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Integration of Ecological and Geospatial Methods to Understand the Relationship between Major Attributes of Wetlands and their Dependent Water Birds in West Bengal: A Review

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Abstract

Characterizing the relationships between species composition and environmental conditions is a basic objective of ecology. The predictors of species composition typically include variables such as climate, topography, land cover and random processes. The objective of the review is to quantify the effect of environmental determinants on water bird population trends in wetlands at various spatial scales by integrating ecological and geospatial methods.

Keywords: waterbirds, wetland attributes, stopover sites, conservation, species distribution modelling

Introduction

Wetlands—with their abundance of food, nesting habitat, and coverare some of the most important and diverse habitats for wildlife in general, and birds in particular (Sather and Smith, 1984). Wetland classification system devised by Cowardin et al., 1979 categorized wetlands into marine (coastal wetlands), estuarine (including deltas, tidal marshes, and mangrove swamps), lacustrine (lakes), riverine (along rivers and streams), and palustrine (‘marshy’– marshes, swamps and bogs) based on their geological features, hydrology and ecology. A more specific definition by Ramsar Convention on Wetlands, an international treaty for the conservation and wise use of wetlands and their resources, is ‘areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters’.

Wetlands form as a result of complex interactions among abiotic and biotic components of the environment. Variations within each of these environmental components and the way in which these components interact can affect the major wetland attributes (aquatic vegetation, vegetation density, turbidity, water depth, water area etc.) in certain ways.It is important to understand the relationship between these environmental variables and major wetland attributes to examine the habitat suitability of the wetlands to support biodiversity in those areas.

In recent times, wetlands have undergone extensive loss and damage due to huge rise in growing global populations and increasing urban and industrial sprawl. An amalgamated review (Davidson, 2014) of 189 reports of change in wetland area discovers that there has been a long-term loss of natural wetlands on an average of 54-57%. This review also states that rate of loss remains high in Asia, where there is a continuous and rapid conversion of coastal and inland natural wetlands. Climate change plays a major role in wetland loss apart from land-use conversion. This loss has an immense adverse effect on ecosystem services provided by these wetlands. Rapid urbanisation has led to construction of buildings by

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damaging a potent wetland. This in turn is affecting the diversity of both flora and fauna dependent on wetland by causing a shift, expansion and fragmentation of species ranges (Chen et al., 2011). This degradation problem due to growing anthropogenic pressure is also affecting the livelihood dependency of most rural people whose major source of earning is wetland fish. Thus, a thorough knowledge of the wetlands in West Bengal and its proper classification based on physico-chemical, hydrological and livelihood dependency will help to identify the wetlands under threat and thus to propose proper management plan for them.

Rate of wetland loss in India is at 2 to 3% of area every year. 70-80% of the wetlands in the Ganges basin have been lost in the past 50 years. Mangrove wetlands have reduced from 700,000ha to 453,000 ha in India.This loss of wetlands across the globe has dangerously reduced the availability of stopover sites for migrating birds and has increased the importance of remaining wetlands to migrants as well as nesting birds(Myers et al. 1987). Yet, these remnant stands are under continual threat of development, pollution, invasion by aggressive plant and animal species, and sedimentation (Bellrose et al. 1983; Illinois Wildlife Habitat Commission, 1985).

A habitat has long been used as a predictor of bird species abundance(Kumar A. et.al., 2005), and various birds have developed different preferences for a specific habitat (Huston, 1994). Wetland attributes are an important factor to be considered by water birds when they select a wetland, so that it is suitable for their needs such as food availability and accessibility, reproduction and less vulnerable to predators(Manu, 2000). A study on species diversity of wild birds in a Nigerian waterfowl sanctuary (Lameed, 2011) revealed a positive relationship between percentage ground cover, shrub density and tree density to bird species recorded. Results of a study made by (Rajpar and Zakaria, 2011) revealed that the habitat characteristics such as vegetation composition, structure and environmentalvariables such as temperature, relative humidity and light intensity were important in determining the distribution, diversity and density of the wetland birds a Natural Wetland Reserve, Peninsular Malaysia.(DesGranges et al, 2006) also revealed that many breeding bird species were strongly associated with specific wetland plant communities.

