Material and Methods
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1. Study Area

This study was conducted in the important wetlands spread over Bardwan, Birbhum, and Purulia districts of south-west Bengal. Some important wetlands of Murshidabad district lying in the vicinity of the Birbhum wetlands have also been included in the study to have an overall idea of the waterbird community composition. However, for detailed observations of the diversity, abundance, assemblage and population trends eight representative important wetlands have been selected (Figure 1). These wetlands were selected on the basis of their variations in

Figure 1. Map of South-west Bengal showing the important wetlands that harbour rich diversity of waterbirds.
size, surroundings, human interference, vegetation, soil type and some basic water parameters like dissolved oxygen concentration, phytoplanktonic productivity, nitrate and phosphate contents, etc. so that each of them can represent a type of the wetlands present in the region. Moreover, they are among the few wetlands that harbour majority of the important winter migrants found in South-west Bengal. These wetlands were Bakreswar Reservoir, Tilpara Reservoir and Ballavpur Tanks of Birbhum district, Ahiron Beel of Murshidabad district; Purulia Saheb Bandh and Adra Saheb Bandh of Purulia district, Mukutmanipur (Kansabati) Reservoir in Bankura and Purulia districts and Purbasthali Oxbow Lake in Bardwan district. A brief description of these wetlands is given below:

1. Wetlands of Birbhum District

The wetlands of Birbhum are located in the lateritic and semi-lateritic belt of south-western West Bengal. These are Bakreswar Reservoir (Lat. 23°50.519' N; Long. 87°24.612' E), Tilpara Reservoir (Lat. 23°56.808' N; Long. 87°30.902' E) and three tanks (Lat. 23°40.999' – 23°41.332' N; Long. 87°39.611’–87°40.019’ E) inside of Ballavpur Wildlife Sanctuary.

a. Bakreswar Reservoir: Situated 12 Km south of Suri, the chief Sub-divisional Town of Birbhum district, Bakreswar Thermal Power Project is just 260 Km away from Kolkata. The reservoir was formed by erecting a dam on Bakreswar River for providing water to Bakreswar Thermal Power Plant, which was commissioned in 1999. The wetland is rich in macrophytes like Sedge (Scirpus spp.), Reed (Fragmites sp.), Water Lily (Nymphaea spp.), Pond weeds (Potamogeton spp.), Eelgrass (Vallisneria spp.), Hornworts (Ceratophyllum spp.), Ditch grasses (Ruppia spp.), Water lettuce (Enteromorpha sp., Pistia sp.), Kans grass (Saccharum spontaneum). They provide rich grazing for many waterbird species. It also supports rich diversity of arthropods, molluscs and fish. Therefore it serves as an attractive safe abode for a rich diversity of avifauna especially for the migratory one. Considering its importance, the reservoir has been included in the list of Prioritised Indian Wetlands (by Indian Ministry of Environment and Forests, 2005). The security personnel of the thermal power plant protect the
reservoir along with its denizens with particular emphasis on the area near the dam. However, the fishermen and tourist often create disturbance to the birds there.

![Figure 2. Bakreswar Reservoir. The dam on Bakreswar River is shown below.](image)

b. **Tilpara Reservoir**: Built on the River Mayurakshi, this Prioritised Indian Wetland is situated some 32 km downstream of Mosanjore Dam (Jharkhand State) and 4 km north-west of Suri right on the Panagarh-Moregram Highway. Commissioned in 1955 the project was aimed at providing year-wide irrigation to the agricultural fields that are normally suffering severe draught. The vegetation of the wetland is very similar to that of Bakreswar, although a considerable proportion of the shallow water area has become covered with water hyacinth (*Eichhornia crassipes*). The reservoir is an abode of a rich diversity of migratory waterbirds. However, exploitation of this wetland is considerably higher than that is Bakreswar. Overfishing, encroaching over the waterbody, motor vehicle washing, and even capturing and hunting of waterbirds have been recorded for several times during the course of the present study.
Figure 3. Tilpara Reservoir. Panagar-Moregram Highway is found on the eastern boundary of the Reservoir.

c. Ballavpur Tanks: Located inside Ballavpur Wildlife Sanctuary, these three man-made wetlands are characterised by high species diversity because of rich biological productivity and strong selection pressures of an aquatic existence (Gibbs 1995). Their location inside a well-fenced protected area prevents them from human infiltration and illegal disturbances and, thus, provides safety to the birds there. The forest personnel keep regular vigil to these wetlands and take care of them including their denizens. Comprehensive list of macrophytes of these wetland is given by (Maiti, et al. 2010). Brief details of these wetlands are given below.

