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A natural disaster in Sikkim caused a significant decline in avifaunal abundance in two important wetlands of North Bengal, India

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Abstract

A study on water bird assemblage was conducted between 2021 and 2024, in the month of January, in two important artificial wetlands, Gajoldoba and Fulbari reservoirs, situated in the Eastern Himalayan foothills of West Bengal, India. Following the Glacial Lake Outburst Flood of South Lhonak Lake on October 3, 2023, in North Sikkim (caused by a cloud burst above the lake), a sharp fall in waterbird population in those wetlands has been noticed. Both the reservoirs, which are connected to the Teesta Mahananda Link Canal, suffered almost the same devastating consequences from the flood that resulted in a massive buildup of silt and sand on the river banks, lowering the water depth and damaging the ecosystem. Photosynthetic organisms were greatly reduced as a result of the flood and siltation; aquatic plants and algae were either carried away or buried under silt and sand. The catastrophic effect led to a significant decrease in fish and numerous aquatic invertebrates and subsequently affected the food chain; as a result, the majority of waterbird species showed a dramatic decrease in abundance. The principal objective of this study is to quantify the magnitude of decline in abundance of waterbird species and the potential causes behind this.

Key words: Abundance, decline of waterbirds, natural calamity, wetlands.

Introduction

Waterbirds represent a significant biological indicator in wetland ecosystems (Zhang et al., 2011; Wang et al., 2020) when evaluating how the quality of a wetland habitat influences waterbird diversity. The loss or deterioration of wetlands has expanded throughout the world as a result of growing human activities in these ecosystems. The area of natural lake wetlands in India has shrunk in recent years due to increased intensity of human activity, such as polder construction and aquaculture operations. With natural wetlands being replaced by paddy fields, aquaculture ponds, and other artificial wetlands (Zhao et al., 2008; Sebastián-González et al., 2009; Ramachandran et al., 2017). These human activities change ecosystems, which affects interspecies competition (Zhao et al., 2013), feeding behavior (Zhou et al., 2010), and the number and distribution of wintering waterbirds (Chen et al., 2011). Artificial wetlands gradually replace natural lake wetland areas as the latter diminish due to anthropogenic pressure (Bellio et al., 2009; Chen and Zhou, 2011). This knowledge has implications for the preservation of waterbird community diversity during particular seasons (Holm and Clausen, 2006; Tanalgo et al., 2015; Chen et al., 2016), for instance, appropriate breeding and foraging sites in summer and winter, respectively (White and Main, 2005; Schuh and Guadagnin, 2018; Stanton et al., 2018). But as multiple studies have shown, natural wetlands contain more diverse waterbird communities than artificial wetlands, and artificial wetlands cannot replace the role of natural wetlands in terms of function (Jones, 2001; Ma et al., 2004; Keddy, 2010).

The main goal of wetland conservation is to preserve habitat and aquatic biota dependent on those habitats (Keddy, 2010). Therefore, successful conservation and management of waterbirds requires knowledge of the habitats most selected by the overall waterbird assemblage as well as those most desired by individual species (Keddy, 2010). Accordingly, a great deal of research has been done all over the world on habitat use, selection, and community organization of waterbirds (e.g., Jones, 2001; Khan, 2010; Sinha et al., 2011; Hazra et al., 2012; Sinha et al., 2012; Sarkar et al., 2014; Khan et al., 2016; Hamza et al., 2016; Elafri et al., 2017; Farinós-Celdrán et al., 2017; Chatterjee et al., 2020; Zala et al., 2022; Gayen et al., 2022; Adhurya et al., 2022; Lenka, 2023; Rather and Gautam, 2023; Abin and Samson, 2024; Atabey and Karakaş, 2024). The complicated topic of migratory bird conservation necessitates an understanding of the movements of individual species over vast distances—even thousands of kilometers—that together sustain habitats for breeding, wintering, and stopping. The two main variables impacting migratory bird habitats, climate change and land-use change, have significantly raised the occurrence of species reductions worldwide (Hazra et al., 2012; Spooner et al., 2018). Due to life-history tactics supported by an interdependent habitat network, climate change and habitat degradation or alteration can expose populations to various threats, and migratory birds are particularly vulnerable to these changes (Zurell et al., 2018). Cross-seasonal effects exacerbate risks since they can impact fitness at all places (breeding grounds, wintering grounds, or stopover areas) in the migration cycle and result in decreases in long-term demographic performance (Sedinger and Alisauskas, 2014).

Growing environmental pressures are likely to outweigh the adaptive plasticity of many species, even though some birds have modified their migration chronology and range extent to correspond with changing climate and land-use patterns (Hitch and Leberg, 2007; Visser et al., 2009; Schmaljohann and Both, 2017). The current study was carried out in the northern region of the Indian state of West Bengal, near the Eastern Himalayan foothills, at the Gajoldoba Reservoir of the Teesta Barrage and the Fulbari Reservoir of the Mahananda Barrage. This area is adjacent to two significant Endemic Bird Areas, the Eastern Himalayan and the Assam Plains, and sits at the intersection of two hotspots: the Himalaya Biodiversity Hotspot and the Indo-Burma Biodiversity Hotspot (Islam and Rahmani, 2004). The diversity and ecology of waterbirds from sub-Himalayan settings, however, have received little attention in published articles (Datta, 2011, 2014; Chatterjee et al., 2013, 2017, 2020). Gajoldoba and Fulbari Reservoirs, which are connected by the Teesta Mahananda Link Canal, are also threatened by overfishing, pollution, habitat degradation, and other human activities.