A large number of water bird species are extremely reliant on one of the major attributes of wetlands: its vegetation, mainly for food and nesting. Decline in bird populations are mainly due to habitat loss and fragmentation, invasion of few non-native plant species and global climate change. Birds play critical roles in wetland ecosystems by acting as herbivores, predators and prey, and being facilitators for plant dispersal. Also, they provide great intrinsic value to wetlands. Therefore, conservationists and wetland scientists have a keen interest in how wetland construction and restoration can support species that require wetlands for survival. Therefore, it becomes important to mark wetland habitats that are suitable for water birds.

Availability of world-wide bioinformatic databases has opened new avenues to analyse species occurrence data which subsequently supports conservation efforts (Jetz et al., 2012). Such studies can bring out an approach towards conservation which is more systematic and based on evidences (Margules and Pressey, 2000, Sutherland et al., 2004). The objective of this review is to propose an integrative approach for combining biological records through surveys with spatial environmental data to construct habitat suitability models. The analysis of these models might prove helpful in making robust conservation management decisions (Guisan et al., 2013).

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Distribution of Wetlands in West Bengal

The lower Gangetic Plains of West Bengal is bestowed with a diverse wetland regime, ranging from freshwater inland wetlands like rivers and lakes, marshes and swamps, mountain wetlands and also coastal wetlands like mangroves, tidal flats, swamps etc. Amongst themanmade wetlands present in West Bengal, there are fish and shrimp ponds, farm ponds, irrigated agricultural land, reservoirs, sewage farms, and canals. NWIA (National Wetland Inventory and Assessment) data states that India represents a total of 15.260 Mega hectare as wetland area, which is 4.63% of the geographical area. The total wetland area is estimated to be 10 Mega hectares after exclusion of rivers and streams. State-wise distribution of wetlands showed that West Bengal has 12.48% of geographic area under wetlands. West Bengal harbours 1327 lakes and a large number of riverine wetlands. Small wetlands (less than 2.25 hectare) are 55,55,557 in number in India out of which West Bengal has highest number of small wetlands (1,38,707) (Source: Ministry of Environment & Forests, Government of India). There are 42 Ramsar sites in India covering 1,081,438 ha of total area out of which West Bengal contains 2 Ramsar sites namely East Calcutta Wetlands (12,500 ha) and Sundarban Wetland (4,23,000 ha) (Ramsar Secretariat, 2019). The AhironBeel in Murshidabad, Patlakhawa- RasomatiBeel and RasikBeel in Cooch Bihar and SantragachiJheel in Howrah have been identified as Wetlands of National Importance and are under the National Programme for Conservation of Aquatic Ecosystem (NPCA).
Apart from classifying wetlands in a conventional way, for wetlands of India, it is imperative to primarily divide them into two classes, A and B. 1. Class A wetlands are within protected area and safeguarded by Indian Forest Act, 1927, where the conservation of wetland habitat is obligatory. 2. Class B wetlandsare water bodies which fall outside any protected area and there are no defined rules to prevent damage of these wetland habitats. Wetlands classified as Class B go unnoticed and are severely threatened.

Wetland Values

Wetlands, with their unique ecological characteristics provide variousecosystem products and services to mankind(Prasad et al., 2002). Ecosystem products include fisheries, water supply for irrigation, non-timber forest products and recreation etc. Major services include flood control, carbon sequestration, nutrient removal, toxic retention and biodiversity maintenance (Turner et al., 2000).The inland freshwater wetlands, oxbow lakes and swamps serve as amajor livelihood source for most of the people in rural West Bengal and therefore, play an important role in improving nation’s economy.

