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RESEARCH

Breeding colony contraction of Asian openbill stork (*Anastomus oscitans*): an eco-spatial monitoring from Keleghai River Bank, India

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Abstract Asian openbill stork (*Anastomus oscitans*) colonies and also the numbers were enormous before some decades in some villages beside Keleghai River bank. However, there has been a significant decline in both the colonies and their populations. This present study investigates the rapid decline in the number of breeding colonies and birds, exploring the reasons behind this phenomenon. To address these inquiries, the study collects perceptions from various stakeholders through extensive field observations and interviews. Expeditions are conducted to comprehend the prevailing situation and associated circumstances. Qualitative observations reveal that human intervention, both direct and indirect, is limiting the development of stork colonies. Data analysis indicates that 37.5% of respondents attribute the contraction of bird colonies to changes in land use, while 26.3% point to the extermination of larger trees along the colony periphery. Additionally, 18.05% of opinions implicate the heavy use of pesticides and fertilizers in the wetland, 6.94% cite local climate change, and 11.11% cite other reasons. To validate the gathered information, the study employed temporal land use land cover (LULC) classification techniques. Random point pattern analysis from Google Image of 2023 is also utilized to reinforce the survey results. It enhances understanding of the spatio-temporal relationship. Subsequently, the study presents the correlation matrix to elucidate the relationship between stork colonies and contributing factors. It provides a clear insight into the underlying situations. Finally, a comparative analysis of the surveyed and spatial analysis information is conducted to detect and validate the perception of stakeholders. Based on these observations, the study formulates conservation measures for the bird habitat and their colonies in the study area.

Keywords Asian openbill stork · Habitat · Nesting · Breeding colony · Human intervention Keleghai River

Highlights
- Asian openbill stork (*Anastomus oscitans*) colonies' development is restricted by human intervention.
- The colonies and the number of Asian openbill stork are under threat.
- Wetland land use alteration is the foremost cause of bird colony contraction.
- Destruction of larger trees from the colony side is another cause.
- Heavy use of pesticides and fertilizer in the wetland for paddy cultivation creates an imbalance in the regional ecosystem.
- Stork become decolonized from this region and may search for new colonies.

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Introduction

The Asian openbill stork (AOS) colony displays high sensitivity to its surrounding habitat, as documented

by Luthin (1987) and Hancock et al. (2010). The basic requirements essential for the biological interaction and adaptation of AOS are outlined meticulously in a list, as highlighted by Das et al. (2014), Mohapatra et al. (2019), and Gula et al. (2023). Selected villages along the Keleghai River bank have strategically accommodated several AOS colonies based on these fundamental biological prerequisites. Easily distinguishable from other large aquatic birds, the AOS is characterized by its greyish-white plumage and distinctive greyish bill with an open space between the mandibles, as described by Robson (2020).

With a vast range in Southeast Asia and widespread distribution across plan land in the Indian subcontinent, AOS colonies predominantly inhabit areas adjacent to riverbanks, wetlands, and marshlands (Das et al., 2014; Birdlife International, 2015; Liu et al., 2015; Robson, 2020; Das et al., 2022). The nesting and reproductive processes of AOS are intricately linked to the region's rainfall and food availability, as outlined by Mukhopadhyay (1980) and Dhua et al. (2013). Habitats such as paddy fields, wetlands, marshlands, and riverbanks are commonly utilized by these birds for food consumption. The bird's habitation is significantly influenced by land use, as emphasized by Sundar (2006). For nesting, AOS exhibits a preference for the tallest and largest trees with sturdy branches, as noted by Garg (2016), often in conjunction with agricultural fields in the landscape (Pramanik et al., 2009; Kumar and Kanaujia, 2016).

The AOS migrates to inhabit in certain villages along the Keleghai River bank, contingent upon the availability of a favourable habitat in the surroundings. These areas may be attributed to the presence of suitable food sources in the vicinity, as highlighted by Greeshma and Jayson (2018), Roy and Sah (2013), and Kumar and Kanaujia (2016). Interestingly, no historical record or information is documenting their arrival and colonization timeframe in the present study region. Typically, these birds arrive from other parts of Asia in the month of May, spending 6 to 7 months to complete their life cycle, as communicated by local stakeholders. AOS colonies are also established in various sites in West Bengal, dictated by the regional environmental conditions, as indicated by Das et al. (2014) and Kumar and Kanaujia (2016).

Currently, in the study area, the colonies and population of AOS face threats, as reported by stakeholders and the President of the Biodiversity Management Committee (BMC) in Patashpur-I Community Development Block, Purba Medinipur, West Bengal. According to information from older individuals in the surrounding villages, there was a significant increase in the number of colonies and birds in previous decades. However, recent reports from local newspapers and stakeholders indicate a decline in the number of birds establishing colonies. Despite this, no investigations, either public or institutional, have been conducted to uncover the truth behind this phenomenon.

Various research studies have generally proposed that alterations in surrounding land use, changing microhabitat conditions, ecosystem simplification, disruptions in the ecosystem food chain, and human intervention in their habitat could be responsible for such ecological incidents. Sharma (2007) and Pramanik et al. (2009) observed this ecological circumstance in Raiganj Bird Sanctuary, Uttar Dinajpur district, West Bengal; Bhattarai (2012) noted it in Chitwan National Park, Nepal; Mohapatra et al. (2019) studied in Nandankanan Wildlife Sanctuary, Odisha; while Zakaria et al. (2023) conducted research in Central Peninsular Malaysia. It is important to note that all these studies were specific to particular areas and cases.

The focus of my investigation is to identify the factors influencing the habitation of AOS in the study area. In pursuit of this inquiry, I initiated various steps, including collecting literature in both published and unpublished forms. Unfortunately, I have not come across any relevant literature addressing this specific aspect. Additionally, I reached out to the Biodiversity Management Committee (BMC), Patashpur-I, in an attempt to obtain published information related to AOS, but they are unable to provide any historical records on this matter.

Given the current scenario, the study commences by exploring stakeholders' perspectives to uncover the underlying reality. Subsequently, a series of measures and analyses are devised to delve into the situation. Numerous cost-effective field excursions are conducted to comprehend the underlying conditions contributing to the decline in the number of AOS and their colonies in certain villages along the Keleghai River bank. Moreover, this study aims to propose practical measures for the sustainable habitation of

AOS, contributing to the protection and conservation of their coexistence with human society.

Materials and methods

Study area

The specific area occupied by AOS colonies encompasses only two villages, namely Paschim Selmabad and Uttar Selmabad, situated on the south side of the Keleghai River. These villages fall within the jurisdiction of the Patashpur Police Station in the Purba Medinipur district of West Bengal, India. However, the broader study area encompasses various shared land uses in the vicinity of these two villages, as illustrated in (Fig. 1). The land use patterns in the background of these villages significantly influence the habitat of AOS.

Methods

This study aims to identify the reasons behind the contraction of AOS colonies and numbers in the vicinity of the Keleghai River bank. To assess the situation, comprehensive field investigations are conducted, involving on-site visits and interviews with knowledgeable stakeholders from neighbouring villages, including Paschim Selmabad, Uttar Selmabad, Gokulpur, Amarpur, Barbaria, Madhabchak, and Gopalpur in Patashpur Community Development Block-1. Following the acquisition of primary information, the study employs spatial data analysis, incorporating satellite images and Google Images to validate the findings obtained from the survey.