The issue has been further exacerbated by the October 3, 2023, Glacial Lake Outburst Flood (GLOF) of South Lhonak Lake in North Sikkim, which was caused by a cloud burst above the lake. The largest hydropower project in Sikkim, the 1200 MW Teesta III dam, was devastated by the GLOF, which also destroyed towns and downstream areas. The dam is located in Chungthang town, Mangan district, approximately 60 km downstream of the lake. Due to the large post-flood buildup of silt and sand in the Teesta River bed, Fulbari Reservoir, which is connected to the Gajoldoba Teesta Barrage via the Teesta Canal, has a similar decline in water depth. The excessive siltation damages aquatic plants and algae and reduces primary productivity by obstructing photosynthesis and lowering light penetration in the water (Lloyd, 1987). Fish and insect populations have decreased as a result of the flood damage to the natural aquatic and wetland habitats (Petts et al., 2002). As a result, there was a dramatic drop in the abundance of both migratory and resident birds. Our study's primary goal is to measure the impact of the natural disaster on the abundance of both local and long-distance migrants in those wetlands, and the change in phytoplanktonic chlorophyll *a* content, as well.

Material and Methods

Study area

Built in the Jalpaiguri district of West Bengal, India, the Gajoldoba Reservoir (26.763897° N, 88.597498° E) was formed in 1998 by building a dam on the Teesta River (Fig. 1). The subsequent associated wetland often draws a diverse range of avian winter migrants. Only a small portion of the Gajoldoba wetland, which is mostly made up of open water, is covered in floating aquatic plants, such as *Hygrophila polysperma* (Roxb.) T. Anderson, 1867, *Eichhornia crassipes* (Mart.) Solms, 1883, *Trapa natans* Linnaeus, 1753, *Wolffia arrhiza* (L.) Horkel ex Wimm., 1857, *Nymphaea* sp. Linnaeus, 1753, *Jussiaea repens* Linnaeus, 1753, and *Neptunia natans* (L.f.) Druce, 1917. *Ceratophyllum demersum* Linnaeus, 1753, *Utricularia flexuosa* Vahl, 1804, *Hydrilla verticillata* (L.f.) Royle, 1839, and *Vallisneria spiralis* Linnaeus, 1753 are also notable in the area (Datta 2011, 2014). Emergent hydrophytes include *Ammania baccifera* Linnaeus, 1753, *Cyperus corymbosus* Rottboll, 1772, *Cyperus cephalotes* Vahl, 1805, *Limnophila indica* (L.) Druce, 1914, *Scirpus articulatus* Linnaeus, 1753, *Potamogeton nodosus* Poiret, 1816, and *Potamogeton pectinatus* Linnaeus, 1753. Another prominent species in this marsh is *Typha latifolia* Linnaeus, 1753 (Datta, 2011, 2014). Several species of water birds can find abundant grazing on these aquatic plants. Additionally, this vegetation sustains a wide variety of fish, mollusks, and arthropods, which draws in a wide range of avifauna, particularly migratory species.

