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Temporal distribution of plankton and fish species at Mithamoin Haor: Abundance, composition, biomass and ecosystem based management approach

Md Nahiduzzaman *, Ehsanul Karim, Nazia Naheen Nisheeth, Anuradha Bhadra, Yahia Mahmud

Bangladesh Fisheries Research Institute, Mymensingh, 2201, Bangladesh

A R T I C L E I N F O

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A B S T R A C T

Wetlands are the major climatically vulnerable habitat globally. In Bangladesh, Haors are the representative of wetland habitat that plays a significant role in ecology, economy, and social structure. In the present study, physicochemical and biological properties and their interaction at Mithamoin haor of Kishoreganj district of Bangladesh were depicted based on the samples collected from July 2020 to June 202. In total, 46 genera representing 4 different groups of phytoplankton were identified comprising the highest percentages of Chlorophyceae (44.52 %). Zooplankton was represented with 13 genera which was dominated by rotifer. During the study, 56 fish species of 7 orders were documented and the dominance was showed by Cypriniformes (46.84 %). Fish biomass was highest during January and the lowest during May. Planktivores were represented the predominant (55.32 %) group in the haor. Water temperature, transparency, pH and water depth were considered as the major environmental factors influencing the phytoplankton, zooplankton and fish biomass of the haor. Although some fish and plankton species have declined over time, the overall diversity of fish and plankton in the Mithamoin haor was relatively stable. Multiple strategies, including an ecologically oriented framework, might be useful for conserving the prevailing fishery resources of this wetland in future.

1. Introduction

Bangladesh is blessed with a wide variety of wetland ecosystems, which are home to 280 freshwater and 490 marine species. Wetlands provide a variety of benefits, including water, fish, edible animals, timber, energy, and recreational opportunities. Wetlands are considered valuable resources for biological conservation since they host a lot of different species and have a lot of different things growing in them [1]. Wetland resources cover half of Bangladesh's geographical area and are home to a rich array of floral and faunal diversity, including those that are threatened with extinction [2]. In particular, haors maintain substantial regional, national, and perhaps global levels of natural fish production and biodiversity. Haor is an exclusive type of wetland in the universe. Haor's land-water transition makes it one of the most dynamic ecosystems. In northeastern Bangladesh, there are approximately 19.37 million people living in the Haor wetland environment with an area of 1.99 million hectares [3–6]. A total of 373 Haor/wetlands spreads throughout Sunamgonj, Sylhet, Habigonj, Maulavibazar, Netrokona, Kishoregonj, and Brahmanbaria districts. Nearly 43 % of the Haor

* Corresponding author.
E-mail address: nahid.bfri83@gmail.com (M. Nahiduzzaman).

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disticts' total area is occupied by these 373 Haors [7,8]. About a quarter of Bangladesh's northeast region is home to the Haor ecosystem [9]. This unique combination of wetland ecosystems comprises rivers, streams, irrigation canals, extensive seasonal flood plains, and hundreds of haors and beels [10]. Primary production is crucial to the growth and distribution of fish species in these natural water bodies. The availability of nutrients in water has a significant impact on primary production. However, changes in river water flow and upwelling regimes affect nutrient concentrations, which in turn affect primary production, leading to swings [11]. Production of zooplankton and fish is very much connected to haor's phytoplankton populations [12]. Therefore, the presence and absence of phytoplankton in a water body can provide vital information and prevalent connections within an aquatic ecosystem [13].

Moreover, due to increased fishing pressure and a variety of human activities that promote silting, river pollution, and the loss of natural reproduction and native fish populations in this haor have declined dramatically over the years [14]. In regard to biotic factors, disruption of the food web through introduced species has also been reported in haor ecosystems of Bangladesh [15]. As the composition, abundance and biomass of plankton and fish in freshwater bodies are highly dependent on both abiotic and biotic factors, temporal and spatial changes in these fisheries resources needs special attention [16,17].

