also collected for the same time period along with waterfowl data during the same visit. The overview of multivariate data was analyzed by Pearson partial correlation using coefficient value (r) and p-value (p). The analysis was done on R using ppcor library. The p values are

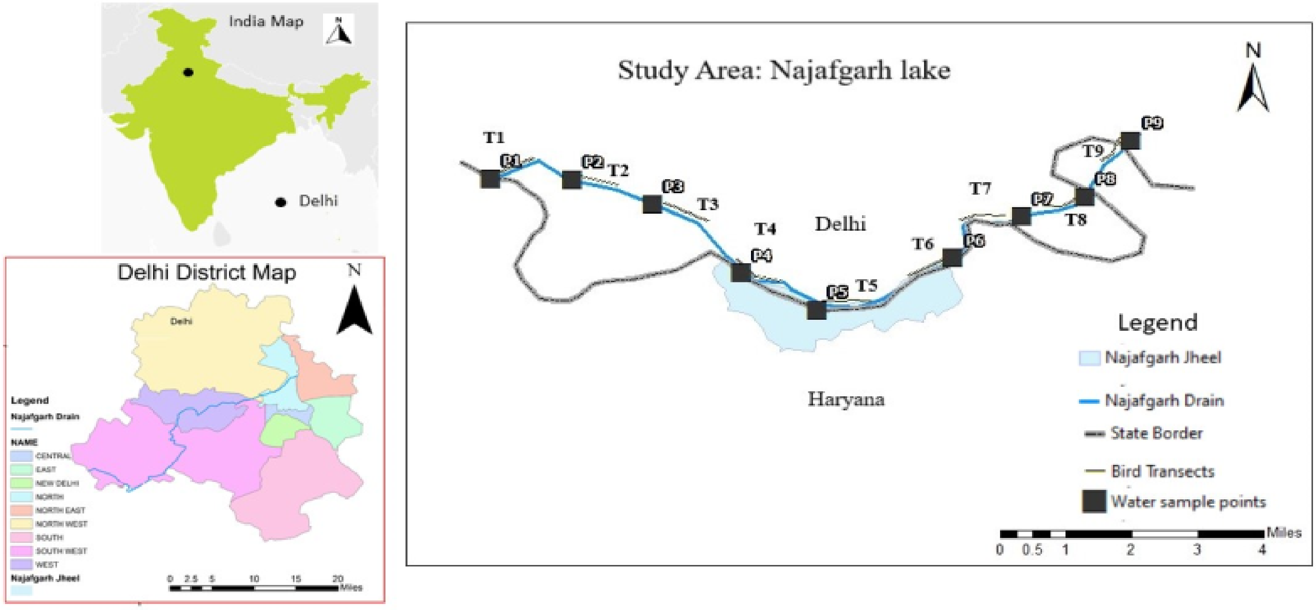

Figure 1. Map of Najafgarh Lake showing data collection points

Table 1. All stressor individual Multicollinearity diagnostics by Farrar – Glauber test; F – test

Parameters	**VIF^a**	**TOL^a**	**VIF^b**	**TOL^b**
Temperature (T)	1.9846	0.5039	1.4395	0.697
pH	5.0295	0.1988	1.9557	0.5113
Electrical conductivity (EC)	8.9157	0.1122	4.5733	0.2187
Dissolved Oxygen (DO)	8.9957	0.1112	2.3515	0.4253
Biological Oxygen Demand (BOD)	6.6335	0.1507	3.0961	0.3230
Total Dissolved Solids (TDS)	61.9371	0.0161	2.8697	0.3485
Total Suspended Solids (TSS)	31.7967	0.0314	*	*
Chlorides (Cl)	4.767	0.2098	1.9409	0.5152
Nitrates (N)	421.9694	0.0024	*	*
Phosphates (P)	377.1488	0.0027	2.3088	0.4331
Sulphates (S)	2.5438	0.3931	2.1205	0.4716

VIF$^{(a,b)}$: Variable Inflation Factors; TOL$^{(a,b)}$: Tolerance; *: Excluded parameters

widely considered significant ($p < 0.01$) and non-significant ($p > 0.01$). The coefficient value (r) can be termed as strongly ($r > 0.5$); moderately ($r= 0.5$ to 0. 3) and weakly ($r < 0.3$) correlated.