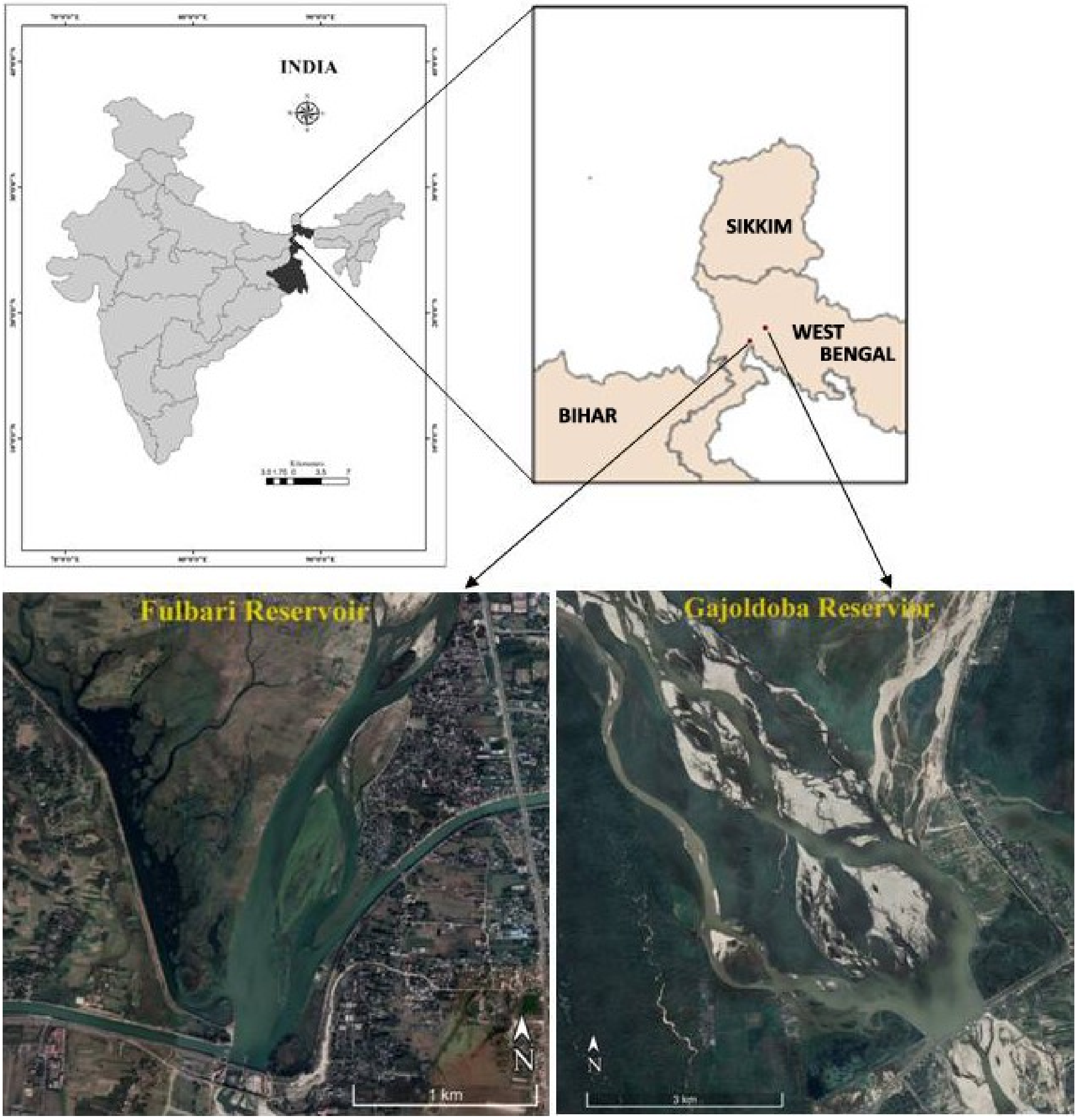

Figure 1: Portion of the Northern part of West Bengal, India showing the location of the study sites upon which the analysis presented here is based. Aerial view of the wetlands under study has also been shown in the figure.

The Fulbari Reservoir (26.644969° N, 88.400858° E), which is also in the Jalpaiguri district, is very important for the sub-Himalayan Terai region in the northern part of West Bengal. It was created in 1998 by the Fulbari-Mahananda Barrage on the Mahananda River and includes a river island that is suitable for bird roosting (Fig. 1). The 25.75-kilometer Teesta Mahananda Link Canal connects the barrage to the Gajoldoba Teesta Barrage. It functions as a crucial framework for water management, preventing floods and supplying water for household and agricultural use. The link canal, allows water flow from Teesta to Mahananda River, and therefore impacts the biodiversity, ecology, and morphology of the reservoir. All year long, water hyacinth *Eichhornia crassipes* (Mart.) Solms, 1883 covers a sizable area of the wetland. Other dominant species include *Pistia stratiotes* Linnaeus, 1753, *Trapa natans* Linnaeus, 1753, *Wolffia arrhiza* (L.) Horkel ex Wimm., 1857, *Nymphoides cristata* (Roxb.) Kuntze, 1891, *Hygrophila polysperma* (Roxb.) T. Anderson, 1867, *Lemna minor* Linnaeus, 1753, *Hydrilla verticillata* (L.f.) Royle, 1839, *Limnophila indica* (L.) Druce, 1914, *Potamogeton nodosus* Poiret, 1816, *Marsilea minuta* Linnaeus, 1771, and *Colocasia esculenta* (L.) Schott, 1832, providing a rich food base for herbivores. This wetland is home to numerous fish and invertebrate species (Jha et al., 2004), as well as a wide range of resident and migratory waterbirds.

The maps of the study sites were constructed by Arc GIS (ArcMap 10.8.2) and Google Earth Pro.

Waterbird census

Waterbird counts were carried out from January 1 to January 30, 2021–2024, in accordance with the Wetlands International's vast Asian Waterfowl Census Program (Wetlands International, 2006, 4th ed.). Depending on the size and accessibility of the wetland, three to five groups of observers used a combination of on-foot and boat access to conduct waterbird counts using the same methodologies as Khan (2010). While bird counts in Fulbari Mahananda Barrage were done on foot, waterbird counts at Gajoldoba Teesta Barrage were done from a country boat in addition to on foot. Beginning at 8:00 a.m. IST, the census continued until all the waterbirds in the wetlands had been tallied. Waterbird counts were performed by a team of eight to ten observers trained in bird identification and census techniques, as well as examination of aerial photographs of different segments of the wetland, as described by Khan (2010). The waterbirds were observed and counted by using field binoculars (Nikon 10X50 Action Extreme ATB and Zeiss 10x42 Terra ED) and digital cameras (Canon 7D Mark II DSLR camera with Canon300 f/4L IS USM lens). Birds were identified using standard local field guides books (Grimmett et al., 2011; Kazmierczak, 2003). The terminology used to describe residing status and guild membership is as follows (Grimmett et al., 2011; Kazmierczak, 2003; https://ebird.org):

Resident: refers to those birds which stay in the wetlands throughout the year.

Winter migrant: refers to those birds which come to the wetlands during the winter season (December to March).

Local migrant: refers to those birds which migrate locally within the specific region or the wetlands.

Herbivorous: refers to those birds feeding on plant-based food for nutrition such as algae, leaves, fruits, seeds, etc.

Carnivorous: refers to those birds feeding on animal-based food for nutrition such as crustaceans, small fishes, small rodents, insects, etc.

Omnivorous: refers to those birds feeding on both animal-based food and plant-based food, based on availability.

Dabbling: refers to ducks that typically feed in shallow water by submerging their head and upending their tail end, such as mallard, teal, pintail, etc.

Diving: refers to ducks that dive underwater in search of food, such as pochard, scaup, tufted duck, etc.