Wetlands as Stopover sites for Migratory birds

Wetlands are extensively used by migratory birds as stop over sites. As birds tend to use the same stop over sites year after year, it is important to protect these habitats so that they can cater to the needs of the migrating birds. The state of West Bengal is an abode to 861 reported bird species (Rahmaniet.al., 2016). Bird Census in 4 important wetlands of Southern Bengal revealed that all these sites are important wintering, nesting and breeding grounds for a number of waterbirds (Majumder et al., 2007). In a recent study conducted by West Bengal Forest department to observe the World Wetland Day on 2nd February 2021, the team documented 1,23,675 waterbirds belonging to 65 speciesfrom 54 wetlands in West Bengal.

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Wetland losses

Anthropogenic influence on our environment is directing a loss between 1/3 to 2/3 of all currently living species (Myers and Knoll, 2001). Global extinction is taking a big toll onbirds and a study (Birdlife International. (2008)indicates that 1 in 8 known bird species are jeopardized by this widespread and rapid decrease in biodiversity on our planet. Van Dooren (2014) states that an interdisciplinary approach is the need of the hour to understand population trends and behaviour of birds and their interactions. with the surrounding environment.

In due course of time, anthropogenic expansion and change in the bioclimatic structure of the world has resulted in loss of many suitable wetland habitats. Wetlands throughout the world have faced tough situations to survive through the phases of destruction and India is no exception.Biologists around the globe are making attempts to identify the habitats that need to be prioritized for conservation (Norman, 2003, Olson and Dinerstein,1998,Stattersfield et al., 2005)

India comprises of numerous natural wetlands such as rivers, lakes, coastal lagoons, mangroves, peat land, coral reefsand manmade wetlandssuch as ponds, farm, irrigated fields, reservoirs, sewage farms and canals. Only 42 of these numerous wetlands have been designatedas Ramsar Sites in India out of which only 2 of them are designated as Ramsar Site in West Bengal (Ramsar Secretariat, 2019) and couple of them fall under the National Programme for Conservation of Aquatic Ecosystem (NPCA). However, many other wetlands which perform potentially valuablefunctions and are an abode to several resident and migratory water birds are continued to be ignored in the policy making process for conservation. Therefore,a large number of wetlandsecosystems are threatened and many are already degraded and lost due to increased anthropogenic interferenceand drainage & conversion for agriculture and aquaculture (Kumar et.al., 2005) Several studies on existing wetlands (Palitet.al., 2019, Sarkar et.al., 2013; Sinha et.al., 2011, Nayak, 2019 and Adhuryaet.al., 2019) has revealed that alteration in wetlands bears a negative impact on population trends of waterbirds. An emerging wetland in South Bengal was studied for long term (Sinha et.al., 2012) and the authors established that the wetland has a potential to become a Ramsar Site in near future if it remains undisturbed and follow its own course. Another emerging habitat for waterbirds was found in Murshidabad district (Dey, 2020).The matter of concern, right now, is the non-inclusion of these old and emerging wetlands under the Indian Government's initiatives, namely, National Programme for Conservation of Aquatic Ecosystem (NPCA).

Relationship between few Wetland Attributes and their dependent water birds

Vegetation

Aquatic vegetation (mainly algae and macrophytes) being the main source of food and energy, are an important wetland attribute, because it functions as the energy source for higher organisms such as water birds. It is reported that more productive systems indicated by higher nutrient and chlorophyll concentration may have a larger food base and, therefore, support increased water bird species richness (Hutchinson 1959; MacArthur 1970; Wright 1983). Many studies have established the fact that wetland vegetation and its faunal composition have a positive influence on waterbird abundance and diversity (Bellrose,1980; Helmers, 1992, Kaminski and Prince 1984; Hanson 2008). Birds choose their stopover and nesting sites on the basis that the chosen wetland habitat meets their immediate needs (Venier

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and Fahrig 1996; Weller 1999). Their reproductive success also depends upon availability of prey in those habitats (Owen 1960; Powell 1983; Hafner et al. 1986).

Wetland area and depth

Waterbird assemblages has a strong relationship with some of the physical wetland attributelike wetland area (Babbitt, 2000) and depth (Edwards and Otis, 1999). Qualitative attributes like food base varies with climatic changes and other water attributes such as water temperature, turbidity, dissolved oxygen, nitrates and phosphates. Therefore, it is important to study the effect of climate on wintering grounds of waterbirds at the onset of migration (Khan et. al., 2005).