Multi-collinearity in the dataset

The bird abundance is considered as response variable with water physiochemical parameters being the explanatory variables. We have 11 stressors which are confined to the lake ecosystem. The partial correlation coefficient using Pearson method with corresponding p values was computed using ppcor library in R. The linear regression models have a basic assumption that there should be no direct collinearity between the explanatory variables within the defined datasets. The presence of collinearity in real datasets is not observed however, multi-collinearity arises with large number of explanatory variables that demonstrate linear relation patterns. Therefore, selection of stressors was conducted by systematically observing pattern of multi-collinearity using Farrar-Glauber test (Imdadullah et al. 2016). This was computed in R version 3.5.1 using mctest library and functions omcdiag and imcdiag.

Probable Regression models for the explanatory variables

Further, post multi-collinearity and removal of highly collinear parameters a regression modelling was piloted. These models are stepwise linear regression model (LRM) as they provide all possible models and best fit models for a given number of variables. The stepwise LRM was computed with R uploading olsrr library with functions lm and ols_step_all_possible function for indicative model selection for only 9 out 11 stressor variables. The analysis required to further shortlist six parameters based model were selected for GLMM analysis.

Therefore, a stepwise LRM has k (This study: 9) number of potential independent variables that have 2^k (This study: 2^9) subset models to be tested (Whittingham et al. 2006). A total of 512 linear regression models with different k values from 1 to 9 were observed. The value where k = 6 observed 84 models in totality. The top five models with highest R-squared value, lowest AIC were distinctive combination models (Table 2), and were further analyzed for GLMM. The selected models were further enumerated as explanatory variables in generalized linear mixed model (GLMM) (Faraway 2016).

Multi stressor analysis (GLMM)

The response (bird density) and explanatory variables (water quality) were transformed using Box-cox transformations for normally distributed dataset, assumption required for GLMM. The probable explanatory variable combinations from LRM were used to develop multi-stressor interaction between the waterfowl abundance. The dredge analysis for model fitting was computed in R using Mumin library with lm function (Barton and Barton 2015) by lowest Akaike Information Criteria (AIC_c) is the most parsimonious model. The analysis from the dredge provided basic insights to nature of interaction (Feld et al. 2016) and impact towards response variable.

Canonical correspondence analysis for wintering bird assemblage

The dataset collected for wintering birds and water quality for two consecutive year (2017 and 2018) in the month of (Janurary-March) using same methodology as above. The wintering waterfowl assemblage and environmental parameters was analyzed using Canonical correspondence analysis (CCA) on log(x+1) transformed abundance dataset (Ter Braak 1986, Palmer 1993). Out of 24 wintering species only 10 wintering species were included as the dataset for remaining was not sufficient for statistical analysis. The output was calculated using R version 3.5.1 using Vegan library and function cca. The output demonstrated ordination diagram with wintering species represented as points and water quality parameters as vectors. The direction and length of the vector represents gradient, differ on the species distribution corresponding environmental parameters, respectively.

RESULTS

Overview of multivariate primary data

a. Waterfowl data: The structure of bird community NJ has conglomeration of wintering waterfowl. The primary bird surveys during the present study found a checklist of 103 species of avifauna along the drain. The data collected had 3 vagrant, 6 local/passage wintering, 70 resident birds and 24 wintering waterfowl species. The relative abundance (RA) of Greater Flamingo (*Phoenicopterus roseus*) was highest with value of 0.2 and Little Stint (*Calidris minuta*) was lowest with a value of 0.00015. In winter wintering category, RA was highest for Bar-headed Goose (*Anser Indicus*) (0.034). The wintering bird population consisted of 15 percent of the total waterfowl abundance in a year.