Grazing: refers to birds that feed on low-growing plants such as grasses in a field or pasture, such as bar-headed geese.

Wader: refers to those birds that wade along shorelines and mudflats in order to forage for food. They can be large (storks and herons), medium-sized (lapwings and jacanas) and small-sized (sandpipers and plovers).

Raptor: refers to "birds of prey" that are hyper-carnivorous bird species that actively hunt and feed on other vertebrates (small birds, mammals and reptiles), such as harriers, kestrel, osprey, etc.

Waterbird abundance

The abundance of each species of waterbird between 2021 and 2024 was compared using the following formula (Paton et al., 2009):

Percent change between January 2021 and January 2024 = $\{(M_{2024} - M_{2021})/ M_{2021}\} \times 100$

Where M_{2021} represents the value acquired in January 2021 and M_{2024} represents the value for January 2024.

Waterbird population trends

Using bird census data, population trends of each species for each wetland were evaluated using the TRIM (Trends and Indices for Monitoring data - Pannekoek and van Strien, 2001) tool. TRIM uses Poisson regression to assess a time series of counts and generate annual indices of abundance and trends. For the purpose of estimating the imputed yearly population indices, the "Time Effect Model" was chosen among the modelling options available in TRIM. The TRIM Imputed index provided a description of the population trend for each species. Overall trends in yearly indices were calculated as summary statistics, taking uncertainty into account. Based on statistical significance and amplitude, these trends were characterized as either a strong increase, a steep decline, a moderate increase, or a moderate decline (Pannekoek and van Strien, 2001). These trends were stated as multiplicative slopes, i.e., as yearly multiplication factors (1 = steady).

Estimation of chlorophyll *a*

Phytoplankton Chlorophyll *a* was measured using spectroscopic techniques (monochromatic method with acidification) on water samples taken from the wetlands twice a month (every two weeks), in accordance with the methodology recommended by Aminot and Rey (2000).

Results

Over the course of the four-year study period (4 months total census), 50,783 waterbirds of 74 different species were documented. Vagrant species, such as Palla's Fish Eagle *Haliaeetus leucoryphus* (Pallas, 1771), Black-Necked Grebe *Podiceps nigricollis* Brehm, 1831, and Common Goldeneye *Bucephala clangula* (Linnaeus, 1758), for example, were excluded in the current analysis, as they do not visit the wetland every year. Of these 74 species, 38 were long-distance winter visitors while the others were residential or local migratory species (Kazmierczak, 2003; Grimmettet al., 2011). Five species: Ferruginous duck *Aythya nyroca* (Guldenstadt, 1770), Lesser adjutant stork *Leptoptilos javanicus* (Horsfield, 1821), Great thick-knee *Esacus recurvirostris* (Cuvier, 1829), River lapwing *Vanellus duvaucelli* (Lesson, 1826) and Northern lapwing *Vanellus vanellus* (Linnaeus, 1758) are designated by the IUCN as near threatened, while the rest are of least concern; except for the Common pochard *Aythya ferina* (Linnaeus, 1758) which is considered vulnerable (IUCN, 2024).

The mean abundance values for each species, shown in Table 1, indicate that 26 of 38 winter migrant species declined in abundance between 2021 and 2024. Species showing more than 50% declines include: Common redshank *Tringa tetanus* (Linnaeus, 1758) (88.89% decline), Eastern marsh harrier *Circus spilonotus* Kaup, 1847 (85.71% decline), Eurasian wigeon *Mareca penelope* (Linnaeus, 1758) (78% decline), Common teal *Anas crecca* Linnaeus, 1758 (77.09% decline), Bar-headed goose *Anser indicus* (Latham, 1790) (73.91% decline), Gadwall *Mareca strepera* (Linnaeus, 1758) (72.47% decline), Ferruginous duck *Aythya nyroca* (Guldenstadt, 1770) (65% decline), Ruddy shelduck *Tadorna ferruginea* (Pallas, 1764) (62.67% decline), Temminck's stint *Calidris temminckii* (Leisler, 1812) (61.86% decline), Common snipe *Gallinago gallinago* (Linnaeus, 1758) (61.11% decline), Red-crested pochard *Netta rufina* (Pallas, 1773) (59.13% decline), Great-crested grebe *Podiceps cristatus* (Linnaeus, 1758) (58.62% decline), and Northern pintail *Anas acuta* Linnaeus, 1758 (58.33% decline). (Table 1). Among the 36 resident, or local migrants, 24 species declined in abundance. Species that exhibited more than 50% reduction are: Common moorhen *Gallinula chloropus* (Linnaeus, 1758) (83.87% decline), Common coot *Fulica atra* Linnaeus, 1758 (81.61% decline), Pheasant-tailed jacana *Hydrophasianus chirurgus* (Scopoli, 1786) (79.59% decline), Common kestrel *Falco tinnunculus* Linnaeus, 1758 (66.67% decline), Black-winged stilt *Himantopus himantopus* (Linnaeus, 1758) (60% decline), Grey-headed swamphen *Porphyrio poliocephalus* Latham, 1801 (56.08% decline) and Great cormorant *Phalacrocorax carbo* (Linnaeus, 1758) (50.55% decline). Nine species of resident, or local migrants, and seven species of winter migrants, however, showed higher abundances. The majority of the feeding guilds that showed an increase in abundance are carnivorous waders, which consume a broad range of invertebrates (Table 1; Fig. 2).