Mithamoin Haor has great significant because of its geo-physical, economic, social and cultural perspective [18]. Mithamoin (about 1105 ha) is an inland freshwater wetland ecosystem located at Mithamoin upazila of Kishoregonj district. This haor consist of about 80 beels and two rivers, Gorauttra and Shilli River. The total fish production of mithamain haor area is 513.41 mt [19]. Because of its abundance of valuable resources, this haor plays a significant role in the country's economy, nutrition, and the quality of life in rural areas. Several investigations have previously been conducted on the plankton and fish diversity of the adjacent haors of this ecologically diverse region [20]. However, there is very limited information is available for physicochemical and biological features of Mithamoin Haor. Considering this fact, the current study aimed to determine the temporal distribution, as well as the relationship between fish, plankton and environmental parameters which could help in answering some critical questions regarding the fisheries resources of this haor. The objectives of the present study were to determine the plankton and fish diversity status and to determine the effect of environmental factors on regulating the temporal dynamics of biological features of Mithamoin haor.

2. Materials and methods

2.1. Location and duration of the study

The study was carried out at the Mithamoin Haor, a wetland in the Mithamoin upozila in the Kishorgonj District of Bangladesh. Three sites (Hossainpur, 24°24′08″ N, 91°05′46″E; Ghagra, 24°24′27″ N, 91°07′15″ E; Gopdighi, 24°26′51″ N, 91°01′52″E) were monitored for one year, from July 2020 to June 2021 (Fig. 1). As a large ecosystem, it serves as a vital breeding and feeding ground for inland freshwater fish species. Small-scale fisherman and other nearby residents also rely on this region for economic support.

2.2. Water quality variables

Temperature, turbidity, depth, dissolved oxygen; pH, NO_3–N, PO_4–P, alkalinity, and TDS were monitored monthly. Black-labeled bottles were used to collect 500 ml of water from each study site between 9:00 a.m. to 12:00 p.m. Temperature (°C), pH, dissolved oxygen (DO), and total dissolved solids (TDS) were determined using a Multi-Parameter Water Quality Meter (HANNA, HI 98194, pH/

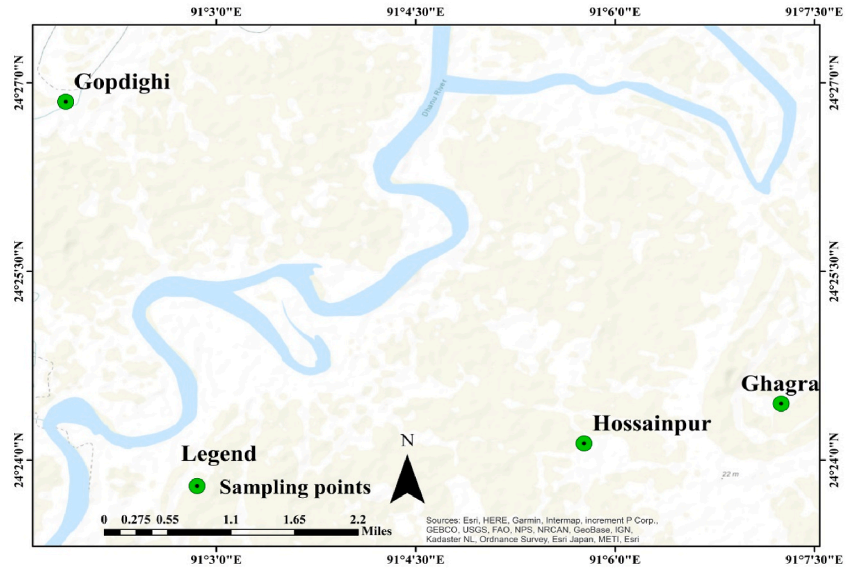

Fig. 1. Location of the study area at Mithamoin haor in Kishorgonj District.

EC/DO). Water depth was measured using a measuring tape. A Secchi disc was used to determine the transparency of the water (in centimeters). The levels of alkalinity (mg/l), nitrates (NO3–N), and phosphates (PO4–P) were determined using a spectrophotometer (model DR-1900).