(i) Tank 1: Located near the northern and eastern boundaries of Ballavpur Wildlife Sanctuary, this wetland is adjacent to human habitation, particularly along its eastern boundary. As a part of Ballavpur Deer Park this wetland faces disturbances created by the visitors of the park.
Moreover, a considerable portion of this tank remains covered with water hyacinth throughout the year.

(ii) Tank 2: Situating adjacent to the north-western boundary of Ballavpur Wildlife Sanctuary, this water body was initially a seasonal one. But in the year 2003 the water body was re-dug and a spill way was constructed to transform it into a permanent water harvesting structure.

(iii) Tank 3: Situating adjacent to the western boundary of Ballavpur Wildlife Sanctuary, this is the largest water body of the sanctuary. It is known to attract 6-8 thousands migratory waterbirds on an average, each year. However, a considerable portion of this wetland remains covered with thick water hyacinth throughout the year.

![Figure 4. Ballavpur Tanks inside Ballavpur Wildlife Sanctuary.](image)

2. Wetland of Murshidabad District

Ahiron Beel (Beel means large lake connected with river system): This wetland, locally known as Chand Beel, is situated almost at the Northern boundary of Murshidabad district
adjacent to Birbhum. Under Ragunathganj Beat of Farraka Range under the jurisdiction of Nadia- Murshidabad Forest Division, it is situated just at the South-eastern side of National Highway 34. This lake is bordered in the Southern side by Ahiron village and Agarpara villages, in the East by Bangabari village, in the North by National Highway-34 and on the Western side by agricultural lands. One serious concern for this agricultural practice is the use of fertilizers and pesticides that result into increased pollution and eutrophication during post monsoon seasons. This wetland is extended from 24°31'44.45"N, 88° 1'50.89"E to 24°31'17.60"N, 88° 22.17"E. It is situated 55 km north to Berhampur. This lake is the result of the ox-bow lake formation of the River Bhagirathi, a tributary of the mighty Ganges. It encompasses an approximate area of 119 ha. The Northern tip of the lake is connected to River Bhagirathi by a small channel and ensures a perennial water supply and drainage of excess water during the monsoons to avoid flooding of the area. The importance of the lake is thus enhanced on account of the barricade against flooding in the months of monsoons and also as the shelter and wintering grounds for the migratory birds during the winter days. This wetland also offers breeding and nesting sites for good number of residential waterbirds. Moreover the lake has a huge potential for attracting tourists on account of its proximity to Farakka barrage and National Highway 34. The depth of the lake varies from 1.5 to 2 meters; maximum depth of lake during monsoons is approximately 3 meters. The flora of the lake consists mainly of Water hyacinth (Eichhornia crassipes), which has spread over a large area of the lake. Plants inhabiting open water are both free floating, submerged and rooted in mud with floating leaves. A good number of potentially useful aquatic macrophytes such as Sola or Pith plant (Aeschynomene aspera), water chestnut (Trapa natans), pink water-lily (Nymphaea pubesens), grow there. Besides these some patches inside the wetland are covered with anchored plants with floating leaves like Crested Floating-heart (Nymphoides hydropillia), Water Thyme (Hydrilla verticillata) and Tape Grass (Vallisneria spiralis). Water Cress or Marsh Herb (Enhydra fluctuans) and Water Spinach (Ipomoe aquatica), while Taro or Elephant’s Ear (Colocasia esculenta) are observed at the water edges. Formation of very thick weeds of floating vegetation is also noted that are very
suitable as nesting grounds of waterfowls. Rich growth of grasses such as Jungle Rice \((Echinochloa colona)\) and Water Grass, \(Hygroryza asiatica\), are also present, which often co-exist with a variety of \(Cyperaceae\) grasses.