Khan, 2010 and Khan et. al., 2016 determined that waterbird diversity was typically influenced by three or more wetland attributes selected as potential predictors for waterbird diversity and abundances. Phytoplanktonic productivity and wetland area are the two main attributes that influenced waterbird diversity estimates, made in his study. Food accessibility, another important factor, has a major influence on wetland habitat selection by waterbirds (Bolduc and Afton 2004). Wetland attributes such as water depth, turbidity, vegetation cover influence food accessibility to waterbirds. Such attributes vary among wetlands or among different seasons in the same wetland habitat, therefore, waterbirds select wetlands with attributes that maximise the abundance and accessibility of their foods (Taft and Haig 2003).

A complete holistic understanding of relationships between few selected wetland attributes and waterbirds inhabiting these wetlands can contribute to the development of a suitable wetland management plan. A study (Ray et.al., 2012) on selected bils of Nadia district in West Bengal has qualitatively characterized and delineated wetlands based on two wetland attributes, namely, turbidity and aquatic vegetation. The study utilized Remote Sensing data and Digital Image Processing techniques to achieve the tedious process of wetland mapping in a relatively shorter duration Thus, the identification of these attributescalls for an integrative approach and the present review may provide guidelines for future progress in this regard.

Repositories for integrative approach

Global Biodiversity Information facility

To estimate global habitat loss, one needs easily accessible biodiversity data and availabilityof the same has posed a big challenge in the past (Bisby, 2000). To overcome such a problem, GBIF has become a boon to biologists. GBIF, the Global Biodiversity Information Facility, is an international organisation which providesopen access biodiversity data, to anyone and anywhere,about all types of life on Earth. At present, there are 1651 host institutions providing more than 1 billion records(http://www.gbif.org/ accessed 2nd March 2021).Research studies have shown that GBIF aids to retrieve large number to accurate data pointsand can be utilized to study biodiversity patterns (Yesson et al., 2007).

Worldclim

Worldclim(https://worldclim.org)is a database that provides maps, graphs, tables and high spatial resolution data of global climate. It provides historical (near current) and future

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weather and climate data which can be used to derive relationships between changing biodiversity patterns and global climate change.

Wetland inventory

Wetland inventories store multi-dimensional information about wetlands at global, national and regional level, so that, it becomes convenient for policy makers to prioritize wetlands which require immediate conservation measures (Rebelo et. al., 2009). Unfortunately, in many cases, these baseline wetland inventories are incomplete, and the information collected is inconsistent. (Finlayson and Spiers, 1999). The geospatial analyses involving a combination of satellite imagery, air photographs and ground information relating to land cover and land use at multiple-scales have given a right direction to develop a uniform baseline inventory and apply the information from these inventories in a proper way to be used for conserving wetlands (Finlayson et al., 1999; Lowry, 2006; Davidson and Finlayson, 2007).

Winsys

Wetland Information System (Winsys) is a scientific inventory of wetlands which houses wetland related information in geospatial format for the state of West Bengal. This information system was created at a pilot scale by Space Application Centre (SAC), Ahmedabad, India, in collaboration with Institute of Wetland Management and Ecological Design, Kolkata, India and National Atlas and Thematic Mapping Organisation, Kolkata, India.This spatial framework can be utilized for monitoring the health of wetland ecosystems,Winsys has provision for extension by incorporating ecological information such as water quality, flora and fauna for important wetlands which have either been investigated earlier or will be studied in future and thereby can be of extensive use to researchers and policy makers to conserve wetlands.

