Emergence of a wetland with the potential for an avian abode of global significance in South Bengal, India

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We studied the waterbird diversity and abundance in a newly constructed wetland in South Bengal for 14 years right from its establishment. Soon after its construction, the wetland began to attract a rich diversity of waterbirds and with the passage of time has proved its potentiality to achieve the status of a wetland of international importance. Since 2005, it continues to support Greylag Goose at populations exceeding 1% threshold, and from 2007 onwards harbours Ruddy Shelduck at populations exceeding 1% threshold. Since the populations of majority of the important species have been increasing, it is expected to achieve the status of a Ramsar Wetland soon, provided we keep the wetland undisturbed and allow it to follow its own course by implementing monitoring programmes on a long-term basis.

Keywords: Diversity estimates, habitat expansion, population trends, waterbird abundance, wetland.

WETLANDS provide excellent habitats for waterbirds. However, natural wetlands are in drastic decline throughout the world[1,2]. Parallelly, man-made wetlands have increased worldwide, and these often provide suitable habitats for waterbirds[3–7]. But very little is known about the waterbirds which are capable of adopting such new habitats, and those which fail to do so[3,5].

The wetlands in Birbhum District, South Bengal, have long been known to support rich diversity of waterbirds. In 1999, an increase in wetland coverage occurred in the region with the creation of the Bakreswar Reservoir[8]. This addition has resulted in a notable change in the scenario of monotonous decline of waterbirds in the region. Since its creation, the Bakreswar Reservoir began to attract waterbirds, especially long-distance migrants. Today it has established itself as a flourishing waterbird habitat proceeding to achieve the status of a wetland of international importance.

This communication presents the first detailed account of waterbird assemblages and population trends in the Bakreswar Reservoir with an attempt to quantify its potentiality of achieving the status of a Ramsar Wetland. Our main objectives are: (1) to analyse the waterbird assemblages; (2) to understand the importance of this wetland by assessing whether it meets the Ramsar Criterion 6 (i.e. regularly supporting 1% threshold of a population of a waterbird species)[9,10]; (3) to identify long-term trends for each waterbird species and (4) to consider the conservation implications of our findings.

This study was conducted in Bakreswar Reservoir (lat. 23°50.519′N; long. 87°24.612′E), Birbhum District (Figure 1). The reservoir (area 6.38 sq. km) was formed by erecting a dam on the Bakreswar River for providing water to the Bakreswar Thermal Power Plant, which was commissioned in 1999. The wetland is rich in macrophytes like sedge (*Scirpus* spp.), reed (*Fragmites* sp.), pond weeds (*Potamogeton* spp.), hornworts (*Ceratophyllum* spp.), water lettuce (*Enteromorpha* sp., *Pistia* sp.), Kans grass (*Saccharum spontaneum*), etc. It also supports a rich diversity of macro-invertebrates and fish. The security personnel of the thermal power plant protect the reservoir along with its denizens. However, fishermen and tourists often create disturbance to the birds there.

To coincide with large-scale Asian Waterfowl Census Programmes coordinated by Wetlands International, waterbirds were counted during 1–30 January of each year from 1998 to 2011. Waterbird counts were performed on foot and country boat by three to five observers using the same methods, as described by Khan[2] and Sinha *et al.*[8]. During each census, counts were begun at 8 h IST and continued until the total waterbird count of the entire wetland was completed.