![Figure 5. Ahiron Beel. National Highway 34 marks its eastern boundary.](image)

3. Wetlands of Purulia Districts

a. Purulia Saheb Bandh (Bandh means dam/dyke) : The wetland is situated in the heart of Purulia town. In 2010, the huge lake, which is considered the lifeline of the residents of Purulia town, was declared a National Lake by the Government of India. This wetland remains covered by ever increasing thick cover of water hyacinth in most of the seasons, which is a serious threat to this wetland and its denizens. Over the years, it houses numerous residential and important migratory birds especially on the winter which remained a special attraction for birdwatchers. Purulia Saheb Bandh houses 17 monocot species of plants. Among them \(Hydrilla verticillata\), \(Vallisneria spiralis\), \(Typha domingensis\) are highly abundant there (Mandal and Mukherjee 2010). Every year, at the height of summer, when the area faces an acute scarcity of drinking water, the residents of Purulia town are supplied with potable water from this lake though the
administration has never been careful in maintaining the purity of its water or keeping its surroundings clean. Owing to a lack of administrative negligence for years the surrounding environment and the purity of water have been affected. Garages and small industries and workshops have been mushroomed at the banks of the lake. Effluents from these illegal workshops such as oil, grease and other chemical components started polluting the water. A private nursing home has also come up there and its discharges also affected the purity of the lake water. However in the recent past a Saheb Bandh Bachao Committee or Save Saheb Bandh Committee was set up to protect the invaluable water reservoir.

Figure 6. Purulia Saheb Bandh in the heart of Purulia town. Thick water hyacinth cover is clearly visible in the figure.

b. Adra Saheb Bandh : Spreading over an area of 84 hectares this wetland is situated in the eastern Part of Purulia district 5 km away from the Adra Railway Station with geographical location 23°29.315’N and 86°42.998’E. It is surrounded by Kang forest (maintained by Indian Railways) in the northern part, proposed Adra Thermal Power Plant in the south-western part,
grassland and cropland in the eastern and southern part. Contrary to Purulia Saheb Bandh, it is less affected by water hyacinths and water pollution by oil and grease. Adra Saheb bandh contains 14 species of monocot plants with predominately *Hydrilla verticillata*, *Vallisneria spiralis*, *Typha domingensis*, as well as *Commelina benghalensis*, *Murdannia spirata* etc. to a lesser extent (Mandal and Mukherjee 2010). This wetland houses numerous residential and migratory waterbirds especially in winter. One serious problem in this waterbody is the regular boating by tourists during the winter that constitutes a regular source of disturbance to the waterbirds. Hunting of waterbirds by the local people is another frequent menace here.

**Figure 7. Adra Saheb Bandh.**

d. **Wetland of Bankura District**

**Kansabati Reservoir**: Covering an area of almost 65 km², this wetland is spread over both Bankura and Purulia districts of South-west Bengal. It is extended from South-western part of Bankura district to the South-eastern part of Purulia district. This Reservoir, the second largest amongst the east Indian wetlands, is around 12 km away from the nearest Khatra town of
Bankura district. It is exactly 2 km from Bangopalpur Reserve Forest and 55 km from Bankura town, the district headquarters. A dam of 10,098 m long and 38 m high was erected on the River Kansabati in 1956 as part of the Indian Second Five-year Plan to provide water to 3,484.77 km² of land in the districts of Pashim Medinipur, Purba Medinipur, Bankura, and Hooghly. Anicut dam built on the Kansabati River near Medinipur town in 1872 was also added to the operations of the project. One successful implementation of the Project Kansabati Reservoir is that it now provides drinking water and irrigation facilities to a good number of villages of Bankura and Purulia districts. The reservoir is extremely rich in waterbirds and supports a huge number of migratory as well as residential waterbirds. Among the present study sites this wetland is the richest in waterbird diversity and is unique for important migratory waterbirds such as Great-crested Grebe, Eurasian Wigeon, Northern Shoveler, Common Pochard and Black-tailed Godwit etc. Bordered by the forests and a deer park, the reservoir has become a picnic spot for tourists that have paved the way for an alarming concern to its health and its denizens.