Primary data collection

Initially, meticulously crafted questionnaires are developed to gather the perspectives of villagers on the question of contraction of AOS colonies and numbers. A set of questions focused on AOS colony contraction is administered to a targeted group of 72 families selected from 14 villages surrounding the AOS colonies (Fig. 2). The family selection involved clustering households with the same surname, known as "Para." The study prioritized the most experienced individuals born before 1960 within a family to respond to the questionnaire. The survey and interview processes spanned from October 2021 to November 2022, conducted during multiple attempts. Communication predominantly took place in the afternoon, a time when family members typically engage in relaxation. Selected individuals are interviewed, and information is recorded at six equal intervals, starting from 1960 to 2020. For instance, respondents provide numerical estimations of AOS colonies for each decade, ranging from 1960 to 1970, 1970 to 1980, 1980 to 1990, 1990 to 2000, 2000 to 2010, to 2010 to 2020.

AOS population estimation

Estimating bird populations through nest counting is a common method used by several ornithologists and ecologists (Bibby et al., 2000; Martin, 1993; Newton, 1998). This approach is particularly useful for bird species like AOS that build nests, as it provides a direct measure of reproductive activity. The present study applied nest count method to estimate the number of AOS in the study area. From a single AOS colony, nesting trees are identified and then count the nests to get the number of AOS. This method has been continued for all existing colonies to sum up the AOS number. For the lack of any AOS population previous records in the study area, study assumes the previous AOS number based on a simple statistical method, i.e., colony per AOS number prediction. A colony is defined as the compact clustered of nesting trees around a pond or beside an agricultural field in the study area.

Data tabulation and analysis

After getting these valuable answers and comments from the respondents, all qualitative information are converted into quantitative form and tabulated categorically from the questionnaires according to the objectives. Then, interval-wise, total sampled numeric information are standardized by using the average method by Bissell (1994) (eq-1). The factors related to AOS habitation have changed from the past and are cleared, while the data table is completed and prepared for analysis (Table 1) (Bissell, 1994).

$$\frac{\sum n}{Sn} = \text{Average value (1960 to 2020 in 10 years interval)} \quad (1)$$

The formula is used to tabulate factors wise information. Where n represents the respondent

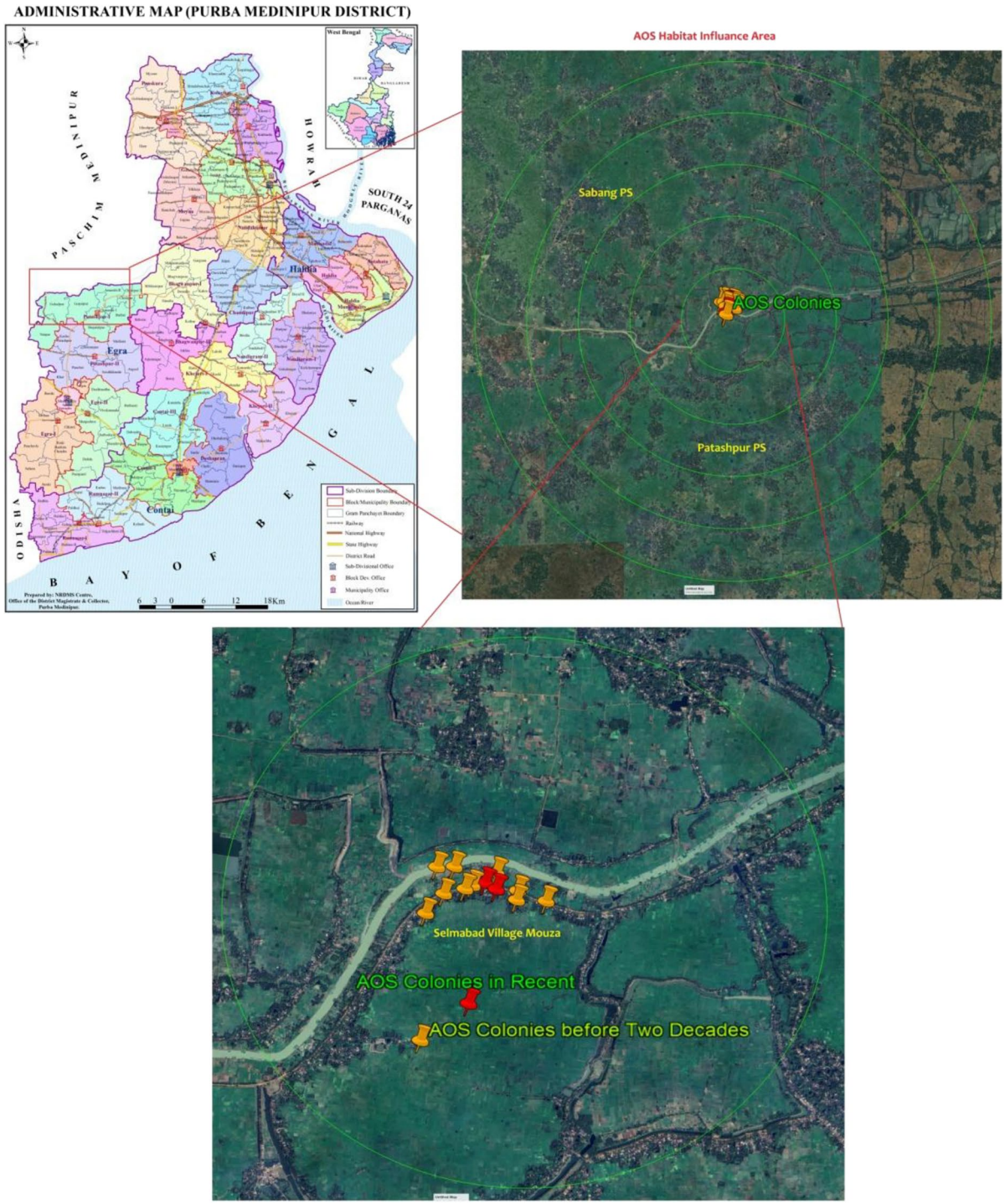

Fig. 1 Location map of colonies of Asian openbill stork in Selmabad village beside the Keleghai River bank under Patashpur and Sabang Police Station, West Bengal

