Expansion of aquaculture threatens the existence of wetlands in Bangladesh

Md. Taskin Parvez • ABM Mohsin

Department of Fisheries, University of Rajshahi, Rajshahi 6205, Bangladesh

Correspondence
Md. Taskin Parvez; Department of Fisheries, University of Rajshahi, Rajshahi 6205, Bangladesh
satil198@gmail.com

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Abstract
Despite positive role of aquaculture in food production, the practice may impact the environment negatively and it is difficult to quantify the loss. In this study, we assessed land use changes in four important wetlands (Hardoho Beel, Angrar Beel, Shaoli Beel and Gopalpur Beel) of Bangladesh through analysis of historical satellite images (1990 – 2020) to show how expansion of aquaculture activities threatens the existence of freshwater wetlands. Since 1990, the water area of all four wetlands decreased significantly over time (all \( p < 0.001 \)). Mean yearly loss of 47.9 ± 79.3 ha, 99.2 ± 185.5 ha, 51.2 ± 61.9 ha and 2.6 ± 4.7 ha were recorded for Hardoho Beel, Angrar Beel, Shaoli Beel and Gopalpur Beel respectively. A decreasing trend in wetland area was recorded in all wetlands, primarily due to excavation of aquaculture ponds. In 2020, aquaculture ponds represented 72% of the core wetland areas. Two wetlands (Hardoho and Gopalpur) were almost totally lost and converted to aquaculture ponds and agricultural lands. This study concludes that the existence of freshwater wetlands in Bangladesh is at stake and recommends further studies to determine its impacts on people’s livelihood and biodiversity.

Keywords: aquaculture expansion, aquaculture impact, biodiversity threat, land use change, wetland

1 | INTRODUCTION
There are numerous aspects of aquaculture practices that have an impact on ecosystem and biodiversity. Aquaculture is often considered mirror agriculture because during many aquaculture practices agricultural lands are being converted into aquaculture ponds. There is a growing trend of converting agricultural lands into aquatic ponds and an opposite trend has been noticed for agricultural lands. There is a lost-lasting concern over the actual or potential impacts of certain aquaculture practices on biodiversity as such practices may be harmful to biodiversity (Diana 2009). This has been identified, at least speculated, by many researchers and organisations working with the environment. However, it is often difficult to determine or quantify the impacts of aquaculture on the environment.

The impacts of aquaculture activities on local biodiversity are usually negative; in some cases it may be neutral but rarely positive (Beveridge et al. 1997). Several negative impacts of aquaculture on biodiversity can be identified (Diana 2009). These include unwanted escape of aquaculture species capable of being invasive; interactions between effluents from aquaculture facilities causing eutrophication and aquatic fauna in receiving waters; expansion of aquaculture in important habitats including mangroves and wetlands; impacts on other aquatic resources for aquaculture inputs such as fish meal preparation can lead to overexploitation of required stocks; transmission of disease causing agents from aquaculture species to wild stocks; possible genetic degradation of natural stocks from escaped hatchery-bred species; increasing killing of fish predators such as birds near aquaculture farms; increasing use of antibiotic and hormone.

However, aquaculture may also positively impact...
examined the changes in land use pattern in four wetlands between 1990 and 2020.

2 | METHODOLOGY

2.1 Study area
The study was carried out in four wetlands (locally called beels) of north-western Bangladesh: Hardoho Beel (24°30'21.8"N 88°34'00.1"E), Angrar Beel (24°29'03.3"N 88°43'30.5"E), Shaol Beel (24°27'24.2"N 89°07'54.5"E) and Gopalpur Beel (24°11’18.1"N 89°08’36.6"E) (Figure 1). Hardoho Beel is situated in Tanore Upazila of Rajshahi district. This wetland is connected to Barnoi River. Angrar Beel is situated in Durgapur Upazila of Rajshahi district. Shaol Beel is located in Singra Upazila of Natore district and this beel is connected to Gumani River and Chalan Beel- the largest wetland of the country (Galib et al. 2009, 2018). Gopalpur Beel is situated in Baraigram Upazila in Natore district and it was a part of Chalan Beel in past.