Figure 8. Kansabati Reservoir, the largest and richest wetland of South-west Bengal.
e. Wetland of Burdwan District

Purbasthali Oxbow Lake: Actually an oxbow lake this freshwater wetland is situated in Kasthashali village, near Chupi of Burdwan district on Bandel-Katwa Railway Route, West Bengal. The lake, which came into existence in the distant past by getting disunited form the main stream of the River Bhagirathi-Hooghly. Today it has lost much of its depth that it had in past. At present with a semi-lunar contour, it flows steadily north to south to connect the main stream on both the extremes exposing unyielding bed of weed and marsh vegetation in places. The total area of this wetland is 1600 ha. The lake vegetation chiefly consists of *Vallisneria natans*, a floating leaf-rooted angiosperm that occurs in abundance and flourishes all through the lake at varying depths. Water Hyacinth has choked substantial portion at the northernmost side whereas species of freshwater Chlorophyceae algae is seen sparsely colonising alongside the lake margins. It happens to be a well known wintering ground for important migratory waterbirds like Red-crested Pochard, Garganey, Eurasian Wigeon, Pheasant-tailed Jacana,

![Figure 9. Purbasthali Oxbow Lake and its connection with River Bhagirathi.](image-url)
Sandpipers etc. and it is also home for great number of residential waterbirds like Asian Open bill, different Herons and many others. One of the greatest problems here is the thick cover of the water hyacinth which almost covers 40% of the total wetland area. Agricultural malpractices in the borders and even in the shallow regions within the wetland made to foster this hyacinth cover quickly. This effect often rises in severity in low rainfall years. In high rainfall and flood-years the River Bhagirathi takes away most of the water hyacinths and in those years the wetland remains pretty cover free to attract more waterbirds.

2. Population census

To coincide with large-scale Asian Waterfowl Census Programme coordinated by Wetlands International, as well as with the periods of arrival and departure of migratory waterbirds in the region (Khan et al. 2005; Khan, 2010; Sinha et al. 2012), waterbird counts were made between January 1 and January 30, during the period from 2006 to 2012. In each selected wetland two censuses were made in each census year (one between 1 and 15 January, while the other between 16 and 30 January) to have a comprehensive idea of the waterbird abundance. Therefore, for each wetland, 14 censuses were made during the seven study-seasons, thereby a total of 112 censuses were made for 8 selected wetlands (7 seasons, 2 censuses per season and 8 wetlands; n = 2 x 7 x 8 = 112 censuses). Waterbird counts were performed using field binoculars on foot and boat, depending on the size and accessibility of the wetland, by five to eight observers, trained in bird identification and census, using the same methods as described by Khan (2010). Bird counts in Ballavpur Tanks and Purulia Saheb Bandh were performed on foot, while waterbirds occupying Bakreswar Tilpara and Kansabati Reservoirs, Purbasthali wetland, Adra Saheb Bandh and Ahiron Beel were counted both on foot and from country boats. In the cases of on-foot counts, the team walked at a slow pace (about 1-1.5 km/ hr) along the bank of the wetland as followed by Bibby et al. (2000) and counted birds using binoculars and spotting scopes. Similar procedure of slow sailing was followed in on-boat counts. Aerial digital photographs of different segments of the wetlands were also taken, which were later examined.
on computers to have a crosscheck of the census data. These examinations provided a second set of census data which were compared with the data obtained from direct bird counts. This crosscheck helped mitigating census errors including observer bias (Khan 2010). During each census, counts were begun at 8:00 hr. IST and continued until the total waterbird count of the entire wetland was completed.

3. Collection of geo-spatial and temperature data

Geo-spatial data were collected using Global Positioning Systems (GPSs) (Garmin ETrex® and ETrex Vista®). These data mainly consisted of latitude, longitude and altitude of the wetland, local sunrise and sunset times and mapping data. District-wise wetland maps were generated on Map Maker Pro Package Version 3.5 [Map Maker Ltd, The Pier, Carradale, Kintyre, PA28 6SQ, UK (www.mapmaker.com)].

Maximum and minimum temperature data for the census dates were obtained from Regional Meteorological Centre, Calcutta, while in each census date three additional readings were taken (at 9-00, 12-00 and 15-00 hrs IST) using digital thermometers. The mean of all these five temperature data was used to analyse the influences of temperature on the abundances of waterbirds. However, for other periods of the year only the mean of maximum and minimum temperatures were used for the purpose.