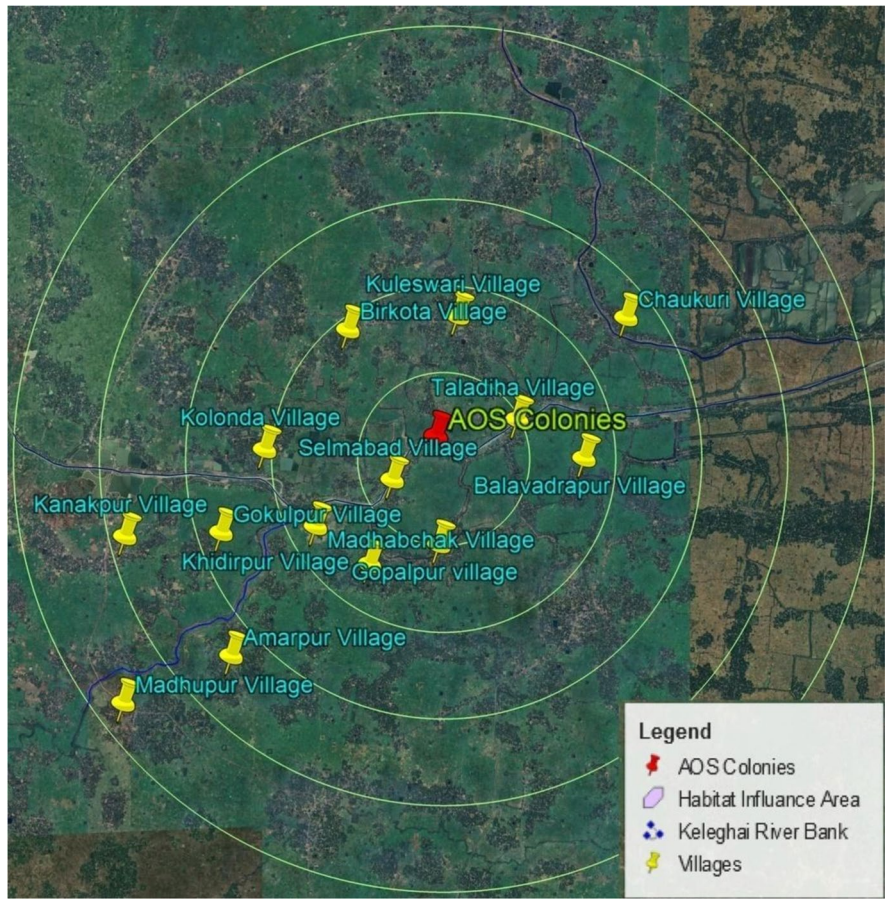

Fig. 2 Primary data collection site (villages) from the surroundings of AOS colony in Keleghai River Basin

Table 1 Quantitative data concerning factors associated with AOS habitation was obtained from the two specific villages, namely, Selmabad and Taladiha, located within the AOS colonies along the banks of the Keleghai River

Year	Average no of AOS colonies	Average no. of commercial fish farming unit	Average no. of mature trees	Average fertilizer used per acre in kg
1960–1970	50	0	280	1.5
1970–1980	42	0	272	2.3
1980–1990	40	2	156	2.6
1990–2000	35	5	84	3
2000–2010	18	9	65	4
2010–2020	8	18	34	8

individual's numeric perception of the factors. And *Sn* is the total number of samples.

Satellite data collection and analysis

The current study employs a land-use/land-cover (LULC) temporal change assessment as an additional approach to validate the findings from the primary data. Satellite images are sourced from the US Geological Survey (USGS) at http://glovis.usgs.gov/ as an open resource. Landsat TM data from 1990 and Landsat 8 (OLI/TIRS) satellite data from 2023, both with a spectral resolution of 30 m, are utilized in the study area. For land-use/land-cover classification, supervised techniques, as described by Pal and Mather (2004, 2005) and Bouaziz et al.

(2017), are applied to analyse the 1990 and 2023 images using ArcGIS 10.4v and various geospatial software. The classification focused on five LULC classes: agricultural land, tree cover, settlement areas, open land, and water bodies. The resulting classified maps for 1990 and 2023 underwent field verification for cross-verification. Ultimately, these maps are deemed acceptable for consideration when the classification accuracy exceeds 85%, as determined by the Kappa coefficient (Smits et al., 2010).

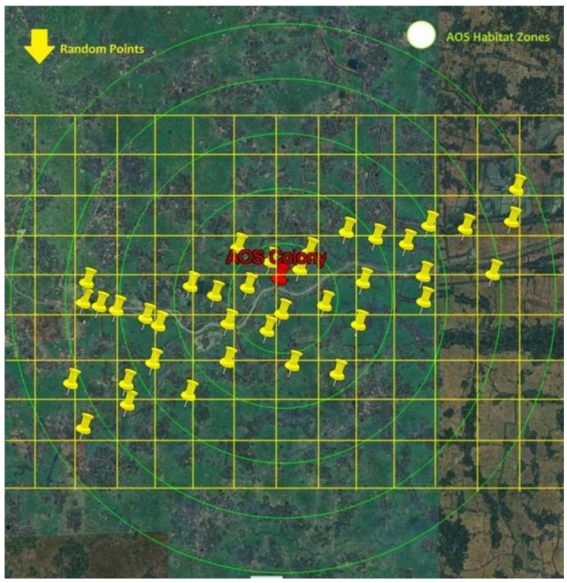

Fig. 3 Random points from the AOS habitation areas along the KR bank for wetland land use change detection

Measurement of temporal changes in wetlands land use characters

The study selects 38 random points out of 136 equal grid points from the AOS habitation area along the Keleghai River to know the temporal changes of wetland land use characteristic patterns. The points are defined and demarcated over the wetlands (Fig. 3) specified by stakeholders' opinions and Google image verification. After that, every selected point's land use temporal patterns are documented with the help of historical Google Image analysis and verified through stockholders' opinions. Every point's temporal condition is recorded at 10-year intervals, starting from 1984 to 2014 and recent information from 2020.

Results

The present study estimates the AOS population number using nest count method. It has been counted that 246 AOS nests are built among 29 nesting trees under adjoining eight colonies from the study area in the recent year, 2023. That means approximately, $246 \times 2 = 492$ AOS have come to the study site to continue their biological reproduction cycle in the present year. Based on this data, the study statistically estimates the numbers of AOS in previous decades (Table 2). From the assumed table information, it has been found that the numbers of AOS have drastically declined between 2000 to 2010. It is interesting to see that in the same period, habitat modification rates also increased consequently such as land use alteration that is discussed in below.

The questionnaire in this study identified five potential causes for the contraction of AOS colonies, including land use change, widespread use of

Table 2 Estimation of number of AOS by nest count and statistical prediction

Year	No of colonies (stakeholder opinion)	Number of AOS (statistical prediction)	Method
1970	50	3075	Predicted numbers of AOS calculated by number of birds per individual AOS colony based on recent nest count
1980	42	2583	
1990	40	2460	
2000	35	2153	
2010	18	1107	
2023	8	492	Actual number of AOS by nest count

pesticides and fertilizers in paddy fields, destruction of larger mature trees in the breeding grounds, local climate change, and other factors. The tabulated response reveals that land use change emerged as the most influential factor contributing to AOS colony contraction in the surrounding villages. Approximately 37.5% of respondents identified land use change as the primary cause (Fig. 4). The destruction of larger mature trees in the habitat ranked as the second most cited factor, with 26.38% of respondents expressing this view. Regarding the use of fertilizers and pesticides, 18.05% of respondents acknowledged its impact. Only 6.94% and 11.11% of respondents attributed the declining AOS colonies to climate change and other factors, respectively.

The majority of opinions emphasized that habitat alteration, particularly in the form of land use change, played a pivotal role in reducing both colonies and the number of birds in their villages. Respondents argued that the habitat ecosystem underwent a significant shift from complex to simple due to three major factors: land use change, extensive use of fertilizers and pesticides in paddy fields, and the destruction of native large-sized trees along the riverbank.

Another perspective is the nature of temporal change of local tree composition and human activities in the paddy field that is derived from questionnaire interviews from surrounding villages. The information about temporal changes regarding the numbers of colonies of AOS and the number of mature trees in surrounding colonies of the birds have declined (Fig. 5 A and C). However, the number of commercial fisheries in adjoining wetlands, and the amount of fertilizer used for cultivation in surrounding agricultural land have increased from 1970 to 2020 (Fig. 5 B and D).