2.3. *Fish specimen collection and identification*

Samples of fish were collected between 6:00 and 8:00 a.m. on each sampling date from selected locations with the assistance of experienced local fisherman. A seine net was employed to capture the fish (with dimensions of 80–100 m in length and 1–2 mm in mesh size). Fish were counted and identified on the sampling site after being collected, but the fish species that were difcult to identify were preserved in 10 % bufered formalin solution and brought to the laboratory for further identification. According to Bhuiyan, Quddus and Shafi, Talwar and Jhingran and Rahman [21–24] fish species were recognized based on their morphometric and meristic traits. Identified fish species were categorized after the classification method of Nelson [25].

2.4. *Study of plankton*

For qualitative and quantitative analyses of plankton, water samples were taken from three different sites in Mithamain Haor. Using a tube sampler, 10 L of water samples from different depths were collected from each site. Finally, plankton net with a 30-μm mesh size was used to filter the water samples. Ten liters of water samples was concentrated into 50 ml and the concentrated samples were stored in plastic vials with 5 % buffered formalin for further study.

A concentrated 1 ml plankton sample was taken via pipette onto a Sedgwick-Rafter cell (S–R cell) for qualitative and quantitative investigation of phytoplankton. The counting chamber of the S–R cell has a special slide design, measuring 50 mm by 20 mm by 1 mm, and holding 1 ml of sample. Each of the one thousand fields in the counting chamber has a volume of 0.001 ml. After placing the sample, the counting chamber was covered with a cover slip to eliminate air bubbles and left for a few minutes to settle the plankton. Plankton was counted using the S–R counting cell under a compound microscope (Optika-Italy WF 1018). The formula below was used to count and quantify plankton in 10 randomly selected cell squares [26].

$$N = A \times 1000 \times c / V \times F \times L$$

where,

N = number of plankton cells per liter.

A = Total number of plankton counted.

C= Volume of final concentrate of samples in ml.

V= Volume of a field in cubic millimeter.

F= Number of the fields counted.

L = Volume of original water in liter.

The colonial as well as filamentous algae each was considered as a single unit. Following the methods of Peenak, Ward & Whipple, Needham & Needham, Prescott, APHA, and Bellinger [27–32], plankton was identified. The number of plankton cells was stated as Cell/L water.

2.5. *Measurement of chlorophyll-a (μg/L)*

For Chlorophyll-a analysis, 100 ml of water samples were filtered through 0.45 mm Whatman GF/C glass fibre filter paper. The filter papers were then crushed with a glass rod before being preserved in 10 ml of acetone in PVC containers. The vials were refrigerated for approximately 14 h. The following day, samples were centrifuged for 15 min at 3500 RPM in a centrifuge machine (Fisher scientific). The Chlorophyll-a concentration then determined using a spectrophotometer (Model DR-1900) at 664 and 750 nm wavelengths and the following formula [33]:

$$\text{Chlorophyll-a}(\mu g / L) = 119(A664\text{-}A750)V \times 100/L \times S$$

Where A664 = Absorbance at 664 nm.

A750 = Absorbance at 750 nm.

V = the volume of acetone extract in ml.

L = the length of light path in the spectrophotometer in cm.

S = the volume of ml of filtered sample.

2.6. *Statistical analysis*

All the data collected were tabulated and tested for normality followed by Kolmogorov–Smirnov test and the Shapiro–Wilk test. Monthly variation in water quality parameters, plankton, and fish composition, abundance, and biomass were analyzed using a one-way analysis of variance (ANOVA) at the 5 % level of significance using SPSS (Statistical Package for the Social Sciences, version 20.0). Interaction among the fish biomass, plankton abundance, and water quality parameters were determined using Pearson's correlation analysis.