East Kolkata Wetland (EKW) report

This extensive report on a Department of Science and Technology, Government of India, sponsored research project includes identification of wetlands using multi-spectral remote sensing data. The report summarises change in land use/land cover due to urbanisation and recommends strategies for developing balanced urban expansion so that wetlands are not disturbed (Sarkar, 2004)

An Integrative Approach

The need of the hour is to build a robust biodiversity conservation plan by bringing all the small, old and emerging wetlands under one umbrella.Prior to the field visits, the sampling area can be divided into grids (say $100m^2$) by Geographical Information System Application (ArcGIS or QGIS). This enables the creation of grids by overlaying them over the satellite imagery of selected wetlands. Satellite imagery of these wetlands can be obtained using Google Earth. These grids can then be used during real time survey to make a checklist of waterbird species present in these habitats. In addition, point count methodcan be adopted to estimate the species diversity and species richness. The waterbird species which are abundant in the wetland area under study can then be selected. The field survey data for these selected water bird species can be supplemented with the spatial distribution data for these birds which can be obtained from the Global Biodiversity Information facility (GBIF) database.

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Wetlands with suitable habitats for waterbirds selected on the basis of geospatial data need to undergo extensive ground truth verification to assess the actual ecological health of the wetland habitat under study. Ground truth reality check is quite important to ascertain the habitat suitability of the selected wetland. The criteria for ground truth verification must include presence of sufficient food-base (Khan et.al., 2016), abundant shelter, minimal anthropogenic disturbance in the area and comparatively less pollution. Therefore, ground truth verification plays an important role as it becomes a deciding factor to assess whether the selected wetland can cater to the needs of the dependent water birds.

The selected wetland can then be (1) intersected for georeferenced species locality points with spatially explicit GIS-based environmental data characterizing wetland habitat.This way, (2) all wetland regions that contain similar habitats compared to known bird localities to characterize the potential distribution of the species can be identified. (3) Next is the identification of the future available habitat based on a range of climate change scenarios (Worldclim database) to predict the changes in species' distributions as climate changes. Localities for each species can then be intersected with contemporary environmental data in a GIS framework. (4) The resulting data can be used with, Maxent, a commonly used ENM algorithm, to model the environmental niche of each wetland bird species. The ENM models will then be used to quantify the probability of occurrence for each species in wetlands of selected area. (5) Each SDM (Species Distribution Model) can then be used with future environmental data from multiple Global Climate Scenario (GCM) predictions to identify areas of suitable habitat in the 2050s, and 2080s across the region. Comparisons of current and future probability of occurrence maps will allow for the identification of sites where current and future habitat will be suitable for a particular species as well as sites where current habitat is suitable, but future habitat will not be suitable (Das S. et al., 2020). These different outcomes will provide important information directing management and conservation efforts on a species-by-species basis.

This integrative approach will be quite useful to select conservation priority sites so that waterbirds suitable habitat receives importance for conservation at Regional, National and International levels.

Conclusion

The expected climatic changes have already been detected and are having measurable impacts on the environment. Accordingly, the use of GIS temperature, precipitation, and landcover data to predict species distributions and understand the impact of changes in climate on biodiversity has recently received an intense amount of interest, and the proposed integrative approach will certainly contribute to our understanding of the impacts of these changes on wetland systems. Merging ecological studies with geospatial data and their associated methodological toolkits will certainly bring explicit hypothesis testing to the field of wetland ecology in relation to their water birds. Hypothesis derived from one approach can be reciprocally tested with data derived from other field and the synthesis of these data can help place population trends in a historical and spatial context.

References

1. Adhurya S., Adhurya S., Roy U. S. (2019), 'Rapid degradation of wetlands and its impact on avifauna: A case study from Ambuja Wetland, West Bengal, India', Indian Birds, 15(2): 43-48

2. Babbitt K. (2000), 'Use of temporary wetlands by anurans in a hydrologically modified landscape', Wetlands, 20: 313–322
3. Bellrose F.C. (1980), 'Ducks, Geese and Swans of North America', Stackpole Books, PA, USA, p. 544

4. Bellrose F.C., Havera S.P., Paveglio J.F.L., Steffeck D.W. (1983), 'The fate of lakes in the Illinois River Valley', Illinois Natural History Survey Biological, Notes 119

5. Bisby F.A. (2000), 'The quiet revolution: Biodiversity informatics and the internet. Science', 289: 2309–2312

6. Bolduc F., Afton A.D. (2004), 'Relationships between wintering waterbirds and invertebrates, sediments and hydrology of coastal marsh ponds', Waterbirds, 27: 333–341

7. Chen I.C., Hill J.K., Ohlemuller R., Roy D.B., Thomas C.D. (2011), 'Rapid range shifts of species associated with high levels of climate warming', Science, 333: 1024–1026.