Discussions

Impact of temporal land use change on AOS habitation

Extreme land use alteration has been found in the surrounding areas of these villages. Mainly, wetlands altered into commercial fisheries and marshlands into paddy fields tremendously after the implementation of river and canal reformation by both State and Central governments. Since 2000, Keleghai River and its adjoining canals have been reformed. These reformed environments are responsible for the destruction of native aquatic ecosystems and also related to habitat loss (Mandal et al., 2021). The aquatic habitat system drastically changed into simplest form in this influence habitat range of AOS. Nearest wetlands used to play a vital role in their food acceptability at the time of breeding and nesting of this bird (Datta and Pal, 1993). Maximum wetlands were in water lodge condition with full of high aquatic species diversity. But recently, paddy cultivation has been practised in almost all wetlands with the help of well drainage conditions argued by BMC (Biodiversity Management Committee) under Patashpur Community Development Block-I. To justify the statement, the study points out some wetland sampling points in Google Image 2023 with the help of stakeholders'

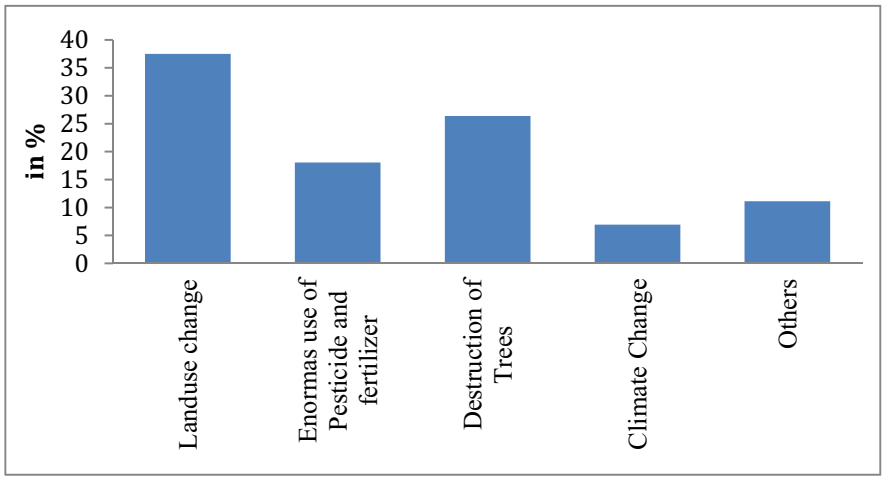

Fig. 4 Representation of respondent consents against responsible factors for declining breeding colonies and numbers of AOS from their surroundings

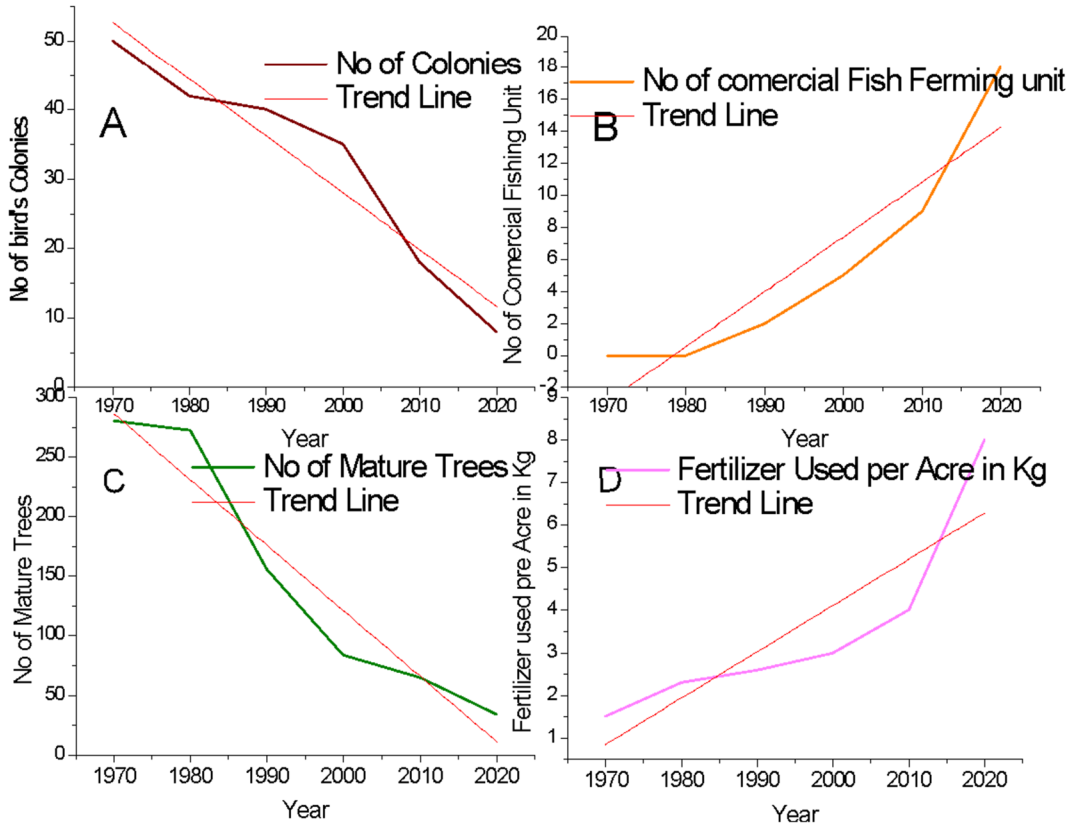

Fig. 5 Change detection graphs represent the temporal status of variables as **A** the number of bird colonies, **B** the number of commercial fishing units, **C** the number of mature trees, and **D** the amount of fertilizer used per acre in kg

opinions. After that, these wetland sampling points are plotted in both land use images of 1990 and 2021. The plotting points show that the wetlands of both sides of the Keleghai River at a 5-km radius have been gradually shrinkage (Fig. 6) and altered into paddy fields and commercial fisheries.

On both sides of the Keleghai River, several wetlands like Selmabad, Rothravari, Kutupur, Gokulpur, Palpara, Andulia, Kanakpur, Rajpur, Nedhua, Dhamsai, and Taladiha altered into paddy fields or commercial fisheries (Fig. 7). As a result, a drastic change has been found in the wetland ecosystem. The food web in the wetland ecosystem becomes simplified, and some of the living components are wiped out from the food chain. This imbalance and simplified ecosystem did not support the AOS habitation and colony development in the previously suitable location. Thus, AOS are now gradually declined from the Keleghai River bank side, especially from the villages where they were usual to develop their colonies.

LULC change detection maps across the Keleghai River basin from 1990 to 2023 show similar circumstances (Fig. 8). These alterations break down the existing ecosystem and lose several aquatic species. Similar results are also found by Imdad et al. (2022) in Rajasthan State. This fact shrinks the food availability of AOS from the wetlands of adjoining villages. Bhatta et al. (2016) found a shrink in the food chain in the wetland in Assam due to this fact. This same circumstance forced AOS to decolonize or migrate from these two villages in the present study area. The same results were also found in several studies by Pramanik et al. (2009), Anila et al. (2016), and Mohapatra et al. (2019) from different sites in India and abroad by Zainul-Abidin et al. (2017).