b. Water quality data: The Pearson partial correlation analysis evaluated pairwise relationship amongst the water quality parameters and their significance. The temperature (T) was moderately correlated with

Table 2**.** Model selection based on stepwise multiple regression linear

Model	**N**	**Predictors**	***R^2***	***Adj. R^2***	**cp**	**AICc**
1	6	Temp, ph, EC, DO, TDS, S	0.582601	0.496242	5.162901	451.406
2	6	ph, EC, DO, TDS, CL, S	0.578069	0.490773	5.457826	451.7947
3	6	Temp, ph, DO, BOD, TDS, S	0.576964	0.489439	5.529724	451.8889
4	6	ph, EC, DO, TDS, P, S	0.574343	0.486276	5.70032	452.1113
5	6	ph, EC, DO, BOD, TDS, S	0.570884	0.482102	5.925383	452.4026

Cp: Mallows's Cp; AICc: Akaike information criterion; R^2: R-squared

Chloride (Cl) (r=-0.452, p=0.021). The potential of Hydrogen (pH) was moderately correlated with Dissolved Oxygen (DO) (r=-0.444, p=0.023), Biological Oxygen Demand (BOD) (r=0.377, p=0.057) and Sulphate (S) (r=0.385, p=0.052). The electrical conductivity (EC) was witnessed to be moderately correlated with DO (r=-0.403, p=0.041), BOD (r=0.485, p=0.012) and Total Dissolved Solids (TDS) (r=0.482, p=0.013). A strong negative relationship was seen among DO and Cl (r=-0.789, p=0.000). Similarly, a strong positive correlation was detected in TDS and Total Suspended Solids (TSS) (r=0.920, p=0.000) and moderately correlated with Nitrate (N) (r= 0.545, p= 0.004) and Phosphate (P) (r=-0.536, p=0.005). A strong positive correlation was observed between N and P (r= 0.996, p= 0.000) and extremely significant (Supplimentary table 1)

Multicollinearity of the explanatory variable

The assessment for location of collinearity was observed by the value of standardized determinant being zero and Farrar – Glauber chi square test had value of 519.0284 which is high and significant. Further, variance inflation factor (VIF) and Farrar-Glauber F-test (Wi), respectively, was exceeding for 11 stressor variables (Table 1). The accepted VIF value for the diagnostic should not exceed 3.338 as the multiple R-squared value is 0.7005 (Rawlings et al., 2001). The VIF values are exceptionally high for TDS, TSS, N and P. The analysis could only explain the collinearity partially, therefore confirming overall multi-collinearity for a model specification with all 11 stressor variables. To comprehend the pattern in multi collinearity correlation based on t-test values. High values of correlation were observed between N and P, TSS and TDS with t- test value of 55.58, 11.478 concluding multi-collinearity effects for these stressors. Therefore it was imperative that only one stressor from each pair was selected for model variable.

Characteristics of waterfowl abundance from multi-stressor analysis

The heterogeneity and seasonality of water quality was observed in nine transects as the drain is connected to the wetland. Based on the top 5 models bird density were to be affected by TDS, DO, pH and BOD (Table 3). The results of GLMM model depict that TDS being a measure of organic and inorganic loading could be one of the key stressor that affects the bird conglomeration in the lake. Out of the five models integrated the model number 3 and 5 had R squared value of 0.5334 (AIC = 82.78956). Similarly, model one, two and four had R squared value 0.4885 (AIC = 85.78956). Therefore, models three and five were considered parsimonious models as explained exploratory linkages between TDS and DO, BOD respectively with least AIC values and higher R squared value. The second most important factors DO and BOD and are complementary with each other.