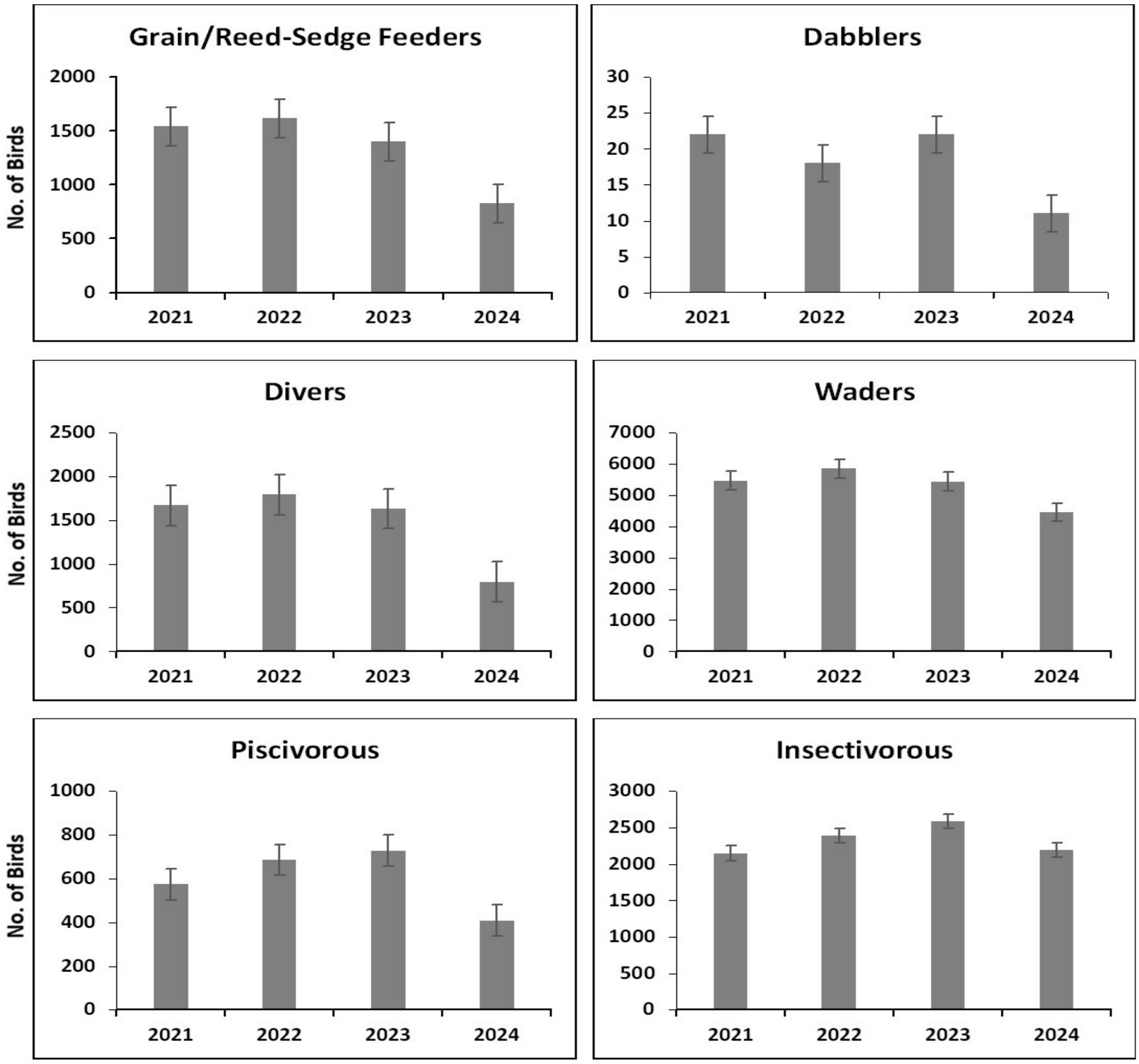

Figure 2: Changes in the abundance (with standard errors) of six guilds of waterbirds in the Gajoldoba and Fulbari wetlands, during the month of January between 2021 and 2024. See Table 1 for the guild membership of each species.

Table 1: List of wetland birds encountered and counted in the study sites during the month of January in 2021–2024 along with their abundance (total number of birds recorded during the four month census across the four years), % change (changes in their abundances), residing status and guild membership.