The image analysis comprises the result of primary data analysis. It has been found that water body (wetland) areas declined and agriculture land increased from 1990 to 2023 in the Keleghai River basin (Table 3). These analysis outcomes strengthen

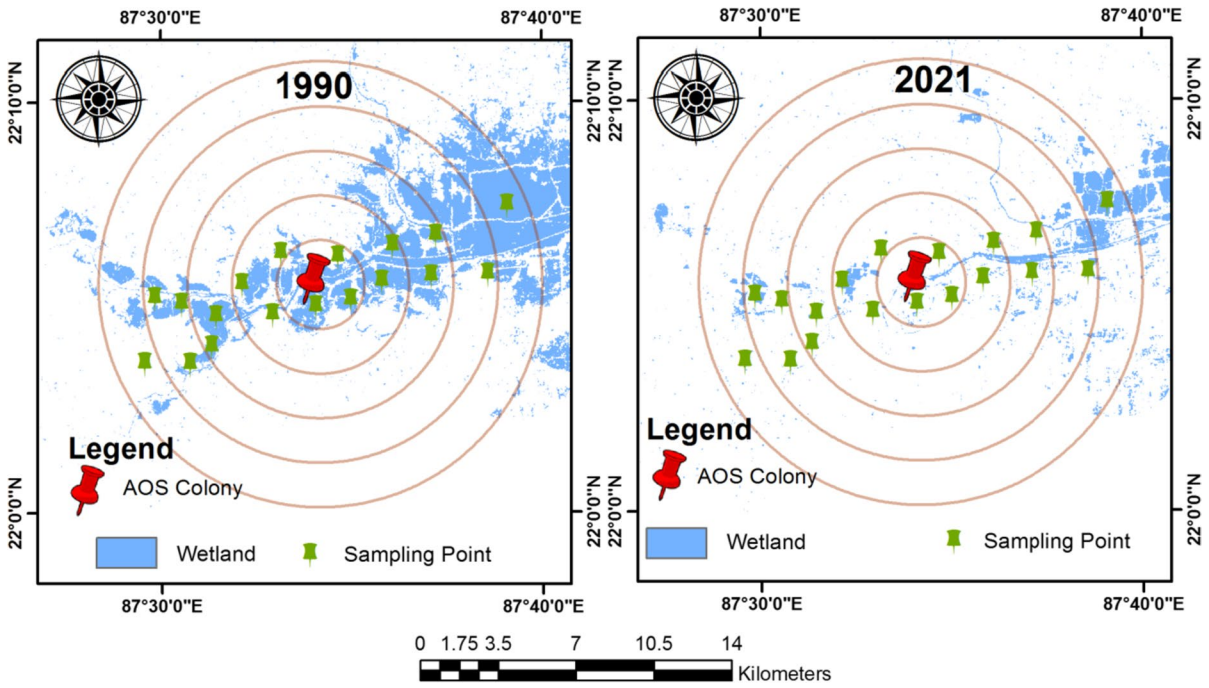

Fig. 6 Presenting the land use alteration status especially wetland alteration into the paddy field from 1990 to 2021. In 1990, the wetlands were living as usual without paddy cultivation. But after, these wetlands are practised by local cultivators as paddy fields through the help of a good drainage system by the adjoining canal of Keleghai River

the concept of respondents' perception that wetlands gradually collapse from the surroundings. In 1990, the wetland (mentioned as water body) area was 7.33%, which is 4.21% out of the total area of the Keleghai River basin in 2023. These alteration processes tremendously affected habitats of the AOS from surrounding habitation.

Temporal changes in wetlands land use and functions

Wetland ecosystem function depends on the utilization of land. Generally, a certain change in land use in wetlands affects the existing ecosystem (Cui et al., 2019; Fang et al., 2020). It may create extinction or introduction of species in an ecosystem to balance the food web patterns (Bhattacharya and Das Chatterjee, 2021). It has been found from random point analysis that massive wetland land use patterns altered and continued from 1984 to 2020 in the AOS habitation area. The nature of wetlands land use patterns converted from single crop to double crop and following commercial fisheries drastically after 2004 (Fig. 9). These alteration processes significantly affected the AOS habitat and niche patterns, especially because they suffer from food availability from the wetlands due to the extinction of some species from the wetland ecosystem. Therefore, AOS leave the previously selected areas from the Keleghai River basin and search for new suitable habitat areas to build their new colonies.

Impact of extensive use of fertilizer and pesticides in paddy field

The second investigation behind the causes of the decolonization of this bird is the extensive use of fertilizer and pesticides in paddy fields. It has been observed that at the beginning of early autumn, AOS start their breeding in their colonies. Their reproduction period is very much season-dependent. At that time, food efficiency is essential for birds in their breeding time (Collias, 1964; Kahl, 1971) as well as for AOS. Consequently, surrounding wet lands and marshlands of these villages beside the Keleghai River were full of aquatic species and they got sufficient food from their habitat

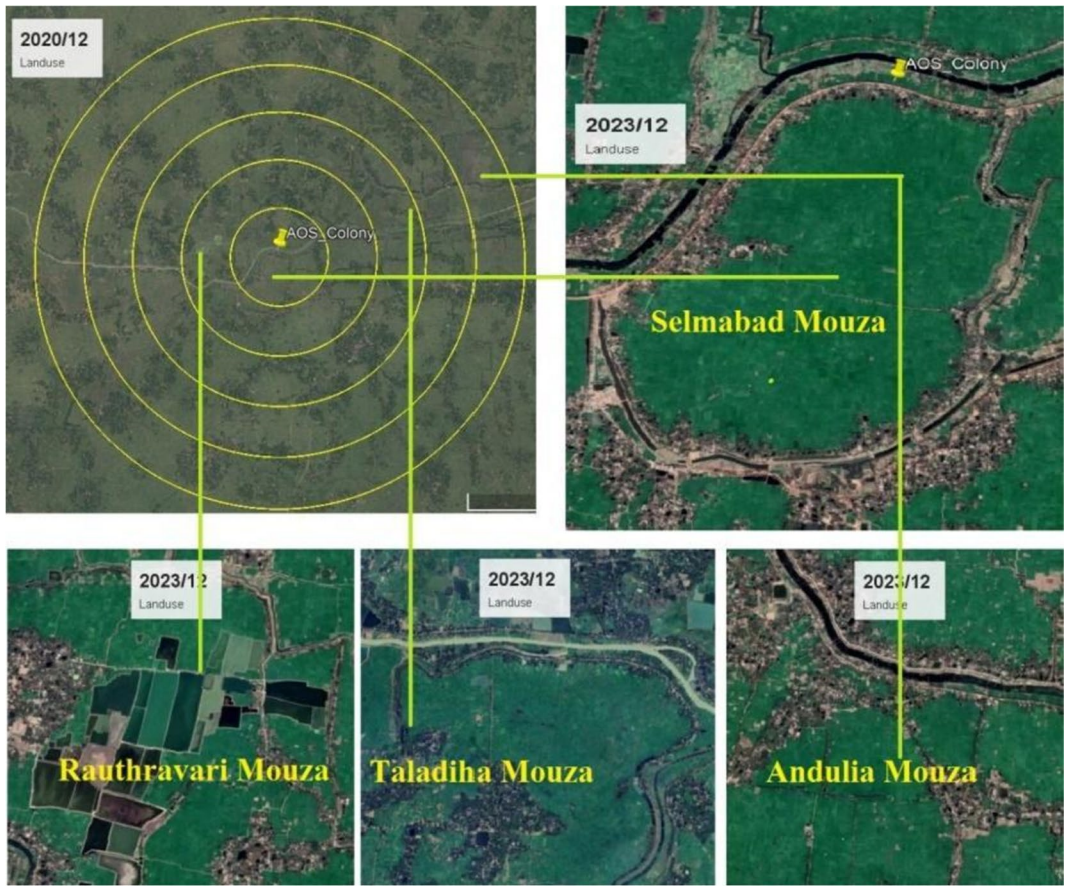

Fig. 7 Represents the wetlands and their altered functions as paddy fields, and commercial fisheries in some village mouzas in the KR basin

range. But in recent years, birds could not get sufficient food from their habitat range because their feeding grounds become converted into paddy fields (Hancock et al., 2010; Zainul-Abidin et al., 2017)) which I already discussed. During this period, paddy cultivator uses huge amounts of pesticides and chemical fertilizers (Fig. 10A) to protect against infection from pests and to fertilize the soil than before. However, these anthropogenic practices help to destroy and shorten the food web from the ecosystem. Significantly, these practices continued. Thus, a negative correlation is found between the number of breeding colonies and the amount of use of fertilizer in the surrounding paddy field (Fig. 11).