Exploratory correspondence between wintering waterfowl and environmental parameters

The CCA plot (Fig. 2) was carried out for wintering waterfowl abundance at NJ and explore the stressor variables linked to their abundance in each transect. The proportion of environmental stressors has been depicted by constrained value 0.76. The biplot for constraining variables direct CCA 1 (constrained Eigen values) was highly correlated with stressors Temperature, EC, DO, TDS; moderately with Cl, P, S and least with pH and BOD. Although, CCA 2 was not correlating directly with any of the stressors, had the most effective correlation with Temperature (Supplementary table 2). The Eigen values of TDS, Temperature and DO indicate that environmental stressors important for wintering waterfowl assemblage.

The Species scores weightage reflect elements in CCA 1 and CCA 2 explained dispersion linkages for ten and two species respectively. The Citrine Wagtail has similar weightages for both. The CCA plot demonstrates Bar-headed goose (*Anser Indicus*) and Greylag goose (*Anser anser*) may have strong linkages positive interaction with P and negative interaction with S and EC. Gadwall (*Mareca strepera*) and Common Shelduck (*Tadorna tadorna*) depict positive interaction with DO and Cl.

DISCUSSION

The freshwater systems are susceptible to accelerating changes and environmental stressors cannot be isolated from the changing dynamics. Stressors such as local, catchment, land-use change