4. Collection of data on habitat variables

a. Plankton and sedge density, and chemical parameters

Plankton samples were collected using plankton nets (number 25 of mesh size 60 mm) and preserved following the method described by Ramachandra and Solanki (2007). The plankton density (number per litre of water) was estimated in the laboratory using both Sedgwick Rafter Slide and drop counts (Ramachandra and Solanki 2007). The sedge density (number of plants per m² of the water body) was determined from number of shoots that were oozed out of the water. The dissolved oxygen, nitrate and phosphate concentrations were estimated using
Aquamerck® Water Testing Kits (E Merck, Germany) and standard methods (APHA 2005). These estimates were made from five to ten randomly selected points within each of the wetlands, depending on its size, during each census period and the mean values were used for the analyses. Phytoplanktonic net primary productivity was measured by employing the light-dark bottle technique (Gaarder and Gran 1927; Wetzel 2001) and conversion of oxygen values to calorific values was made following Eaton et al. (1995).

b. Fish density

Fish density was estimated using catch-effort method (Johnson 1965) using cast nets, used by the local fishermen, made of fine mesh (6 mm) having a radius of 1.5 m. Cast nets are suitable for majority of the wetlands, especially the shallow ones (Meador and Kelso 1990; Schoor et al. 1995). During each census 30 random cast net deployments (10 deployments each along the edge, midline length and midline breadth of the wetland) were made from a country boat and the mean number of fish caught per deployment was used to measure fish density. However, the fishes having total lengths beyond 10 cm were excluded from the counts, since they were not manageable for most of the waterbirds recorded in this study. For the fish densities, fish collections were reported as number of fish/m². Since the shape of the cast net after landing approximated an ellipse, the deployment area was estimated from the area formula for an ellipse ($\pi \times r_1 \times r_2$), where $r_1$ was ½ major axis length and $r_2$ was ½ minor axis length. Cast net sampling area was (estimated by throwing the cast net 10 times onto a land surface) estimated at 2.4±0.2 m².

5. Diversity estimates

The collected abundance data for all the census years were processed for diversity estimations with regard to the total number of species (i.e. species richness) and individuals in each wetland, as well as to the Pielou's Evenness (Pielou 1969), Shannon-Weiner or Shannon-Weaver diversity (Shannon and Weaver 1949), Brillouin's diversity (Brillouin 1956) and Margalef’s richness (Margalef 1958) using the program PAST (version 2.10) (Hammer et al. 2001).
Shannon-Wiener diversity is the very widely used index for comparing diversity between various habitats (Clarke and Warwick 2001) and it has been used in this study to compare diversity between different wetlands considered in this study. Brillouin diversity has also been used in this study because it is suitable for the estimation of diversity of non-random samples and the present study was based on total counts, in which the question of random samplings did not arise. The differences in various diversity components of waterbirds among the wetlands were analysed using one-way ANOVA.

6. Community analysis

a. Non-metric Multidimensional Scaling (NMS)

Community analyses were performed on log (x+1) transformed abundance data for all waterbird species recorded during the study period. For the ordination of waterbird communities, non-metric multidimensional scaling (NMS) procedure on the abundance data for all waterbirds grouped by year was adopted, using Bray-Curtis dissimilarities. NMS has been the most effective (McCune and Grace 2002) and widely used (e.g. Paton et al. 2009; Khan 2010; Sinha et al. 2011) ordination method for ecological community data. It iteratively searches for the best positions of n communities on k dimensions (i.e. axes). The ordination presented here shows the relative distance between the waterbird communities in multivariate space: communities that are more similar in species composition appear closer together on the ordination plot than those are dissimilar (Ludwig and Reynolds 1988; McCune and Grace 2002). The grouping by year allowed a determination of temporal variations in community structure of the wetland.

b. Multi-response permutation procedure (MRPP)

A multi-response permutation procedure (MRPP) was performed on the data using the Bray-Curtis dissimilarities as the distance measure and wetlands as the grouping variable. MRPP is a nonparametric procedure highly recommended for ecological data (McCune and Grace 2002). The resultant T-statistic describes the separation between the wetlands, with a more negative value of T indicating a stronger separation, while the A-statistic, describes within-wetland
homogeneity compared to random expectation (higher values indicate higher homogeneity). This test was used to determine whether the waterbird communities differed statistically among the wetlands.