Crisis of food availability for AOS habitation

Ultimately, the processes of land use alteration and unscientific paddy cultivation have contributed to the partial elimination of various aquatic species in the habitation areas, particularly the surrounding wetlands. At the onset of the rainy season, intensive pesticide use results in the destruction of mollusc communities in wetlands, which is a crucial food source for AOS (Kahl, 1971; Sawangproh, 2021) (refer to Fig. 10B). This impact extends beyond mollusc communities, affecting other lower trophic level communities, including small fish and aquatic insects, leading to their gradual reduction in the wetland ecosystem, as observed by Mandal et al.

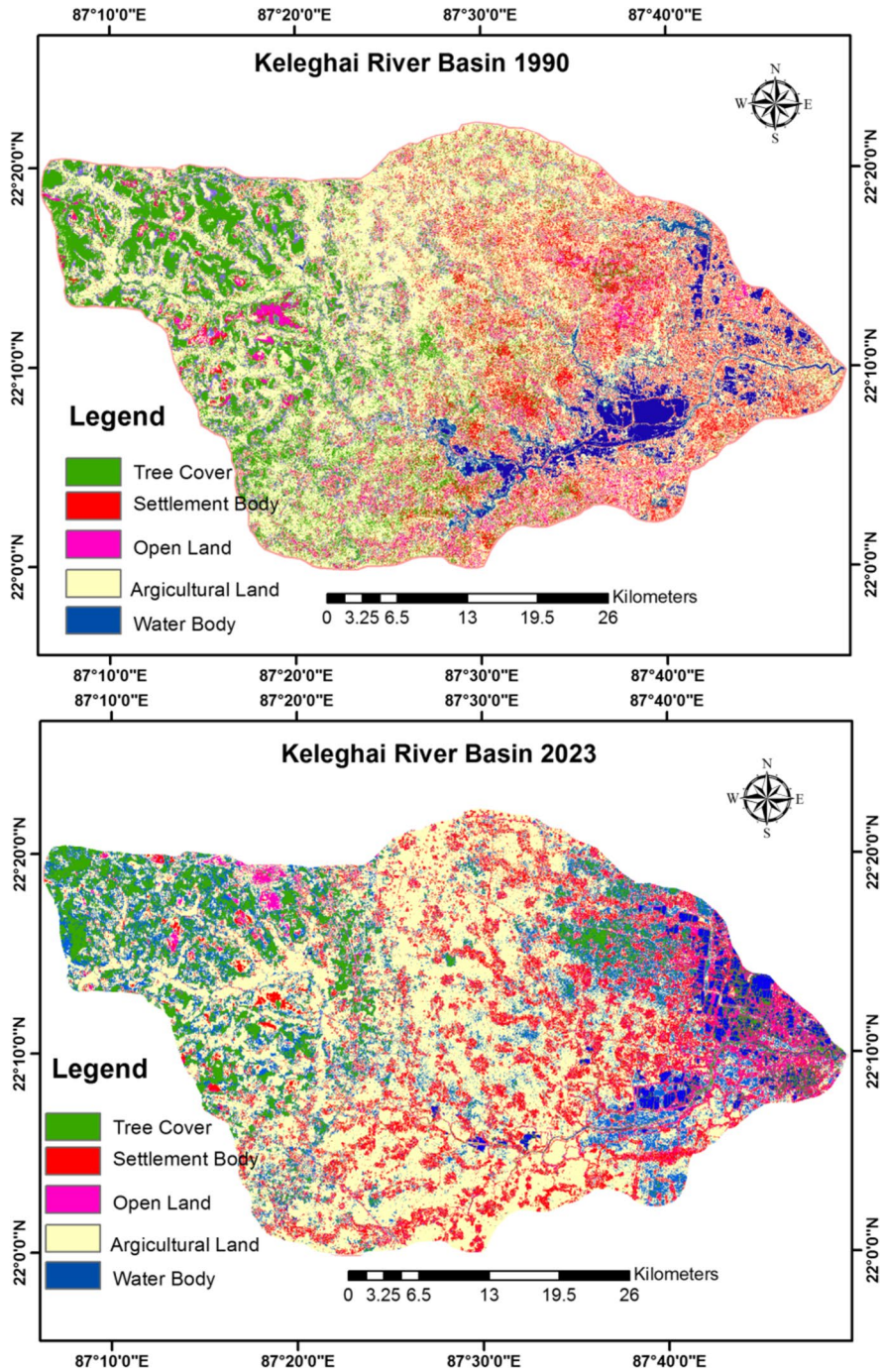

Fig. 8 LULC maps of the KR basin in 1990 and 2023. The comparison shows especially wetlands of this river basin shrink massively and alter into paddy fields

(2021). Consequently, the entire wetland ecosystem undergoes a simplification process, affecting the food web and food chain dynamics. The substantial reduction in biotic communities within the wetland ecosystem creates a food crisis for AOS habitation. Chatterjee et al. (2023), in Jogmaya Sarovar (Ranjan Dih), Purulia district, West Bengal, predicted a similar scenario. During their breeding period, AOS faced food unavailability in the surrounding wetlands, leading to disappointment and hindering colony development in their designated habitat areas. Consequently, they decolonize from the region and

Table 3 Comparison of LULC class area in % of selected two years in KR basin

LULC class	Year-1990 Area in %	Year-2023 Area in %
Water body	7.33	4.21
Agriculture land	52.93	55.68
Tree cover	20.35	21.18
Built-up are	10.63	10.21
Open land	8.74	8.64

may seek out new colonies in the subsequent years (Arya et al., 2021).

Destruction of native large-size trees from nesting place

Another significant result has come from the villagers' recommendation that colonies and the number of birds decline due to the diminishing of large and

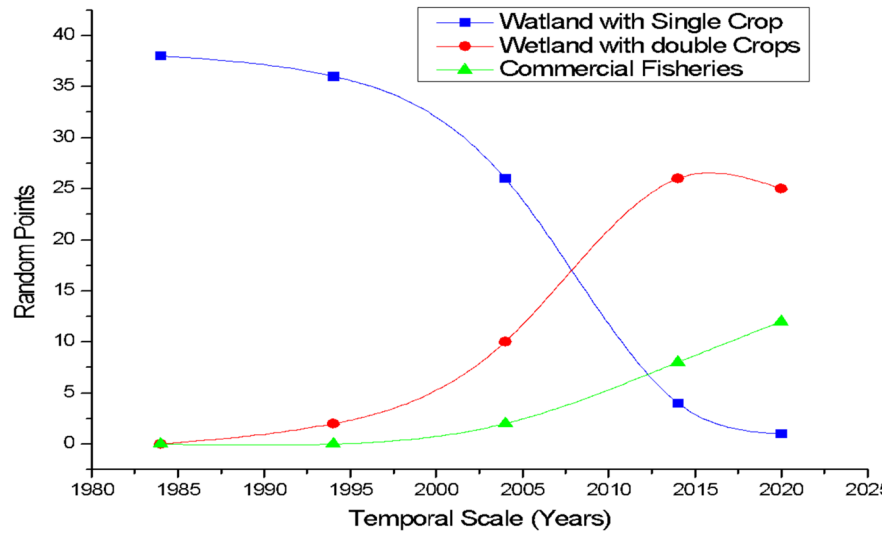

Fig. 9 Temporal change of wetlands utilization from the surrounding AOS colony along Keleghai River

Fig. 10 **A** Pesticide used in the paddy field in Selmabad village, and **B** a single AOS busy to collect molluscs from the paddy field, and **C** AOS birds are resting in a tree at the edge of the paddy field in early winter.