8. Cowardin L.M., Carter V., Golet F.C., LaRoe E.T. (1979), 'Classification of Wetlands and Deepwater Habitats of the United States'. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC
9. Das S., Mukherjee A., Gupta S. (2020), 'Spatial prioritization of selected mining pitlakes from Eastern Coalfields region, India: A species distribution modelling approach', Conservation Science and Practice, 2(216): 1-17. https://doi.org/10.1111/csp2.216

10. Davidson N.C. (2014), 'How much wetland has the world lost? Long-term and recent trends in global wetland area. Marine and Freshwater Research' 65. 936-941. 10.1071/MF14173.

11. Davidson N.C., Finlayson C.M., (2007), 'Earth Observation for wetland inventory, assessment and monitoring, Aquatic Conservation: Marine and FreshwaterEcosystems' 17: 219-228

12. DesGranges et al, 'Modelling wetland bird response to water level changes in the Lake Ontario – St. Lawrence River Hydrosystem', Environmental monitoring and assessment, 113: 329-365, 2006

13. Dey S.R. (2020), 'Sagardighi Ash Pond: A New Water Bird Habitat in Murshidabad district, West Bengal, India', International Journal of Advanced Life Science Research, 3(4): 26 – 36, https://doi.org/10.31632/ijalsr.20.v03i04.004

14. Dooren V. (2014), 'Flight ways: life and loss at the edge of extinction': Columbia University Press

15. Edwards N., Otis D. (1999), 'Avian communities and habitat relationships in South Carolina Piedmont beaver ponds', American Midland Naturalist, 141: 158–171

16. Finlayson C.M., Davidson N.C., Spiers A.G., Stevenson N.J., (1999), 'Global wetland inventory: current status and future priorities', Marine and Freshwater Research, 50 (8): 717-727

17. Finlayson C.M., Spiers, A.G. (Eds.), (1999), 'Global Review of Wetland Resources and Priorities for Wetland Inventory', Supervising Scientist Report144, Supervising Scientist, Canberra.

18. Guisan A., Tingley R., Baumgartner J. B., Naujokaitis-Lewis I., Sutcliffe P.R., Tulloch A.I.T, Regan T.J., Brotons L., McDonald-Madden E., Mantyka-Pringle C., Martin T.G., Rhodes J.R., Maggini R., Setterfield S.A., Elith J., Schwartz M.W., Wintle B.A., Broennimann O., Austin M., Ferrier S., Kearney M.R., Possingham H.P., Yvonne M. (2013), 'Predicting species distributions for conservation decisions', Ecology Letters, 16: 1424-1434
19. Hafner H., Dugan P.J., Boy V. (1986), 'Use of artificial and natural wetlands as feeding sites by little egrets (Egrettagarzetta L.) in the Camargue southern France', Colonial Waterbirds, 9: 149–154
20. Hanson A. (2008), 'Chemical limnology and waterbird use of an urban constructed wetland', ActaZoologicaAcademiaeScientiarumHungaricae, 54(1): 35–44.
21. Helmers D. L. (1992), 'Shorebird Management Manual, Western Hemisphere, Shorebird Reserve Network', Manomet, MA, USA, 58

22. Huston M.A. (1994), 'Biological Diversity – The Coexistence of Species', Cambridge University Press: Cambridge

23. Hutchinson G.E. (1959), 'Homage to Santa Rosalia, or why are there so many kinds of animals', American Naturalist, 93: 137–145

24. International B. L. (2008), 'State of the world´ s birds: Indicators for our changing world'. Birdlife International

25. Jetz W., McPherson J.M., Guralnick R.P. (2012), 'Integrating biodiversity distribution knowledge: toward a global map of life', Trends Ecol. Evol., 27, 151–159.