3. Results

3.1. Water quality parameters

Water quality parameters measured over the study period are summarized in Table 1.Water temperatures varied considerably between sampling months. The water temperature for May was noticeably higher than the average of the preceding months. Furthermore, the water temperature for January was considerably lower compared to any other month. Water transparency varied substantially during the sampling months, exhibited the highest value in March (42.38 ± 0.21 cm) and the lowest in November (24.29 ± 050 cm). The water depth was significantly higher during July (6.30 ± 0.77 m) and the lowest in March (1.16 ± 0.02 m). Water pH ranged from 8.83 ± 0.07 in November to 6.14 ± 0.03 in July, with no statistically significant differences across the sampling months. DO was highest in November and lowest in April. The ammonia-nitrogen was not differed among the different sampling months. However the highest NH_3 was recorded in February and lowest in July. In case of NO_3–N and PO_4–P, the highest value was observed in March and the lowest in July. The total alkalinity was significantly higher in June and the lowest in July. Furthermore, significantly higher value of TDS was recorded in May and the lowest in July.

3.2. Composition, abundance and biomass of phytoplankton species

46 phytoplankton taxa from 4 major classes—Chlorophyceae, Bacillariophyceae, Cyanophyceae, and Euglenophyceae—were recorded during the study period consisting of 13 taxa of Bacillariophyceae, 8 of Cyanophyceae and 3 of Euglenophyceae (Table S1). Chlorophyceae (44.52 %) was the dominant group of phytoplankton, followed by Bacillariophyceae (29.19 %), Cyanophyceae (18.70 %), and Euglenophyceae (7.60 %). The phytoplankton abundance peaked in March (19.74 × 10^4 indi. L^{-1}), November (12.89 × 10^4 indi. L^{-1}), and June (10.47 × 10^4 indi. L^{-1}) (Fig. 2). Chlorophyll-a concentration was the highest during April followed by March and May (Fig. 3).

3.3. Zooplankton composition and abundance

Thirteen genera of zooplankton were identified from the study area (Table S2). Rotifers contributed five genera, whereas cladocerans and copepods contributed were contributed four genera each. Cladocerans dominated zooplankton with 43.70 % of the total abundance. Rotifers accounted for approximately 30.61 % and copepods for 25.67 % of the total zooplankton population. Abundance of zooplankton varied significantly between sampling months whereas the highest abundance was recorded in December (2.15 × 10^2 indi. L^{-1}), followed by November (1.54 × 10^2 indi. L^{-1}) and January (1.57 × 10^2 indi. L^{-1}). Generic abundance of zooplankton was insignificant ($P > 0.05$) and quite similar within the months of April, May, June, and February (Fig. 4).

Table: 1
Water quality parameters differences in the course of sampling months in Mithamoin Haor.