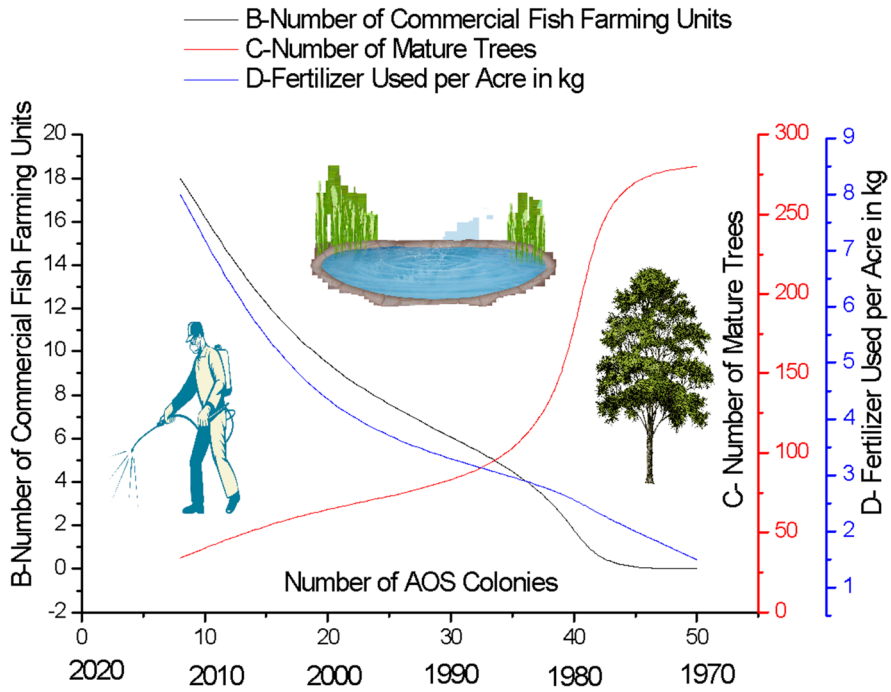

Fig. 11 Representing the temporal relation between numbers of breeding colonies and selected three variables as commercial fish farming units, number of mature trees, and fertilizer use in acre per kg. The variables numbers are considered temporally from 1970 to 2020

tall trees from the background of the area. Choudhary (2023) also found that the greater adjutant stork (*Leptoptilos dubios*) colony is very sensitive for selecting trees in the Kosi River in the Bhagalpur district, Bihar. The perception of the villagers also coincides with the statement of Choudhary (2023). Collected data analysis shows a positive relation between the number of breeding colonies and the number of mature trees (Fig. 11) in the bank of Keleghai River. The AOS colonies were enormous when the numbers of mature trees were also greater in number. The selection of trees for the construction of their breeding colonies is a matter of fact (Koju et al., 2019). According to Somnath Das Adhikary, President of BMC, Patashpur Community Development Block-I, trees like Tentul (*Tamarindus indica*), Arjun (*Terminalia arjuna*), Hijal *(Barringtonia acutangula*), and Siris (*Albizialebbeck*) are mostly favourable for nesting for these birds due to herd and dense pattern of top twigs and branches (Fig. 12). This statement regarding AOS colony development is similar to several ornithologist studies such as Roy and Sah (2013), Das et al. (2014), and Meganathan and Jeevanadham (2017). Unfortunately, these trees are abolished in a few decades in their breeding colony. Many native breeding colonies of AOS in the river bank are destroyed due to the reformation of the Keleghai River. At the time of reformation, favourable trees are cut down without any excuse from the riverside. Hijal trees, one of the most suitable trees for the development of AOS nesting, are wiped out from the river bank due to canal reformation. Existing other trees in their colony do not fully support making a suitable nest to develop a colony.

AOS habitat loss by human activities and its consequence

From the above discussion, it is clear that the habitat of AOS is gradually being degraded due to human activities (Fig. 13). Extensive land use alterations in Keleghai River basins have directly affected bird ecosystems. These human-induced changes have narrowed the diet of AOS. Not only that, enough suitable trees to build nests are being cut from their habitats. Most importantly, the AOS birds have been deprived of the nutrients they need during their breeding for several years. The main reason for this is the conversion of wetlands along the river into paddy fields. Not only that, the extensive application of chemical fertilizers and pesticides in the paddy fields has extensively destroyed the natural ecosystem. This profit-seeking approach of humans has not given importance to the habitat and ecological importance

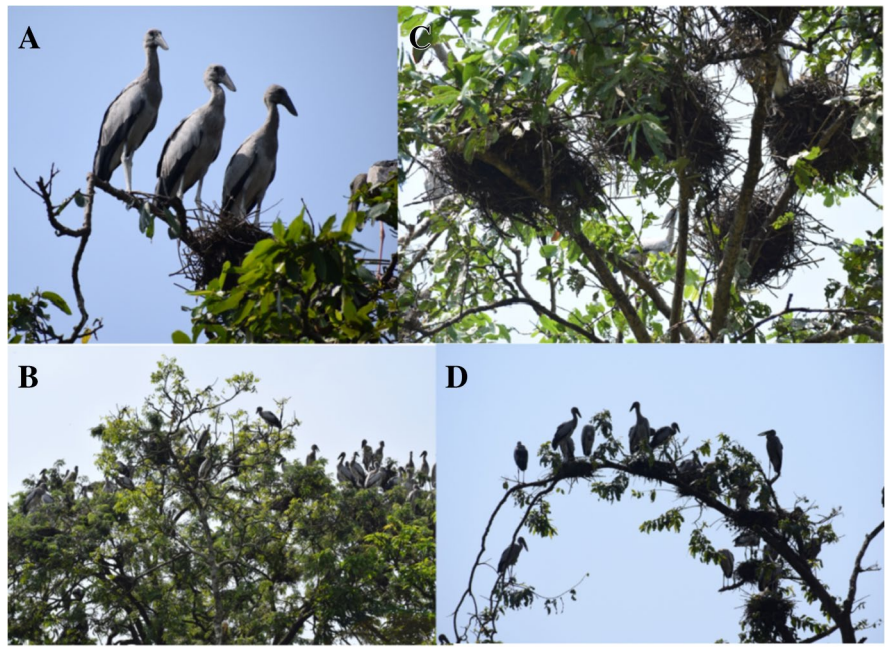

Fig. 12 Nests over **A** Mango (*Mangifera indica*), **B** Tentul (*Tamarindus indica*), **C** Hijal (*Barringtonia acutangula*), and **D** Arjun (*Terminalia arjuna*) trees of AOS in their breeding colony in Selmabad Village