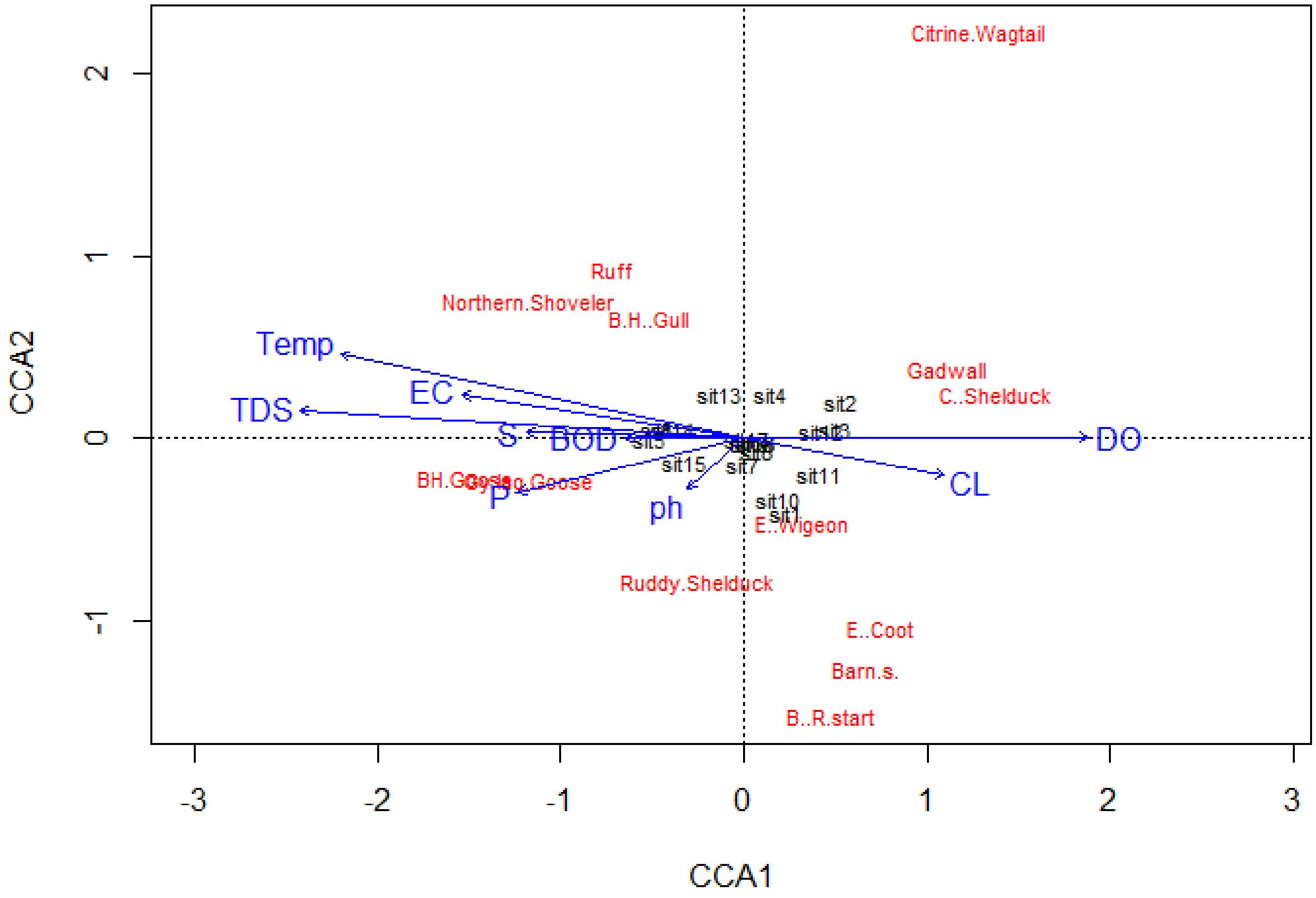

Figure 2. Canonical correspondence analysis (CCA) of wintering waterfowl at Najafgarh lake where Red marking are Wintering waterfowl and Blue marking are water quality parameters

Table 3. GLMM model outputs for the models selected through Stepwise LRM

	Model	AICc	*Adj. R^2*
1	lm(formula = yT ~ Temp + DO + TDS + 1)	85.78956	0.4885
2	lm(formula = yT ~ Ph + DO + TDS + 1)	85.78956	0.4885
3	lm(formula = yT ~ BOD + TDS + BOD:TDS + 1)	82.48298	0.5334
4	lm(formula = yT ~ pH + TDS + DO + 1)	85.78956	0.4885
5	lm(formula = yT ~ DO + TDS + DO:TDS + 1)	82.48298	0.5334

yT: Transformed values of bird density; AICc: Akaike information criterion; R^2: R-squared

and global warming (Jackson et al. 2016) have affected freshwater systems around the world. Understanding towards an interaction between these multiple stressors is largely unknown (Piggott et al. 2015). Potential interactions between stressors include additive, antagonistic, synergistic, mitigating and successive (Jackson et al. 2016) where the dependency of one stressors effect the other. Therefore, it is particularly difficult to predict interactions and consequences towards ecosystem services.

Aspects of multi-stressor on waterfowl density

The physio-chemical parameters play an important role in waterfowl abundance (Murphy et al. 1984). High abundance rate has been observed in productive ecosystems and sewage areas due to nutrient availability that is correlated with abundant food sources (Hoyer and Canfield 1990, Tere and Parasharya 2013). The NJ area is partly owned by the government and part holdings are private. The constructions on the flood bank, untreated sewage, industrial wastage is directly loaded into the lake (Goswami 2017). Thus, NJ environment has high level of nutrient loading and requires management interventions. The yearly monitoring conducted on Transects 1, 2 and 3 (T1, T2, T3) starting from Dhansa were cleaner but reasonably polluted in Transect 4, 5, 6 (T4, T5, T6). The BOD was 17.190 highest in winters for transects 7, 8, 9 (T7, T8, T9). Studies in the past have described a positive trend between nutrients load and waterfowl abundance, but heavily loaded nutrient in dams, rivers harbor less waterfowl abundance as compared to moderately polluted areas (Nilsson and Nilsson 1978, Suter 1994). The similar trend was observed during the present study in NJ where highest bird conglomeration was observed in moderately polluted transects (T4, T5 and T6) as compared to less (T1, T2 and T3) and highly polluted transects (T7, T8 and T9). Further, oxygen being a fundamental driver in wetland ecosystem and its demand largely affected by increase in the organic loading (Wetzel 2001). This could also be interpret the results at NJ for short term linkages between local stressors and waterfowl density observed a point of association between DO and bird density. Such trends have been observed in tropical wetland studies of India (Patra et al. 2010).