c. Indicator Species Analysis (ISA)

In order to identify the species that were important in structuring the waterbird community, indicator species analysis (ISA) was performed (Dufrene and Legendre 1997) for the common species (species with a total of 500 individuals recorded over the 7 census years) with samples grouped by wetland. ISA identified species associated with wetlands by calculating an indicator value, which reflected both frequency and abundance of species in defined wetlands. Significance of indicator values was assessed using Monte Carlo simulations with 4,999 permutations. All the multivariate analyses were performed using PC-ORD for Windows, Version 6.04 (McCune and Mefford 2006) and standard procedures outlined in McCune and Grace (2002).

7. Population trends

Comparisons of the abundance of each waterbird species between 2006 and 2012 were performed between the values for the counts performed in 2006 and in 2012 using the following formula (Paton et al. 2009; Sinha et al. 2011, 2012):

\[
\text{Percent change between 2006 and 2012} = \left( \frac{M_{2012} - M_{2006}}{M_{2006}} \right) \times 100
\]

[where \( M_{2012} = \text{value for the year 2012} \); \( M_{2006} = \text{value obtained in 2006} \)].

Population trends were analysed on Poisson-based Log-linear modelling framework using the programme Tends and Indices for Monitoring Data (TRIM, Version 3.54; Pannekoek and van Strien 2001). TRIM happens to be the standard tool in the framework of the Pan-European common bird monitoring project (www.ebcc.info <http://www.ebcc.info>). It analyses time
series of counts and produces estimates of yearly indices and trends, while at the same time examines the significance of parameters using Wald $\chi^2$ test.

8. Habitat relationships

To determine the variables that best predicted the abundances and assemblages of waterbirds, Canonical Correspondence Analysis [CCA; MVSP 3.2; Kovach Computing Services (www.kovcomp.com) and PC-ORD for Windows, Version 6.04; McCune and Mefford 2006] of the waterbird census data was used. CCA tests whether community composition is more strongly influenced by the environmental variables than by chance. CCA is a direct gradient analysis, which iteratively develops an ordination of species and sampling sites (sampling times here), combined with multiple regressions on a series of environmental gradients (ter Braak 1986; ter Braak and Prentice 1988). The environmental variables are reduced to a few orthogonal axes as composite environmental gradients structuring species distribution patterns. A down-weighting procedure for rare waterbird species was applied for this analysis; forward selection was not possible within MVSP. Monte Carlo permutation tests ($n = 998$) using both eigenvalues of the CCA axes and species environment correlations was run to test the null hypothesis that there was no relationship between the environmental variables and waterbird community structure. For the CCA axes values linear combination scores (i.e. LC scores) were used. LC scores are in environmental space and each axis is formed by linear combinations of environmental variables (McCune and Grace 2002). The use of LC scores is highly recommended for ecological studies (ter Braak 1994, McCune and Grace 2002).

Seven wetland variables were taken into account in this study. These were phytoplankton density, sedge density, zooplankton density, fish density, and nitrate and phosphate contents. Multicollinearity among these environmental variables was not excessive except for wetland area [variance inflation factor (VIF) ranged between 1.272 (for Phosphate) and 5.517 (for Area)] (cf. Table 8).
Although CCA caters information of the habitat association of individual species, its main goal is to determine relative effects of environmental variables on the community as a whole. Therefore, generalised linear models (GLMs) (SPSS version 16.0.0; www-01.ibm.com/software) with Poisson distribution and logarithmic link (typical for count data, Bolker et al. 2008) were also used to identify the environmental variables most important in determining the abundances of individual waterbird species in these wetlands. A backward elimination procedure was used to select the final models. However, to have a better understanding of influences of wetland attributes dissolved oxygen concentration (DO) and phytoplanktonic net primary productivity (PP) were also included in this analysis.