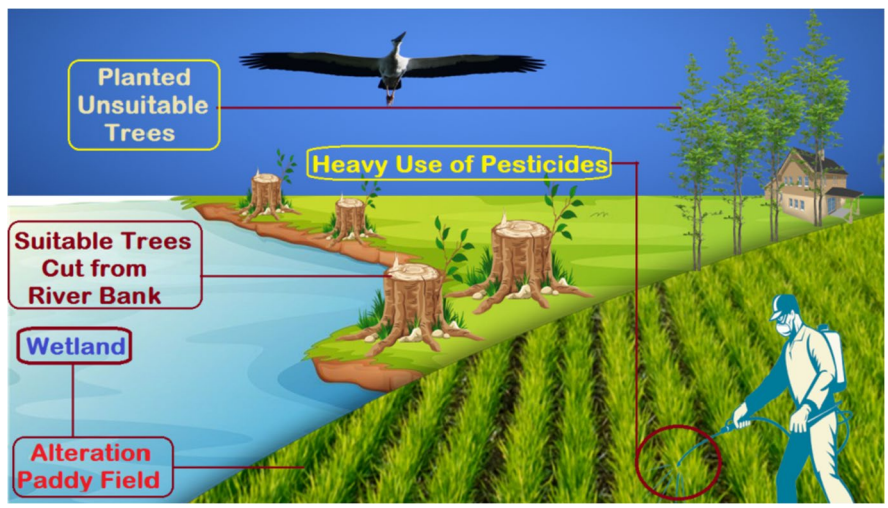

Fig. 13 Pictorial representation of habitat quality loss due to human activities and direct intervention in the habitation of AOS in the Keleghai River bank

of AOS birds in their surroundings. As a result, the birds are forced to look for nests elsewhere.

The disruption of habitat and the resulting imbalance in the ecosystem lead to a decline in the provision of ecosystem services to society stated by Green and Elmberg (2014) and Siva and Neelanarayanan (2021). Similarly, the removal of AOS from the local ecosystem may increase the population of harmful aquatic insects and reduces environmentally friendly elements, impacting the availability of traditional food, production and recreation.

The correlation between the bird population and the biodiversity in a given area serves as a significant indicator of environmental quality, as noted by Kumar (2012). AOS, recognized for their ecological versatility and ability to inhabit various types of habitats, are widely regarded as valuable indicators of environmental health (Järvinen and Väisänen, 1979). The reduction in the population of AOS birds in the study area indicates a gradual deterioration of wetland ecosystem qualities. Consequently, the Keleghai River basin's ecosystem will be significantly

impacted, leading to a notable threat to species diversity. In particular, indigenous aquatic species struggle to coexist with the changing environment, resulting in their extinction. AOS has a direct impact on wetland ecosystems. They contribute to the regulation of aquatic populations, preventing overpopulation of certain species and promoting biodiversity in wetland ecosystems (Mukhopadhyay, 1980) by participating as keystone species. Not only that they raise soil fertility by leaving their huge droppings in the wetlands. The local stakeholders can understand the importance of AOS birds in their surrounding habitats when they face and tackle maximum harmful effects of anthropogenic activities like use of chemical pesticides and fertilizer in the paddy fields. Another ramification of the decline in AOS bird numbers is that the upcoming generation may miss out on experiencing the natural beauty of these birds. This, in turn, hampers their ability to contribute to local tourism and educational efforts aimed at raising awareness about the importance of preserving natural habitats.

Conservation measures for restoring AOS birds and their colonies

The surrounding human societies of the target villages are tremendously careless about the ecosystem services of the bird community as well as of AOS. The birds are an important element of this environment, but the people of the society of today have not yet understood it properly. Whether these birds will continue to exist in the villages beside the Keleghai River is questionable if do not take any advance drives to protect these birds. The present study concludes that both society and administration should come to the front and way out some management steps.

Recommendations for conserving the AOS

At first, an awareness camp is very urgent for sharing ideas about the importance of AOS in the ecosystem as well as the rural economy. With the support of local administration, a regular monitoring system should be developed for understanding the habitat pattern of AOS in detail. The most demandable measure for investigating the habitat nature of birds is GPS tracking (Bouten et al., 2013). From the tracking information new ideas and concepts will open

Table 4 List of suitable native trees for planting along the Keleghai River bank which have potential facilities to build a colony of AOS

Local name of suitable tree	Scientific name
Arjun	*Terminalia arjuna*
Banyan	*Ficus benghalensis*
Bael	*Aegle marmelos*
Hijal	*Barringtonia acutangula*
Tetul	*Tamarindus indica*
Kadam	*Neolamarckia cadamba*
Asbathya	*Ficus religiosa*
Jam	*Syzygium cumini*

that help to conserve and protect them regionally. Not only that to get back the qualitative habitat of AOS, the selected trees (Table 4), which have suitable nesting environments, should also be planted inside and outside of the Keleghai River bank. For example, Hara et al. (2017) studied that suitable tree plantations enhanced AOS numbers and colonies in the peri-urban areas in Bangkok. At the time of the field investigation, I was informed by the villagers that unwillingly they destroyed the big trees (where AOS built a nest) because of intolerable heavy bird noise and huge droppings. To manage this circumstance, expert opinion and advanced techniques should be employed. For example, a thin layer of the net under the breeding colonies may restrict the droppings from falling into the house and its surroundings. Another measure is controlling the use of pesticides and fertilizer in the paddy field. If the cultivators use bio-fertilizers in their crop fields, then the wetland ecosystem will not disturb and it will raise species diversity. In the realm of cultural landscape planning and management, Naito et al. (2014) demonstrated a successful case by employing the reintroduced oriental white stork (Ciconia boyciana) as an indicator species. Their findings revealed that promoting organic-based rice farming on a regional scale to establish a core habitat for this bird can yield dual benefits for both local farmers and the economy. This is achieved through increased prices for the rice cultivated in these fields and the adoption of environmentally friendly labelling, utilizing the bird as a symbol on the product labels. The tolerable species diversity in the wetland is a good feeding ground for AOS at the time of their reproduction. Finally, land use alteration

from wetlands to commercial fishing points across the Keleghai River bank should be maintained scientifically or closed strictly. These alterations not only affected the AOS colony's development but hampered the regional ecosystem as well as the societal economy stated by Singha and Pal (2023) and Pal and Singha (2023).

Conclusions

This study addresses the issue of AOS colony contraction in the study area through field investigations and observations. The impact of climate change on decline of AOS colonies and numbers from the study area will be an interesting research topic. Periodical information of AOS existence, their spatial distribution, and temporal climatic data are very much essential for that kind of study. Similarly, assessing the bird count over consecutive years without advanced tools, techniques, and funding support is challenging. So, further research could be possible when the requirements are available. On the basis of present observation, the findings reveal a gradual decline in the number of breeding colonies, impacting both the historical tradition and the local ecosystem. Unfortunately, no initiatives from authorities have been undertaken to protect or manage this situation. The present study aims to shed light on the actual conditions leading to the contraction of AOS colonies along the Keleghai River bank, documented in this literature. Additionally, the study proposes conservation measures for AOS. Addressing this issue urgently, the study suggests the formation of a local-level committee with institutional support to protect and conserve the beautiful AOS birds in the villages along the Keleghai River bank.

Data availability

The datasets generated or analyzed during the current study are available on request from the corresponding author.

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