2.2 Study approach
Yearly changes in wetland areas between 1990 and 2020 were analysed based on Landsat (NASA-USGS) satellite images of the study areas, captured on 31 July every year. Being captured in the mid of rainy months (i.e. 31 July), these satellite images effectively represent the wetland water area. The images were analysed using QGIS (version 3.12.2) software to calculate the water area. In addition, number of ponds and their areas were also calculated using QGIS to compare expansion of aquaculture ponds against total wetland area. The image processing and analysis were carried out in the Aquatic Biodiversity Lab of the Department of Fisheries, University of Rajshahi in 2021. In addition, three field visits were made to each of the studied wetlands in October, November and December of 2020 to compare the number of aquaculture ponds and to record relevant activities (e.g. excavation of new ponds).

3 | RESULTS

3.1 Changes in wetland area over time
In 1990, area of Hardoho Beel, Angrar Beel, Shaol Beel and Gopalpur Beel were 1443.8 ha, 3155.4 ha, 1643.3 ha and 81.8 ha respectively. Analysis of the satellite images revealed that the water area of all four wetlands decreased significantly over time (Figure 1; all p < 0.001). Mean yearly loss of 47.9 ± 79.3 ha, 99.2 ± 185.5 ha, 51.2 ± 61.9 ha and 2.6 ± 4.7 ha were recorded for Hardoho Beel, Angrar Beel, Shaol Beel and Gopalpur Beel respectively.

In 2020, water area of the wetlands was 5.8, 179.5, 106.7 and 2.8 ha for Hardoho Beel, Angrar Beel, Shaol Beel and Gopalpur Beel respectively.

Two wetlands (Hardoho and Gopalpur) were almost fully lost and converted to aquaculture ponds and agricul-

FIGURE 1: Map of the study areas (modified from Banglapedia).
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Tural lands (Table 1). Yearly change in wetland showed a decreasing trend in wetland area in all wetlands. The highest yearly mean loss of wetland area was recorded for Angrar Beel (Mean ± SD: 99.2 ± 185.5 year⁻¹) whereas the lowest loss was recorded for Gopalpur Beel (2.6 ± 4.7 year⁻¹).

3.2 Expansion of aquaculture in wetlands
In 2020, 895.2 ha, 2524.3 ha, 1068.3 ha and 57.3 ha areas were converted into aquaculture ponds in Hardoho Beel, Angrar Beel, Shaoil Beel and Gopalpur Beel respectively. These represented 60%, 80%, 65% and 70% of the total area of Hardoho Beel, Angrar Beel, Shaoil Beel and Gopalpur Beel respectively. Analysis revealed that until 2006, there were no aquaculture ponds in the studied wetlands. Massive excavation work for aquaculture was recorded between 2011 and 2015 (Figure 2). A total of 326, 482, 378 and 42 aquaculture ponds were recorded in 2020 in Hardoho Beel, Angrar Beel, Shaoil Beel and Gopalpur Beel respectively. All aquaculture ponds were constructed in the middle of the wetlands. However, continuous excavation of new ponds for aquaculture was recorded in all wetlands.

**FIGURE 1:** Loss of wetland areas between 1990 and 2020. Grey shaded area represents 95% confidence interval.

**FIGURE 2:** Excavation of aquaculture ponds in four wetlands between 1990 and 2020.
4 | DISCUSSION
A remarkable transformation of natural wetlands took place in the study area, most into aquaculture ponds. This poses a grave threat to the existence of studied wetlands as most of ponds were excavated in the middle of the wetlands. There is a common perception among many people of Bangladesh that this practice could be beneficial as more fish can be produced and due to less or no flooding because of construction of aquaculture ponds people can produce more agricultural crops. This is because people in Bangladesh, especially those are with limited educational background, are not very conscious of biodiversity conservation (Galib et al. 2018). Moreover, aquaculture in wetlands is often encouraged by the governments to increase fish production. This is a common scenario in Asian countries, particularly in South and East Asian countries (Jones et al. 2021).