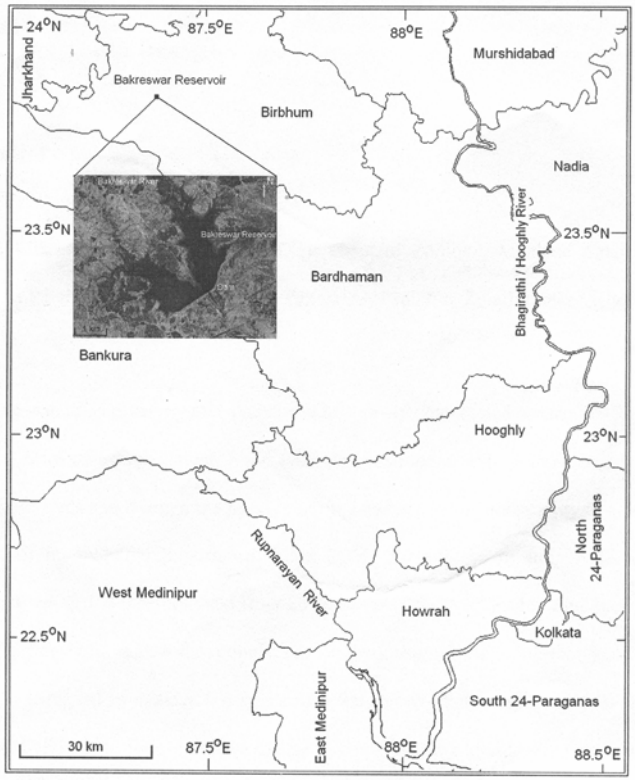

Figure 1. Map of South Bengal showing the Bakreswar Reservoir. Aerial view of the reservoir is also shown.

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Table 1. Different components of waterbird diversity in Bakreswar Reservoir for the period between 1998 and 2011 (figure in parenthesis represents the year in which the components were recorded)

Diversity components	Maximum	Minimum	Mean ± SE
Number of species	40 (2000 and 2010)	32 (1998)	37.5 ± 0.77
Number of birds	7342 (2011)	1469 (2003)	4021.6 ± 518.9
Shannon–Weiner diversity	2.863 (2002)	2.598 (2011)	2.76 ± 0.02
Evenness	0.503 (2003)	0.371 (2010)	0.425 ± 0.01
Margalef's species richness	4.876 (2000)	3.707 (2011)	4.467 ± 0.08

Table 2. Poisson-based log-linear models for the population trends of waterbird species in Bakreswar Reservoir between 1998 and 2011

Species	Index[a]	Estimate ± SE[b]	χ^2 (df = 1)[c]	P	Inference[d]
Great Cormorant (*Phalacrocorax carbo*)	1.79	0.051 ± 0.023	6.31	0.012	Moderate increase
Little Cormorant (*Phalacrocorax niger*)	2.25	0.059 ± 0.023	10.19	0.001	Moderate increase
Little Grebe (*Tachybaptus ruficollis*)	2.94	0.080 ± 0.019	19.26	< 0.001	Moderate increase
Great Crested Grebe (*Podiceps cristatus*)	1.52	0.041 ± 0.065	0.79	0.373	Uncertain
Greylag Goose (*Anser anser*)	6.49	0.104 ± 0.036	12.92	< 0.001	Moderate increase
Bar-headed Goose (*Anser indicus*)	631.88	0.537 ± 0.206	6.84	0.009	Moderate increase
Lesser Whistling Duck (*Dendrocygna javanica*)	6.91	0.141 ± 0.068	11.22	< 0.001	Uncertain
Ruddy Shelduck (*Tadorna ferruginea*)	5.31	0.142 ± 0.032	28.94	< 0.001	Strong increase
Northern Pintail (*Anas acuta*)	3.51	0.089 ± 0.025	18.08	< 0.001	Moderate increase
Common Teal (*Anas crecca*)	4.49	0.137 ± 0.033	17.08	< 0.001	Strong increase
Gadwall (*Anas strepera*)	1.93	0.053 ± 0.021	6.12	0.013	Moderate increase
Eurasian Wigeon (*Anas penelope*)	2.75	0.091 ± 0.023	22.44	< 0.001	Moderate increase
Northern Shoveler (*Anas clypeata*)	6.43	0.146 ± 0.066	15.75	< 0.001	Moderate increase
Cotton Pygmy Goose (*Nettapus coromandelianus*)	6.49	0.104 ± 0.036	12.92	< 0.001	Moderate increase
Red-crested Pochard (*Rhodonessa rufina*)	2.09	0.055 ± 0.027	4.52	0.033	Moderate increase
Ferruginous Duck (*Aythya nyroca*)	10.9	0.133 ± 0.062	14.35	< 0.001	Moderate increase
Tufted Duck (*Aythya fuligula*)	12.98	0.226 ± 0.043	89.36	< 0.001	Strong increase
Common Moorhen (*Gallinula chloropus*)	0.41	–0.050 ± 0.054	4.13	0.042	Uncertain
Common Coot (*Fulica atra*)	11.65	0.175 ± 0.031	52.64	< 0.001	Strong increase
Pheasant-tailed Jacana (*Hydrophasianus chirurgus*)	2.21	0.057 ± 0.015	15.87	< 0.001	Moderate increase
Grey-headed Lapwing (*Vanellus cinereus*)	1.84	0.049 ± 0.023	4.87	0.027	Moderate increase

[a]Model-based indices calculated from the summation of model predictions of all time points from 1998 to 2011 (n = 14), i.e. the model-based time totals; the index for 1998 is 1.00. [b]Slope parameter estimate. [c]Wald χ^2 test for significance of slope parameter. [d]Model-based inference.