Waterbird species	Abundance	% Change	Residing status	Guild membership
Bar-headed goose *Anser indicus* (Latham, 1790)	55	-73.91	Winter migrant	Grazing; Herbivorous
Lesser whistling duck *Dendrocygna javanica* (Horsfield, 1821)	5330	-46.05	Resident/local migrant	Dabbling; Omnivorous
Ruddy shelduck *Tadorna ferruginea* (Pallas, 1764)	5148	-62.67	Winter migrant	Diving; Carnivorous
Cotton pygmy goose *Nettapus coromandelianus* (Gmelin, JF, 1789)	126	-60.71	Resident/local migrant	Dabbling; Omnivorous
Gadwall *Mareca strepera* (Linnaeus, 1758)	7914	-72.47	Winter migrant	Dabbling; Omnivorous
Falcated duck *Mareca falcata* (Georgi, 1775)	17	–	Winter migrant	Dabbling; Omnivorous
Eurasian wigeon *Mareca penelope* (Linnaeus, 1758)	1502	-78.00	Winter migrant	Dabbling; Omnivorous
Mallard *Anas platyrhynchos* Linnaeus, 1758	477	-45.45	Winter migrant	Dabbling; Omnivorous
Northern Shoveler *Spatula clypeata* (Linnaeus, 1758)	385	-25.30	Winter migrant	Dabbling; Omnivorous
Northern pintail *Anas acuta* Linnaeus, 1758	287	-58.33	Winter migrant	Dabbling; Omnivorous
Common teal *Anas crecca* Linnaeus, 1758	2388	-77.09	Winter migrant	Dabbling; Omnivorous
Common pochard *Aythya ferina* (Linnaeus, 1758)	389	-39.84	Winter migrant	Diving; Carnivorous
Red-crested pochard *Netta rufina* (Pallas, 1773)	1364	-59.13	Winter migrant	Diving; Herbivorous
Ferruginous duck *Aythya nyroca* (Guldenstadt, 1770)	815	-65.00	Winter migrant	Diving; Carnivorous
Tufted duck *Aythya fuligula* (Linnaeus, 1758)	823	-13.29	Winter migrant	Diving; Carnivorous
Common Merganser *Mergus merganser* Linnaeus, 1758	37	-33.33	Winter migrant	Diving; Carnivorous
Great-crested grebe *Podiceps cristatus* (Linnaeus, 1758)	120	-58.62	Winter migrant	Diving; Carnivorous
Little grebe *Tachybaptus ruficollis* (Pallas, 1764)	223	-55.32	Resident/local migrant	Diving; Carnivorous
Asian openbill-stork *Anastomus oscitans* (Boddaert, 1783)	109	-33.33	Resident	Wader; Carnivorous
Black stork *Ciconia nigra* (Linnaeus, 1758)	14	–	Winter migrant	Wader; Carnivorous
Lesser adjutant stork *Leptoptilos javanicus* (Horsfield, 1821)	25	–	Resident	Wader; Carnivorous
Red-naped ibis *Pseudibis papillosa* (Temminck, 1824)	171	83.33	Resident	Omnivorous
Indian pond heron *Ardeola grayii* (Sykes, 1832)	296	11.84	Resident	Carnivorous
Purple heron *Ardea purpurea* Linnaeus, 1766	31	-50.00	Resident	Carnivorous
Grey heron *Ardea cinerea* Linnaeus, 1758	22	133.33	Resident	Carnivorous
Little egret *Egretta garzetta* (Linnaeus, 1766)	404	16.67	Resident	Carnivorous
Intermediate egret *Ardea intermedia* Wagler, 1829	62	-13.33	Resident	Carnivorous
Great egret *Ardea alba* Linnaeus, 1758	27	-14.28	Resident	Carnivorous
Cattle egret *Bubulcus ibis* (Linnaeus, 1758)	1033	-33.82	Resident	Carnivorous
Oriental darter *Anhinga melanogaster* Pennant, 1769	7	-50.00	Resident	Diving; Carnivorous
Little cormorant *Microcarbo niger* (Vieillot, 1817)	876	-29.72	Resident	Diving; Carnivorous
Great cormorant *Phalacrocorax carbo* (Linnaeus, 1758)	299	-50.55	Resident	Diving; Carnivorous
Indian cormorant *Phalacrocorax fuscicollis* Stephens, 1826	29	-44.44	Resident	Diving; Carnivorous
Peregrine falcon *Falco peregrinus* Tunstall, 1771	11	–	Resident/local migrant	Raptor; Carnivorous
Common kestrel *Falco tinnunculus* Linnaeus, 1758	10	-66.67	Resident/local migrant	Raptor; Carnivorous
Osprey *Pandion haliaetus* (Linnaeus, 1758)	15	-25.00	Winter migrant	Raptor; Carnivorous
Eastern marsh harrier *Circus spilonotus* Kaup, 1847	18	-85.71	Winter migrant	Raptor; Carnivorous
Pied harrier *Circus melanoleucos* (Pennant, 1769)	14	–	Winter migrant	Raptor; Carnivorous
Hen harrier *Circus cyaneus* (Linnaeus, 1766)	4	–	Winter migrant	Raptor; Carnivorous
Common moorhen *Gallinula chloropus* (Linnaeus, 1758)	748	-83.87	Resident	Omnivorous
Grey-headed swamphen *Porphyrio poliocephalus* (Latham, 1801)	443	-56.08	Resident	Omnivorous
White-breasted waterhen *Amaurornis phoenicurus* (Pennant, 1769)	190	24.44	Resident	Omnivorous
Common coot *Fulica atra* Linnaeus, 1758	689	-81.61	Local migrant	Diving; Carnivorous
Great thick-knee *Esacus recurvirostris* (Cuvier, 1829)	14	–	Resident	Wader; Carnivorous
Pacific golden plover *Pluvialis fulva* (Gmelin, JF, 1789)	3540	5.00	Winter migrant	Wader; Omnivorous
Little ringed plover *Thinornis dubius* (Scopoli, 1786)	397	20.51	Winter migrant	Wader; Carnivorous

Table 1: (Continued).