On average, yearly 47.9 ha, 99.2 ha, 51.2 ha and 2.6 ha areas were lost in Hardoho Beel, Angrar Beel, Shaoil Beel and Gopalpur Beel respectively. In Bangladesh, a reduction in overall wetland areas has been reported by Khan et al. (2022), Salam et al. (2020) conducted a study on beel (= wetland) encroachment where they found about 80% water of the total area have been decreased between 1981 and 2016. Arefin et al. (2020) carried out a study for the detection of changes in land use pattern of water surface area in Chalan Beel, Bangladesh using a hybrid modelling approach in the winter season and considered four sites and showed loss of 40%, 8%, 8% and 80% area decrease in site 1, site 2, site 3 and site 4 respectively. In another study, Islam et al. (2011) showed that the wetlands in Dhaka are undergoing rapid change. In 1960, water bodies and lowlands covered a total of 2952.02 ha and 13527.58 ha respectively and they shrank to 2103.62 and 12717.73 ha respectively in 1988. This further worsened, taking up an area of 1990.71 ha in 2008, showing that the lowlands continue to fall off. Thus, between 1960 and 2008, the aquatic water bodies and lowlands dropped by 32.57% and 52.58% respectively. Due to the losing the area, the Dhaka city face a great water logging problem.

The present study also showed that, a huge pond excavation work has taken place in every wetland. The conservation started in recent decades, around 2009 increased sharply in 2014 – 2015. Many influential people have started aquaculture in wetland areas of the country. In addition, people who owned lands within the wetland boundary have also started aquaculture to earn more profit. Influence of politically active and elite people in fisheries management of a habitat has been recognised (Bhuiva 2014). This was also true for the wetlands of the present study.

In conclusion it should be noted that the wetland habitats are facing a great threat from multiple sectors and aquaculture is one of them. Although government encouraged people to protect these ecosystems from destruction but a lack of coordination between people and responsible bodies yields poor success in this regard. As monetary profit from aquaculture and agriculture can be obtained directly and rapidly than from the wetland ecosystem services, people are more interested in earning money. The loss of wetlands might affect the wild fish abundance and richness negatively. Adverse effects on fishermen’s livelihood (e.g. income and fish consumption), a vulnerable community in Bangladesh (Islam et al. 2013; Galib et al. 2016; Shalehin et al. 2022), may be also expected. We recommend further studies to determine impacts of loss of wetland habitats on people’s livelihood and biodiversity.

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CONFLICT OF INTEREST
The author declares no conflict of interest.

AUTHORS’ CONTRIBUTION
MTP & ABM research design; MTP primary data collection; MTP data analysis; MTP & ABM manuscript preparation; ABM research supervision.

DATA AVAILABILITY STATEMENT
The data that support the findings of this study are avail-

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**TABLE 1: Status of transformation of wetlands into aquaculture ponds and agricultural fields.**

| Wetlands     | 1990 Total area (ha) | 2020 Total area (ha) | Agriculture area (ha) | Water area (ha) | Total pond (ha) |
|--------------|----------------------|----------------------|-----------------------|----------------|-----------------|
| Hardoho      | 1443.8               | 895.2                | 542.8                 | 5.8            | 326             |
| Angrar       | 3155.4               | 2524.3               | 451.9                 | 179.5          | 482             |
| Shaoil       | 1643.3               | 1068.2               | 468.4                 | 106.7          | 378             |
| Gopalpur     | 81.8                 | 57.3                 | 21.7                  | 2.8            | 42              |
| Mean±SD      | 1581.1±1258.2        | 1136.3±1025.3        | 371.2±236.3           | 73.7±85.5      | 307±188.2       |

Mean±SD is the mean and ± standard deviation.
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MT Parvez https://orcid.org/0000-0002-1444-2980
ABM Mohsin https://orcid.org/0000-0002-5493-2503