The census data for all the years were processed for waterbird diversity using the program PAST (version 2.10)[11]. Population trends were analysed on Poisson-based log-linear modelling framework using the program TRIM (version 3.54)[12]. 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, the significance of which is examined by Wald χ^2 test.

A total of 56,313 waterbirds belonging to 42 species were recorded during the course of this study. Among them 19 species were long-distance winter visitors, whereas the others were residential or local migrants[8,13]. Shannon–Weiner diversity of waterbirds in different census years (Table 1) ranged between 2.598 (in 2011) and 2.863 (in 2002), while the highest species evenness (0.503) was observed in 2003 and the lowest (0.371) in 2010. The Margalef's species richness was highest in 2000, whereas it was lowest in 2011. The mean number of waterbird species was highest in 2000 and 2010 and lowest in 1998, while the total number of birds was highest in 2011 and lowest in 2003.

Among 42 waterbird species encountered in this study, 23 were either vagrants or exhibited low abundance. Therefore, the species for which a total of at least 500 individuals were encountered over the 14 census periods, were considered for population trend analysis. However, Northern Shoveler and Ferruginous Duck were considered for this analysis since they were important long-distance migrants here[8].

The model-based index values for each species (Table 2) indicated that 18 of 21 common and important waterbirds increased between 1998 and 2011. Species showing strong increases included Ruddy Shelduck, Common Teal, Tufted Duck and Common Coot. Other species, excepting Great Crested Grebe and Lesser Whistling Duck, exhibited moderate increase during the period.

The census data suggest that the Bakreswar Reservoir met Ramsar Criterion 6 consistently during the period from 2005 to 2011 (7 years at a stretch), during which it supported populations of Ruddy Shelduck exceeding 1%

Table 3. Global significance of Bakreswar Reservoir as indicated by the populations of individual species with 1% threshold (i.e. 1% of the South Asian population; Ramsar Criterion 6)

Species	2003–11 (range)	Mean ± SD	1% threshold	# Censuses > 1%	Maximum % met
Bar-headed Goose	0–898	86 ± 234.18	560	1	1.6
Greylag Goose	0–292	138.86 ± 109.01	250	5	1.17
Ruddy Shelduck	38–578	341.1 ± 200.5	500	7	1.16

One per cent threshold population estimates were taken from refs 9 and 10. '# Censuses' refer to the number of surveys in which Ramsar Criterion 6 (i.e. 1% criterion) was met between 1998 and 2011 (maximum in all the cases = 14).

threshold (i.e. 1% of the South Asian populations). Moreover, Greylag Goose met 1% threshold at a stretch for five years from 2007 to 2011. Bar-headed Goose also met 1% threshold in 2011 (Table 3).

Our study confirms that the Bakreswar Reservoir is gradually attaining its potential to establish itself as a Ramsar Wetland provided this trend is maintained. Two long-distance migratory waterbirds tend to regularly use this wetland at levels of abundance that are deemed globally significant, while the populations of some other species have been increasing.

On the other hand, consistent increase in the abundances of the waterbirds may well have been associated with the development of the Bakreswar Reservoir as an attractive waterbird abode. We were impressed with the abundance and diversity of waterbirds in this wetland soon after its construction. The construction of this wetland was completed in 1999 and the waterbirds began to arrive in large numbers from 2001 onwards. Compared to the 1998 inventory, waterbird species diversity has increased in the recent years. Soulliere and Monfils[14] obtained similar results from their study on a constructed wetland complex in Michigan. These increasing trends may well be attributed to the adequate size of food sources of different species, especially reed and sedge, to cater more to the waterbirds[8]. The highest species richness and density of waterbirds is known occur in reed beds[15]. Moreover, many waterbirds, especially Ruddy Shelduck and Greylag Goose, feed on both of these macrophytes in Birbhum[16]. Adequate protection of the Bakreswar Reservoir rendered by the West Bengal State Electricity Board might have also played a positive role in making the wetland a flourishing waterbird abode.