Prospective relationships of wintering waterfowl and stressors

The water bird density is higher through the months of early December to early March as its winter wintering season. Previous studies have depicted dependence of some waterfowl species on physical characteristics of an ecosystem (Kulshan 1993). The CCA analysis concluded a linkage of wintering waterfowl with immediate local conditions of the NJ, which could be an indicative of lower trophic levels. The food availability and production is dependent on the resource availability in a wetland. Therefore, wintering waterfowl has a wide geographic range which innate them towards comparison of responses against sites suitable for habitation (Kulshan 1986). Therefore, wintering waterfowl are conducive indicators of environmental change. Thus early studies on prospective associations on the aspect could serve as early warnings and trends.

CONCLUSION

Research describing interlinkages of anthropogenic stressors and its impact on waterfowl diversity in freshwater wetlands has been limited for urban landscapes in India. The purpose of the present study has been to understand the factors those could be primarily linked with avifaunal diversity and abundance in NJ to provide inputs toward urban wetland habitat management and conservation. The NJ supports good diversity and density of waterfowl and extensive ornithological research could be conducted. Further, the study underlines that avian species density in a suburban area near metropolitan city is considerably influenced by the immediate anthropogenic factors. Thus, it is critical that urban wetland habitats of Delhi should be conserved ecologically with their existing ecosystem services to maintain the wintering habitats. These important aspects of the study also serve as a baseline to assess the water quality decline due to urbanizations and gradual habitat change. The rapid deviations in habitat requirements in growing urban cities require management of wetlands must be built on regional knowledge. It is understood that there are policy interventions towards conservation of NJ under considerations of the local government. The local stressors at NJ are key factors in developing a management plan for conservation of the wetland. Therefore, we endorse regular and long term monitoring of waterfowl for adoptive maintenance of the NJ management plan aimed at conservation.

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Authors' contributions: The first author (CB) has conducted the field work, analysed the samples, data and prepared the draft manuscript. The senior author (SB) supervised the work, reviewed the manuscript. Both the authors jointly finalized the manuscript.

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Supplementary table 1. Details of Partial Correlation Analysis

Parameters	**Temp**	**ph**	**EC**	**DO**	**BOD**	**TDS**	**TSS**	**CL**	**N**	**P**	**S**
Temp	1										
P value	0										
ph	-0.072	1									
P value	0.728	0									
EC	-0.23	-0.093	1								
P value	0.259	0.653	0								
DO	-0.305	-0.444	-0.403	1							
P value	0.13	0.023	0.041	0							
BOD	0.164	0.377	0.485	0.129	1						
P value	0.425	0.057	0.012	0.531	0						
TDS	0.122	0.136	0.482	0.281	-0.051	1					
P value	0.553	0.508	0.013	0.164	0.803	0					
TSS	-0.161	-0.203	-0.332	-0.239	0.031	0.92	1				
P value	0.433	0.321	0.097	0.239	0.879	0	0				
CL	-0.452	-0.223	-0.119	-0.789	-0.103	0.194	-0.203	1			
P value	0.021	0.274	0.563	0	0.616	0.343	0.321	0			
N	0.137	0.177	-0.213	-0.211	0.136	0.545	-0.298	-0.145	1		
P value	0.505	0.386	0.296	0.301	0.506	0.004	0.14	0.48	0		
P	-0.158	-0.213	0.217	0.176	-0.114	-0.536	0.284	0.118	0.996	1	
P value	0.441	0.295	0.288	0.389	0.58	0.005	0.16	0.565	0	0	
S	-0.109	0.385	-0.136	0.269	0.051	-0.074	0.04	0.122	0.125	-0.071	1
P value	0.597	0.052	0.509	0.183	0.806	0.721	0.846	0.552	0.544	0.732	0

Supplementary table 2. Details of Canonical Cluster Analysis

Call:
cca(X = R1, Y = R2)

Partitioning of scaled Chi-square:

	Inertia	Proportion
Total	0.22552	1.0000
Constrained	0.17201	0.7627
Unconstrained	0.05352	0.2373

Eigen values, and their contribution to the scaled Chi-square

Importance of components:

	CCA1	CCA2	CCA3	CCA4	CCA5	CCA6	CCA7	CCA8	CCA9
Eigenvalue	0.1159	0.02126	0.01635	0.007128	0.005522	0.003064	0.001969	0.0008305	0.0000265
Proportion Explained	0.5137	0.09426	0.07249	0.031608	0.024486	0.013585	0.008731	0.0036825	0.0001175
Cumulative Proportion	0.5137	0.60800	0.68049	0.712099	0.736584	0.750169	0.758900	0.7625823	0.7626998
	CA1	CA2	CA3	CA4	CA5	CA6	CA7	CA8	
Eigenvalue	0.02857	0.01057	0.00599	0.003467	0.002342	0.001301	0.001035	0.000245	
Proportion Explained	0.12669	0.04685	0.02656	0.015372	0.010386	0.005769	0.004589	0.001086	
Cumulative Proportion	0.88939	0.93624	0.96280	0.978169	0.988555	0.994325	0.998914	1.000000	

Accumulated constrained eigenvalues
Importance of components:

	CCA1	CCA2	CCA3	CCA4	CCA5	CCA6	CCA7	CCA8	CCA9
Eigenvalue	0.1159	0.02126	0.01635	0.007128	0.005522	0.003064	0.001969	0.0008305	0.0000265
Proportion Explained	0.6736	0.12358	0.09505	0.041442	0.032104	0.017812	0.011447	0.0048282	0.0001541
Cumulative Proportion	0.6736	0.79716	0.89221	0.933655	0.965759	0.983571	0.995018	0.9998459	1.0000000

Scaling 2 for species and site scores

* Species are scaled proportional to eigenvalues

* Sites are unscaled: weighted dispersion equal on all dimensions

Species scores

	CCA1	CCA2	CCA3	CCA4	CCA5	CCA6
Citrine. Wagtail	0.4359	0.32374	-0.09465	0.0115640	-0.112921	-0.04547
C..Shelduck	0.4701	0.03534	0.18248	0.0330378	0.016032	-0.05020
E..Coot	0.2535	-0.15149	-0.04867	-0.1097793	0.083822	-0.05006
Northern.Shoveler	-0.4010	0.11092	0.05815	0.0107097	0.106118	-0.03099
Ruddy.Shelduck	-0.0869	-0.11504	-0.01279	0.2327663	0.014125	0.02738
Ruff	-0.2426	0.13522	-0.12981	0.0531776	0.099568	0.01924
B..R.start	0.1631	-0.22123	-0.09747	0.1241641	-0.032257	-0.07460
Gy.lag.Goose	-0.3989	-0.03435	0.02767	-0.0035085	-0.039901	-0.02972
BH.Goose	-0.5156	-0.03193	0.05685	-0.0963877	-0.096943	-0.02689
Barn.s.	0.2301	-0.18405	-0.18243	-0.0565435	-0.057329	0.07894
B.H..Gull	-0.1755	0.09666	-0.11904	-0.0006108	-0.003852	0.09595
E..Wigeon	0.1105	-0.06895	0.33113	0.0520933	-0.060819	0.08530
Gadwall	0.3774	0.05521	0.09850	-0.0753048	0.072071	0.05429

Site scores (weighted averages of species scores)