26. Kaminski R., Prince H. (1984), 'Dabbling duck-habitat associations during spring in delta marsh, Manitoba', Journal of Wildlife Management, 48: 37–50.

27. Khan T.N. (2010), 'Temporal changes to the abundance and community structure of migratory waterbirds in Santragachi Lake, West Bengal, and their relationship with water hyacinth cover', Current Science, 99 (11): 1570-1577

28. Khan T.N., Sinha A., Basu D., Chakraborty S., (2005), 'A preliminary observation of diversity and threats to the survival of migratory waterfowls in an avian abode near Kolkata', Journal of Natural History, 1: 56-57

29. Khan T.N., Sinha A., Hazra P. (2016), 'Population trends and community composition of migratory waterbirds in three emerging wetlands of global significance in southwestern Bengal, India', Journal of Threatened Taxa, 8(3): 8541–8555, http://dx.doi.org/10.11609/jott.2652.8.3.8541-8555

30. Kumar A., Sati J. P., Tak P. C., Alfred J.R.B. (2005), 'Handbook on Indian Wetland Birds and their Conservation', 1: 1-32: Zoological Survey of India

31. Lameed G.A. (2011), 'Species diversity and abundance of wild birds in Dagona-Waterfowl Sanctuary Borno State, Nigeria', African Journal of Environmental Science and Technology, 5(10): 855-866

32. Lowry J.B.C., (2006), 'The Application of Low-cost GIS Software and Data for Wetland Inventory, Assessment and Monitoring', Ramsar Convention Secretariat, Gland, Switzerland, http://www.ramsar.org/lib/lib_rtr_index.htm Ramsar Technical Report No. 2

33. MacArthur R. (1970), 'Species packing and competitive equilibrium for many species', Theoretical Population Biology, 1: 1–11

34. Majumdar S., Mookherjee K., Saha G.K. (2007), 'Migratory waterbirds of wetlands of Southern West Bengal, India', Indian Birds, 3(2): 42-45

35. Manu S. (2000), 'Effects of habitat fragmentation on the distribution of forest birds in south western Nigeria with particular reference to the Ibadan Malimbes and other Malimbes', PhD thesis, University of Oxford

36. Margules C.R., Pressey R.L. (2000), 'Systematic conservation planning', Nature, 405: 243–253.

37. Myers J.P., Morrison R.I.G., Antas P.Z., Harrington B.A., Lovejoy T.E., Sallaberry M., Senner S.E., Tarak A. (1987), 'Conservation strategy for migratory species', American Scientist, 75(1): 18-26

38. Myers N., Knoll A. H. (2001), 'The biotic crisis and the future of evolution', Proceedings of the National Academy of Sciences, 98: 5389–5392 (2001)

39. Nayak A. (2019), 'Bar-headed Goose: first record of migratory Anserindicus in Gangdua Dam of Bankura District, West Bengal, India', Bird-o-soar #27. In: Zoo's Print 34(3): 28-31

40. Norman M. (2003), 'Biodiversity hotspots revisited', Bioscience, 53(10), 916–917
41. Olson D. M., Dinerstein E. (1998), 'The global 200: A representation approach to conserving the Earth's most biologically valuable ecoregions', Conservation Biology, 12(3), 502–515
42. Owen D.F. (1960), 'The nesting success of the heron Ardeacinera in relation to the availability of food', Proceedings of the Zoological Society of London, 133: 597–617

43. Palit D., Mukherjee A. and Gupta S. (2019) 'Bioresources and Socio-economic Developmental Plans (SDPs) in Wetland Ecosystem: A Case Study' in 'Wetland: Crisis and Options', Chap 12: 171-185, New Delhi: Associated Publishing Company

44. Powell G.V.N. (1983), 'Food availability and reproduction by Great White Herons Ardeaherodias a food addition study', Colonial Waterbirds, 6: 139–147

45. Prasad S.N., Ramachandra T.V., Ahalya N., Sengupta T., Kumar A., Tiwari A.K., Vijayan V.S., Vijayan L. (2002), 'Conservation of wetlands of India – a review', Trop. Ecol., 43 (1), 173–186.