Waterbird species	Abundance	% Change	Residing status	Guild membership
Kentish plover *Anarhynchus alexandrinus* (Linnaeus, 1758)	770	-6.25	Winter migrant	Wader; Carnivorous
River lapwing *Vanellus duvaucelli* (Lesson, 1826)	310	81.95	Resident	Wader; Carnivorous
Red-wattled lapwing *Vanellus indicus* (Boddaert, 1783)	425	47.73	Resident	Wader; Carnivorous
Grey-headed lapwing *Vanellus cinereus* (Blyth, 1842)	2347	-17.45	Winter migrant	Wader; Carnivorous
Northern lapwing *Vanellus vanellus* (Linnaeus, 1758)	4790	-46.77	Winter migrant	Wader; Carnivorous
Black-winged stilt *Himantopus himantopus* (Linnaeus, 1758)	78	-60.00	Resident	Wader; Carnivorous
Pied avocet *Recurvirostra avosetta* Linnaeus, 1758	15	33.33	Winter migrant	Wader; Carnivorous
Bronze-winged jacana *Metopidius indicus* (Latham,1790)	477	-31.91	Resident	Wader; Omnivorous
Pheasant-tailed jacana *Hydrophasianus chirurgus* (Scopoli, 1786)	146	-79.59	Resident	Wader; Omnivorous
Common snipe *Gallinago gallinago* (Linnaeus, 1758)	123	-61.11	Winter migrant	Wader; Omnivorous
Common sandpiper *Actitis hypoleucos* (Linnaeus, 1758)	142	4.76	Winter migrant	Wader; Carnivorous
Marsh sandpiper *Tringa stagnatilis* (Bechstein, 1803)	27	-50.00	Winter migrant	Wader; Carnivorous
Green sandpiper *Tringa ochropus* Linnaeus, 1758	104	16.67	Winter migrant	Wader; Carnivorous
Little stint *Calidris minuta* (Leisler, 1812)	272	90.91	Winter migrant	Wader; Carnivorous
Temminck's stint *Calidris temminckii* (Leisler, 1812)	247	-61.86	Winter migrant	Wader; Carnivorous
Dunlin *Calidris alpina* (Linnaeus, 1758)	68	-33.33	Winter migrant	Wader; Carnivorous
Common greenshank *Tringa nebularia* (Gunnerus, 1767)	198	45.83	Winter migrant	Wader; Carnivorous
Common redshank *Tringa totanus* (Linnaeus, 1758)	32	-88.89	Winter migrant	Wader; Carnivorous
Spotted redshank *Tringa erythropus* (Pallas, 1764)	19	-33.33	Winter migrant	Wader; Carnivorous
Small pratincole *Glareola lactea* Temminck, 1820	2180	45.71	Resident	Wader; Carnivorous
Brown-headed gull *Chroicocephalus brunnicephalus* (Jerdon, 1840)	10	–	Winter migrant	Carnivorous
Pied kingfisher *Ceryle rudis* (Linnaeus, 1758)	40	-33.33	Resident	Diving; Carnivorous
White-throated kingfisher *Halcyon smyrnensis* (Linnaeus, 1758)	96	3.85	Resident	Diving; Carnivorous
Common kingfisher *Alcedo atthis* (Linnaeus, 1758)	41	-33.33	Resident	Diving; Carnivorous
Stork-billed kingfisher *Pelargopsis capensis* (Linnaeus, 1766)	29	-37.50	Resident	Diving; Carnivorous
White wagtail *Motacilla alba* Linnaeus, 1758	184	-27.91	Local migrant	Wader; Carnivorous
White-browed wagtail *Motacilla maderaspatensis* Gmelin, JF, 1789	66	-33.33	Resident	Wader; Carnivorous
Citrine wagtail *Motacilla citreola* Pallas, 1776	649	20.13	Winter migrant	Wader; Carnivorous

Table 2: Poisson-based Log-linear models for the population trends of waterbird species at the Gajoldoba and Fulbari wetlands, during January in 2021–2024 (For the sake of brevity, only the species that showed significant changes in the trend analysis are listed in the table).

Species	Index	Estimate± SE	Wald X^2(df = 1)	*P*	Inference
Anser indicus	0.309	-0.368 ± 0.046	70.18	< 0.001	Steep decline
Dendrocygna javanica	0.593	-0.199 ± 0.101	4.38	0.036	Moderate decline
Anas crecca	0.267	-0.499 ± 0.148	17.71	< 0.001	Steep decline
Anas platyrhynchos	0.588	-0.194 ± 0.064	10.13	0.001	Steep decline
Mareca strepera	0.354	-0.424 ± 0.205	6.65	0.010	Steep decline
Spatula clypeata	0.910	-0.029 ± 0.005	31.71	< 0.001	Moderate decline
Mareca penelope	0.285	-0.483 ± 0.119	25.76	< 0.001	Steep decline
Aythya nyroca	0.419	-0.341± 0.099	16.31	< 0.001	Steep decline
Aythya fuligula	0.694	-0.131± 0.061	4.69	0.030	Moderate decline
Anas acuta	0.806	-0.071±0.016	18.58	< 0.001	Moderate decline
Aythya ferina	0.579	-0.182 ±0.027	47.26	< 0.001	Steep decline
Podiceps cristatus	0.656	-0.144±0.030	23.24	< 0.001	Steep decline
Phalacrocorax carbo	0.549	-0.22 5±0.083	8.30	0.004	Steep decline
Circus spilonotus	0.306	-0.584 ±0.398	5.64	0.017	Moderate decline
Gallinula chloropus	0.286	-0.551 ±0.253	10.59	0.001	Steep decline
Porphyrio poliocephalus	0.339	-0.329 ±0.124	11.92	< 0.001	Steep decline
Fulica atra	0.149	-0.595 ± 0.058	135.87	< 0.001	Steep decline
Vanellus duvaucelli	1.959	0.224 ± 0.017	187.49	< 0.001	Strong increase
Vanellus indicus	1.483	0.129±0.010	157.29	< 0.001	Strong increase
Himantopus himantopus	0.504	-0.253 ±0.103	6.93	0.008	Steep decline
Metopidius indicus	0.610	-0.149 ±0.040	21.69	< 0.001	Steep decline
Hydrophasianus chirurgus	0.214	-0.585 ±0.395	5.23	0.022	Moderate decline
Calidris temminckii	0.324	-0.349 ±0.050	62.14	< 0.001	Steep decline
Tringa totanus	0.129	-0.693 ±0.103	94.23	< 0.001	Steep decline
Tringa erythropus	0.499	-0.191 ±0.092	6.65	0.010	Moderate decline
Chroicocephalus brunnicephalus	0.492	-0.208 ±0.100	4.41	0.036	Moderate decline
Ceryle rudis	0.645	-0.142 ±0.014	143.27	< 0.001	Steep decline
Alcedo atthis	0.622	-0.150 ±0.037	23.40	< 0.001	Steep decline
Motacilla maderaspatensis	0.694	-0.133 ±0.067	4.28	0.038	Moderate decline
Motacilla citreola	1.199	0.059 ±0.025	5.46	0.019	Moderate increase
Overall Trends	0.584	-0.202 ±0.105	4.32	0.038	Moderate decline