Parameters	Temperature (°C)	Transparency (cm)	Water depth (m)	pH	DO (mg/l)	NH_3 (mg/l)	NO3–N (mg/l)	PO4–P (mg/l)	Total alkalinity (mg/l)	TDS (mg/l)
July	29.64 ± 0.25^b	28.58 ± 0.33^h	6.30 ± 0.77^a	6.14 ± 0.03^i	5.05 ± 0.10^{efg}	0.01 ± 0.00^g	0.13 ± 0.01^g	1.15 ± 0.01^h	77.97 ± 0.82^k	83.77 ± 1.79^k
August	28.41 ± 0.87^d	26.43 ± 0.24^i	5.50 ± 0.25^b	6.77 ± 0.06^e	5.24 ± 0.10^e	0.02 ± 0.01^{ef}	0.13 ± 0.01^g	1.18 ± 0.02^{fg}	85.98 ± 1.69^j	97.46 ± 1.31^j
September	27.94 ± 0.26^e	24.46 ± 0.21^j	5.30 ± 0.22^b	7.15 ± 0.02^d	6.18 ± 0.05^d	0.02 ± 0.01^{de}	0.15 ± 0.01^f	1.17 ± 0.01^g	95.90 ± 1.89^i	104.92 ± 1.96^i
October	26.72 ± 0.42^f	24.29 ± 0.50^j	3.75 ± 0.45^c	7.75 ± 0.10^c	6.32 ± 0.06^d	$0.02 \pm 0.00c^{de}$	0.13 ± 0.01^g	1.18 ± 0.01^{fg}	106.35 ± 0.17^h	104.97 ± 3.40^i
November	23.88 ± 0.61^g	30.55 ± 0.30^g	2.71 ± 0.55^d	8.83 ± 0.07^a	7.81 ± 0.07^a	0.03 ± 0.01^{abc}	0.15 ± 0.02^f	1.21 ± 0.01^{ef}	108.86 ± 0.55^g	115.64 ± 1.41^g
December	23.35 ± 0.27^h	32.44 ± 0.17^f	2.60 ± 0.34^d	8.23 ± 0.08^b	7.72 ± 0.16^a	0.03 ± 0.01^{abc}	0.20 ± 0.02^e	1.22 ± 0.01^e	112.18 ± 0.07^f	112.09 ± 2.89^h
January	18.24 ± 0.11^j	34.39 ± 0.23^e	1.67 ± 0.12^e	7.74 ± 0.15^c	7.14 ± 0.02^b	0.03 ± 0.00^{ab}	0.27 ± 0.02^d	1.28 ± 0.02^d	113.73 ± 0.09^e	119.62 ± 2.48^f
February	19.55 ± 0.27^i	36.37 ± 0.15^d	1.51 ± 0.11^{ef}	6.52 ± 0.13^g	6.84 ± 0.10^c	0.03 ± 0.01^a	0.37 ± 0.01^b	1.40 ± 0.10^b	114.27 ± 0.06^e	124.23 ± 2.36^e
March	29.25 ± 0.05^c	42.38 ± 0.21^a	1.21 ± 0.06^g	6.26 ± 0.08^{gh}	5.16 ± 0.05^{ef}	0.03 ± 0.01^{abc}	0.40 ± 0.01^a	1.50 ± 0.01^a	116.18 ± 0.09^d	132.35 ± 1.67^d
April	28.68 ± 0.31^d	40.58 ± 0.24^b	1.18 ± 0.08^g	6.42 ± 0.35^{fg}	4.11 ± 0.31^h	0.02 ± 0.01^{bcd}	0.37 ± 0.02^b	1.48 ± 0.01^a	125.61 ± 2.02^c	136.32 ± 2.11^c
May	30.18 ± 0.03^a	39.08 ± 1.29^c	1.16 ± 0.02^g	6.54 ± 0.43^g	4.94 ± 0.49^g	0.03 ± 0.01^{abc}	0.31 ± 0.02^c	1.36 ± 0.01^c	130.64 ± 2.06^b	140.45 ± 1.30^a
June	29.80 ± 0.07^b	32.98 ± 1.24^f	2.76 ± 0.52^d	6.92 ± 0.44^e	5.03 ± 0.29^{fg}	0.02 ± 0.01^{abcd}	0.30 ± 0.01^c	1.27 ± 0.02^d	135.14 ± 3.57^a	140.15 ± 1.97^a
F-value	1071.96	1020.54	222.32	134.34	324.06	8.38	551.03	146.72	1101.40	631.43
P-value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