	CCA1	CCA2	CCA3	CCA4	CCA5	CCA6
sit1	0.697609	-2.77836	-1.563311	0.12484	0.85064	-2.0312
sit2	1.566137	1.36318	-0.062874	-0.95314	-1.13121	-0.8179
sit3	1.480641	0.37561	-0.476068	-0.84759	-0.07892	-2.4607
sit4	0.455307	1.69869	-1.622533	-1.27783	-1.02075	1.9830
sit5	-1.515240	-0.03694	-0.669614	0.58403	0.71804	-0.4652
sit6	-1.384109	0.31942	1.491282	-1.43524	0.03645	0.3647
sit7	0.003532	-0.99266	1.380966	2.60691	1.61647	-1.1910
sit8	0.233942	-0.47982	0.186738	1.14793	0.48988	0.5739
sit9	0.146025	-0.18073	0.329083	1.89257	-0.17111	1.3349
sit10	0.562439	-2.26639	-1.803769	0.29201	-0.09088	1.1079
sit11	1.237198	-1.35447	1.639815	-1.43600	2.60302	1.1999
sit12	1.258376	0.28039	1.895582	1.18423	-0.53913	-1.5780
sit13	-0.382355	1.65368	-0.434260	0.08554	0.59306	0.7237
sit14	-1.129073	0.35394	-0.468674	-0.36169	0.34356	-1.1492
sit15	-0.938734	-0.91560	0.685444	-2.15201	-4.37842	-0.1288
sit16	0.146025	-0.18073	0.329083	1.89257	-0.17111	1.3349
sit17	0.074504	0.02286	0.001396	1.80738	-0.19378	2.6260
sit18	0.146025	-0.18073	0.329083	1.89257	-0.17111	1.3349

Site constraints (linear combinations of constraining variables)

	CCA1	CCA2	CCA3	CCA4	CCA5	CCA6
con1	0.35767	-2.0042	-1.2203	-0.4679	0.37258	-1.7031
con2	1.49325	0.3188	0.4486	-0.5099	-0.06753	-0.5337
con3	1.08600	1.0394	-0.8545	-0.2919	-0.64607	-0.2623
con4	0.46956	1.5680	-1.2601	-0.6306	-0.13599	1.2025
con5	-1.65818	0.1162	-0.6961	0.1642	0.68104	-0.5052
con6	-1.35042	0.4575	1.4766	-1.8928	-0.58608	0.2502
con7	-0.39258	0.4550	0.3164	0.8158	0.01728	0.8662
con8	0.26223	0.5751	1.0763	1.0376	1.02790	0.8353
con9	0.05380	-0.5082	0.9693	2.2506	0.07883	0.8655
con10	0.87470	-1.9432	-1.7160	-0.8912	-1.07317	0.6353
con11	1.16130	-1.3774	1.2586	-1.1637	2.42359	1.0425
con12	1.43427	0.6334	1.5067	0.6716	-0.74831	-2.4291
con13	0.06409	0.9575	-0.5433	-0.1638	0.64470	-0.2617
con14	-1.00140	-0.1428	-0.3044	0.7195	0.75879	-0.9863
con15	-0.80366	-1.5335	0.5851	-0.2682	-2.05963	0.3433
con16	-0.07138	-0.1328	1.2216	1.1533	-1.64295	0.8808
con17	0.05814	-0.3120	-0.7354	1.1515	-1.31060	0.6551
con18	0.45553	-0.6724	-0.1012	2.1560	0.44138	1.6762

Biplot scores for constraining variables

	CCA1	CCA2	CCA3	CCA4	CCA5	CCA6
Temp	-0.7661	0.375381	0.06894	0.1479	-0.074030	0.41886
ph	-0.1059	-0.224204	0.40895	0.5262	-0.144725	0.44314
EC	-0.5357	0.195364	0.16400	0.6228	-0.144640	0.21552
DO	0.6552	0.005529	-0.10086	-0.4389	0.008308	-0.47957
BOD	-0.2252	0.003563	0.18320	0.7134	-0.217287	0.50616
TDS	-0.8436	0.126689	0.33128	0.3646	-0.015891	0.10494
CL	0.3801	-0.165679	0.17430	0.5980	0.022554	0.26389
P	-0.4293	-0.235962	-0.51398	0.3013	0.232825	-0.03393
S	-0.4140	0.025399	-0.35614	0.3178	0.595838	-0.25215