46. Rahmani A.R., Islam M.Z., Kasambe R.M. (2016), 'Important Bird and Biodiversity Areas in India: Priority Sites for Conservation', Bombay Natural History Society, Indian Bird Conservation Network, Royal Society for the Protection of Birds and BirdLife International, UK, xii+1992pp

47. Rajpar M.N., Zakaria M. (2011), 'Bird species abundance and their correlation with microclimate and habitat variables at Natural Wetland Reserve, Peninsular Malaysia' International Journal of Zoology, 1-18

48. Ramsar Secretariat (2019), 'The list of wetlands of international importance', Gland, Switzerland: The Secretariat of the Convention on Wetlands

49. Ray R., Mandal S., Dhara A. (2012), 'Characterization and mapping of inland wetland: A case study on selected Bils on Nadia District', International Journal of Scientific and Research Publications, 2(12): 1-10

50. Rebelo L. M., Finlayson M. and Nagabhatia N. (2009), 'Remote Sensing and GIS for wetland inventory, mapping and change analysis', Journal of Environmental Management, 90: 2144-2153

51. Sarkar A. (2004), 'Mapping and monitoring of East Kolkata Wetlands with multi-temporal remote sensing data and GIS approach', Report of a Department of Science and Technology, Government of India, sponsored research project

52. Sarkar B., Hazra P., Kumar S.P., Ghosh P., Banerjee A., Khan T.N. (2013), 'Habitat Attributes and waterbird use of four Wetlands in Manas National Park, Assam, India', Proceedings of Zoological Society, (DOI 10.1007/S12595-013-0074-3)

53. Sather J.H., and Smith R.D. (1984), 'An overview of major wetland functions and values', United States Department of the Interior, Fish and Wildlife Service, Division of Biological Services, Western Energy and Land Use Team

54. Sinha A., Hazra P., Khan T.N. (2011), 'Population trends and spatiotemporal changes to the community structure of waterbirds in Birbhum District, West Bengal, India', Proceedings of the Zoological Society 64(2): 98-108 (DOI 10.1007/S12595-011-0018-8)

55. Sinha A., Hazra P., Khan T.N. (2012), 'Emergence of a wetland with the potential for an avian abode of global significance in South Bengal, India', Current Science 102(4): 613-616

56. Stattersfield A. J., Crosby M. J., Long A. J., Wege D. C. (2005), 'Endemic bird areas of the world: Priorities for biodiversity conservation', United Kingdom: Birdlife International

57. Sutherland W.J., Pullin A.S., Dolman P.M., Knight T.M. (2004), 'The need for evidence-based conservation', Trends Ecol. Evol., 19: 305–308.

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 2, 2021, Pages. 3585 - 3596
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58. Taft O.W., Haig S.M. (2003), 'Historical wetlands in Oregon's Willamette valley implications for restoration of winter waterbird habitat', Wetlands 23: 51–64

59. Turner R.K., van der Bergh J.C.J.M., Soderqvist T., Barendregt A., van der Straaten J., Maltby E., van Ierland E.C. (2000), 'Ecological-economic analysis of wetlands: scientific integration for management and policy', Ecol. Econ., 35 (1): 7–23

60. Venier L., Fahrig L. (1996), 'Habitat availability causes the species–abundance–distribution relationship', Oikos, 76: 564–570
61. Weller M.W. (1999), 'Wetland birds: Habitat resources and conservation implications', Cambridge: University Press
62. Wright D.H. (1983), 'Species-energy theory an extension of species area theory', Oikos, 41: 496–506

63. Yesson C., Brewer P.W., Sutton T., Caithness N., Pahwa J.S., Burgess M., et.al. (2007), 'How Global Is the Global Biodiversity Information Facility', PLoS ONE, 2(11): 1124, https://doi.org/10.1371/journal.pone.0001124