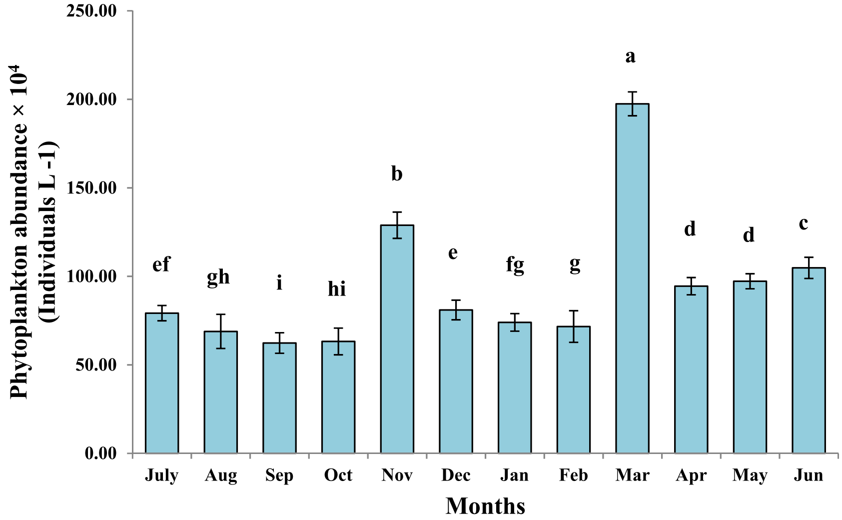

Fig. 2. Phytoplankton abundance in Mithamoin Haor during the research period × 10^4 (individuals L-1) (Initials that differ above the bars shows a statistically substantial difference ($P \leq 0.05$).

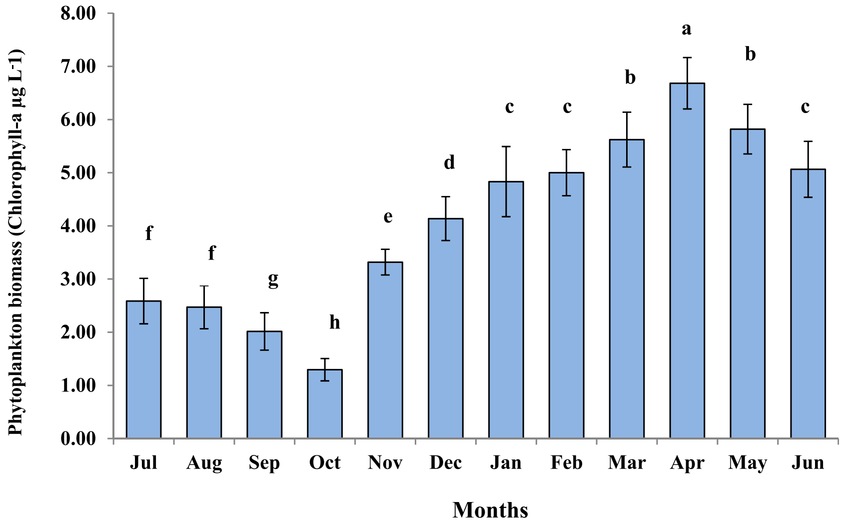

Fig. 3. Chlorophyll-a (phytoplankton) biomass over the course of the study in Mithamoin Haor (Various letters above each bar represent statistically significant differences ($P \leq 0.05$).

3.4. Fish catch composition and biomass

Fig. 5 depicts the classification of 56 species collected from three sampling sites into seven orders including 18 families. Cypriniformes constitute the highest number of species, followed by the Clupeiformes, Perciformes, and Siluriformes. Biomass of the fish captures varied considerably by fish order (Fig. 6). The catch of Cypriniformes was substantially greater than that of all other orders ($P > 0.05$), followed by Channiformes and siluriformes. The highest fish biomass was recorded in January (166.41 ± 5.89 kg) and the lowest in May (3.13 ± 0.43 kg) (Fig. 7).

3.5. Relation between plankton and fish

The phytoplankton and zooplankton biomass showed a fluctuating pattern, except for the months of April to June (Fig. 8). The fish biomass throughout the sampling period showed increasing trends from October to January and the trends coincided during the months of February to June.