9. Relationships between wetland attributes and zooplankton and fish densities

To quantify the extent to which the occurrence and abundance of zooplankton and fish can be explained by combinations of wetland properties Redundancy Analyses (RDA) in canonical correlation (Rao 1964, ter Braak and Verdonschot 1995) (PC-ORD for Windows, Version 6.04; McCune and Mefford 2006) was performed. RDA is a multivariate generalisation of linear regression on the correlation matrix (data standardised by species). This is a canonical form of principal components analysis that identifies major gradients within the set of dependent variables (Jongman et al. 1987). In addition, it maximises the correlation of these gradients with another set of independent variables, assuming linear relationships between the two sets of variables. The multiple correlations of the canonical coefficients (based on the percentage of variance explained) and the correlation coefficient (inter-set correlation) were also used for the interpretation of this analysis, where the first one measures the species data variance along the axes and the second one correlates the wetland attributes with those same axes. The results of the multivariate analysis were visualised by mean of biplots, which attempted optimally to represent the joint effect of wetland attributes on zooplankton and fish abundances (i.e. major food source plot) and their community composition (i.e. community plot) in single planes (ter Braak 1990 a, b).
Although RDA caters information of the habitat association of individual species, its main goal is to determine relative effects of environmental variables on the community as a whole. Therefore, generalised linear models (GLMs) with Normal distribution and logarithmic link (typical for count data, Beher et al. 2008) (SPSS, Version 16; IBM; www-01.ibm.com/software) were used to identify the wetland attributes most important in determining the abundances of zooplankton and fish at the wetland. A backward elimination procedure was used to select the final models. Starting with a full model it was progressively simplified by eliminating variables that were furthest from statistical significance until the final model was obtained.

10. Analysis of Global significance of the wetlands

The global significance of the waterbird populations were assessed by comparing the population for each species in each wetland during each census year from 2006 to 2012 with South Asian population estimates, acquired from Wetlands International’s Waterbird Population Estimates (Wetlands International 2006) and Status of Waterbirds in Asia (Wei et al. 2009). These comparisons were made in order to determine which species met Criterion 6 of the Ramsar Convention for wetlands of global significance (i.e. regularly supporting 1% of the individuals in a population of a species of subspecies of waterbird). Total number of waterbirds recorded in each of the wetlands during each study year was also estimated to examine whether they met Criterion 5 of the Ramsar Convention (i.e. regularly supporting 20,000 or more waterbirds).

11. Potential threats to the waterbirds

Data on the direct and indirect threats to the waterbirds were collected during each census period. For detecting the threats careful reconnaissance were made in and around each of the wetlands for detecting any sign of waterbird carcass, feathers, egg-shells, waterbird traps and other devices used for killing or capturing waterbirds, hunters, poachers, wetland area loss or reclamation, eutrophication, water hyacinth cover, overfishing, runoffs etc. Waterbird carcasses
and other body parts whenever observed were identified and counted. Information on hunting or poaching was also collected from the local people and nature lovers. The factors responsible for the mortality of the waterbirds were investigated and noted down and they were ranked as per intensity. The criterion for level of threat (LT) is based on Collar et al. (1994). LT for particular wetlands were presented as annual percentages of threat levels (Upadhyaya and Saikia 2010). Data on uses and threats at each wetland sites were collected on a standardised format prepared for the purpose. However, to have a more comprehensive idea of the potential threats in addition to 8 wetlands studied for population trends and community composition, three newly recorded wetlands have also been studied. They were Mayureswar wetland complex (Birbhum district), Agradwip and Patuli island complexes (Burdwan district) .

The condition of the waterbird habitat, with respect to the area clogged with water hyacinth was assessed during all the census years following Khan (2010 and 2012). Aerial photographs were also taken, which helped in making the initial layout of the wetlands. The percent cover of the water hyacinth was estimated mainly from aerial photographs and Global Positioning system (GPS) (Garmin; eTrex®) data on Map Maker Pro Package, Version 3.5 [Map Maker Ltd, The Pier, Carradale, Kintyre, PA28 6SQ, UK (www.mapmaker.com)] following Khan (2010 and 2012).

The effects of water hyacinth cover on the phytoplankton density, dissolved oxygen concentration, phytoplanktonic productivity, zooplankton density and fish, as well on the important waterbirds have assessed using GLMs. The impacts of the wetland attributes on the zooplankton density and fish density were also assessed using GLMs. However, in these cases Normal distribution with logarithmic link was used instead of Poisson distribution with logarithmic link. The same procedure of backward elimination was used for these models also.