Therefore, our findings show that the observed increase in waterbirds is associated with the addition of the Bakreswar Reservoir in the wetland chain of the region, thus expanding the amount of habitat available for the waterbirds. Such increase in waterbirds in response to habitat expansion has been a widespread phenomenon in different parts of the world[1,7,17]. However, since wetland vegetation and faunal composition have a positive influence on waterbird abundance and diversity[18,19], a newly constructed wetland obviously requires some time to accumulate the required flora and fauna (i.e. resources for the waterbirds), so that it can support a rich variety of waterbirds in sufficient numbers. This might have constituted one of the important causes of lower waterbird diversity and abundance observed during the earlier phases of the Bakreswar Reservoir. Therefore, it failed to support adequate number of waterbirds, and thus Greylag Goose and Ruddy Shelduck populations could not meet 1% level during the first seven years of its establishment. However, with the passage of time along with the accumulation of required food resources for these birds (especially reed and sedge), they began to arrive at levels of abundance that are deemed globally significant.

The processes governing waterbird abundance and diversity are not yet well understood. This lacuna certainly limits the options for implementing management strategies aimed at optimizing waterbird diversity. However, the Bakreswar Reservoir has already shown its potentiality and if we leave it undisturbed and allow it to follow its own course by implementing monitoring programmes on a long-term basis, it will certainly become one of the richest Ramsar sites in southeast India.

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Scenedesmus as a potential source of biodiesel among selected microalgae

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Energy security has become a national issue and several attempts are being made to seek viable alternatives in the form of renewable energy to meet the futuristic needs. Biofuel production from microalgae is considered as an effective strategy in this endeavour. Seven microalgae, viz. *Chlorella, Haematococcus, Ulothrix, Chlorococcum, Scenedesmus, Rivularia* and *Scytonema* were selected from 16 isolated cultures from six freshwater bodies. *Ulothrix* sp. reached a high growth rate of 0.42 ± 0.01 g/l and low lipid content of 5.56 ± 0.81% on the 15th day of incubation. Under similar conditions, *Scenedesmus* sp. reached a growth rate of 0.38 ± 0.01 and recorded a lipid content of 27.4 ± 0.75%. Algal oil samples were analysed by thin layer chromatography and Fourier transform infrared spectroscopy. The fatty acid composition was detected by gas chromatography. *Scenedesmus* sp. showed the highest amount of oleic acid (11.77 mg g^{-1} dry wt). The results suggest that *Scenedesmus* sp. is useful for producing biodiesel, based on its high lipid and oleic acid contents.

Keywords: Biodiesel, fatty acid, growth analysis, lipid content, microalgae.

GLOBAL warming and the exhaustion of fossil fuels are major worldwide problems. Thus, the production of biodiesel using various materials, such as plants, microalgae and animal fat, has been attempted as an alternative energy source[1]. Bioenergy is one of the most important components to mitigate greenhouse gas (GHG) emissions and for substitution of fossil fuels. The study of algae for fuel has become a hot topic in recent years with energy prices fluctuating widely and GHG emissions increasingly becoming a cause for concern.

Biomass has been focused upon as an alternative energy source, since it is a renewable resource and fixes CO_2 in the atmosphere through photosynthesis. If biomass is grown in a sustained way, its combustion has no impact on the CO_2 balance in the atmosphere, because the CO_2 emitted by the burning biomass is offset by the CO_2 fixed by photosynthesis[2]. Among biomass, algae usually have a higher photosynthetic efficiency. Many algal species have been found to grow rapidly and produce substantial amounts of triacylglycerol or oil, and are thus referred to as oleaginous algae. It has long been postulated that algae could be employed as cell factories to produce oils and other lipids for biofuels and other biomaterials[3]. An accurate method for lipid quantification in algal biomass is necessary for the purpose of selecting optimum species and growth conditions. In this study, the algal growth rate, biomass production, lipid content and productivity of microalgal cultures isolated from freshwater bodies were determined. Furthermore, the fatty acid composition was detected using gas chromatography (GC), and algal oil samples analysed using thin layer chromatography (TLC) and Fourier transform infrared (FTIR) spectroscopy.

Water samples for microalgae isolation were collected from different sites (in and around Gandhigram Rural Institute-Deemed University, Gandhigram, Tamil Nadu, India) that appeared to contain algal growth in freshwater bodies. All samples were collected at about the same time between 0800 to 1100 h. Surface water and water at a depth of 0.50 m were collected at each location. Water

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