Eleven resident, or local migrant species, and sixteen winter migrants revealed significant declines in the trend analysis (Table 2). The overall trend between 2021 and 2024 was estimated as a moderate decline (Wald χ^2 = 4.32; P = 0.038). In addition, the chlorophyll-a content in both wetlands dramatically decreased after the October 3, 2023, Glacial Lake Outburst Flood (GLOF) at South Lhonak Lake in North Sikkim. In the Fulbari Wetland, the monthly average phytoplankton chlorophyll-*a* content ranges from 2.83 to 7.75 mg/m3 (January to September 2023) and decreased to 0.0–0.44 mg/m3 (October 2023 to April 2024). In the Gajoldoba wetland, it ranged from 1.6–5.32 mg/m3 (January to September 2023) and then decreased to 0.0–0.28 mg/m3 (October 2023 to April 2024).

Discussion

Sedimentation has an impact on aquatic biota at the population and community levels and causes homogenization of certain species. This implies that a few invading species that can withstand disturbance may eventually replace regionally unique faunas (Walters et al., 2003). This might pose a severe threat to biodiversity, which could have a significant disruptive impact on aquatic ecosystems. In addition to having a detrimental impact on primary production (Lloyd, 1987), suspended solids can raise turbidity and reduce water clarity, which can lower oxygen levels to potentially stressful, or lethal, levels for fish and invertebrates (Petts et al., 2002). Furthermore, excessive fine particles in suspension, or deposited, can kill fish at any stage of their lives because they irritate and damage their gills (Schleiger, 2000), change their blood physiology (Sutherland and Meyer, 2007), impair their ability to move or swim (Berli et al., 2014), among other detrimental factors. Consequently, there was a notable decline in the abundance of piscivorous avian species in the study areas. Significant silt and sand deposition resulted in a decrease in the number of diver, dabbler, and grain/reed-sedge feeder bird species by burying most of the floating and submerged aquatic plants beneath the sediment (Fig. 2).

Because benthic invertebrates have fewer adaptations to deal with excessive sedimentation, the accumulation of silts is physiologically more selective on benthic macroinvertebrate assemblages than hyporheic ones (Buendia et al., 2013; Descloux et al., 2014). Since invertebrates have nowhere to hide and must leave the river substrate to avoid suffocation, a reduction in the availability of refuges due to fine sediment can also increase the density of invertebrate drift, i.e. the downstream transport of invertebrate organisms. Vadher et al. (2015) showed that when the water level was lowered, 93% of the invertebrates moved into subsurface sediments. This data corroborates with the increasing trends of bird species (Table 2) such as the River lapwing (*Vanellus duvaucelli*) (Wald χ^2 = 187.49; P <0.001), Red-wattled lapwing (*Vanellus indicus*) (Wald χ^2 = 157.29; P <0.001), and Citrine wagtail (*Motacilla citreola*) (Wald χ^2 = 5.46; P = 0.019) in both wetlands, as these species forage on the sandy banks and feed primarily on insects and other aquatic or terrestrial macroinvertebrates.

Conclusion

Our study shows that, despite being preliminary and having some methodological flaws, because of the short time frame and small number of wetlands: (1) The majority of waterbird species have drastically decreased after the GLOF disaster. (2) The amount of phytoplanktonic chlorophyll-*a* content in the wetlands also decreased significantly. (3) The chlorophyll content of the water bodies is directly related to the productivity of the wetlands and the availability of food resources, which in turn, determines the waterbird choice of habitat and number in these wetlands. Siltation and suspended sediment have a negative impact on water quality, which in turn affects the aquatic biota; and undoubtedly has a detrimental effect on the avifauna that depends on wetlands. Our study sought to offer the first data elucidating how significant Sub-Himalayan wetlands in North Bengal are affected by natural disasters as it relates to waterbird groups. Therefore, a thorough, long-term study is desperately needed, and the present study could offer guidelines for future research in this area.

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Author contributions

Field survey and data collections were done by Priyanka Saha and Prantik Hazra. Data analysis was done by Prantik Hazra and preparation of manuscript was done by both the authors.

Conflict of interest

The authors declare that there are no conflicting issues related to this research article.

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