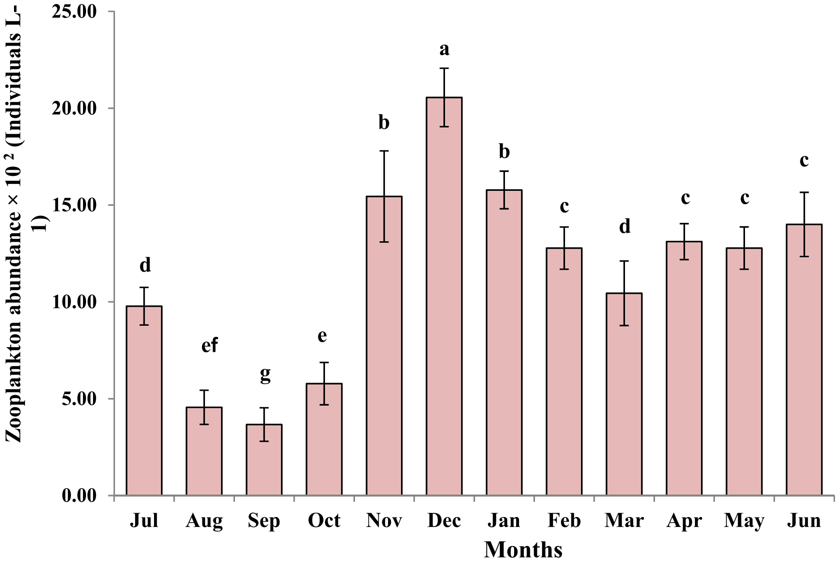

Fig. 4. Zooplankton abundance in Mithamoin Haor, throughout the study (Significant differences ($P \leq 0.05$) are denoted by various letters above the bars.

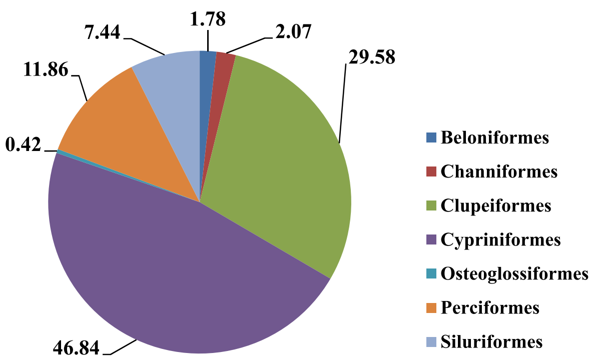

Fig. 5. Fish Catch Composition in Mithamoin Haor, during the study period.

3.6. *Categories of fish based on feeding habit*

During the study period, fishes were divided into four groups (Fig. 9) according to feeding habit as follows: planktivores (55.32 %), omnivore (20.77 %), carnivore (16.66 %) and detrivore (7.26 %).

3.7. *Relationship among water quality, phytoplankton, zooplankton, and fish populations*

An overview of the association with environmental variables, phytoplankton, zooplankton and fish shown in (Table 2). Water temperature linked positively with phytoplankton abundance ($r = 0.262$, $P = 0.001$) and negatively with zooplankton abundance ($r = -0.437$, $P = 0.000$). Fish biomass was shown to be inversely proportional to water temperature ($r = -0.813$, P 0.0001). There was a positive correlation between transparency and the abundance of phytoplankton and zooplankton ($r = 0.606$, $P = 0.000$; $r = 0.500$, $P = 0.000$). Alternatively, water transparency was inversely associated with fish abundance ($r = -0.07$, $P = 0.470$). There was a significant inverse relationship between water depth and the abundance of both zooplankton and phytoplankton ($r = -0.590$, $P = 0.000$; $r = -0.437$, $P = 0.000$). It was correlated negatively to fish abundance ($r = -0.204$, $P = 0.034$). Both zooplankton abundance and fish biomass were positively correlated with water pH ($r = 0.346$, $P = 0.000$; $r = 0.644$, $P = 0.000$). Phytoplankton and zooplankton abundance were also positively related with NO3–N and PO4–P levels ($r = 0.431$, $P = 0.000$; $r = 0.346$, $P = 0.000$; and $r = 0.249$, $P = 0.009$). It was inversely associated to fish abundance ($r = -0.142$, $P = 0.143$ and $r = -0.203$, $P = 0.035$) respectively.

4. Discussion

The physicochemical status of an aquatic ecosystem significantly influences the occurrence and distribution of the aquatic biota

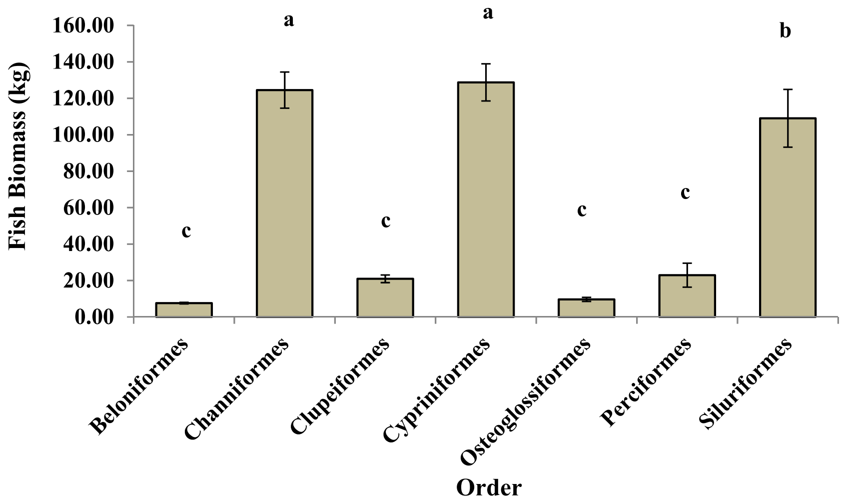

Fig. 6. Order wise Biomass of fish catches in Mithamoin Haor, over the research period (The letters above the bars represent statistically significant differences (P ≤ 0.05).

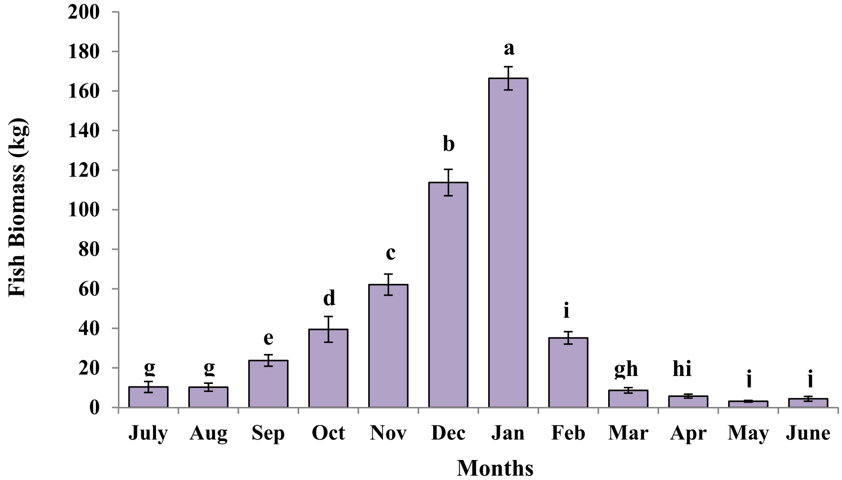

Fig. 7. Monthly variations of fish biomass in Mithamoin Haor, for the period of investigation (Different letters above bars show significant difference (P ≤ 0.05).

[34]. In this study during the July–October, high rainfall and increased surface runoff caused an increase in the water turbidity and a decrease in water transparency, and had a positive correlation with phytoplankton, zooplankton and fish biomass. High turbidity was also noted by Haldar et al. [35], which supported the findings of Chowdhury and Maztunder [36]. DO levels fluctuate from 7.810.07 mg/L in November to 4.110.31 mg/L in December.mg/L in the month of April Similar studies have found that the DO concentrations in Karimganj haor range from 6.40 to 6.90 mg/L [37], while in Hakaluki haor, the DO concentrations at different sampling points ranged from 3.1 to 7.0 mg/L, with a mean content of 5.03 mg/L [38]. Higher pH in November could be attributed to the high photosynthetic activity by phytoplankton whereas the lowered pH value in July was due to heavy rainfall. The pH of water showed the positive relationship with phytoplankton, Zooplankton and fish biomass. Very little pH variation has been recorded, and the changes in pH could be caused by algae photosynthesis [39]. According to previous measurements [40], the pH of the Karimganj haor in Kishoreganj ranges from 7.45 at St-3 in December to 7.15 at St-1 in February, with a mean pH of 7.30 within the research area. Monthly variation was also apparent in the varying PO4–P, NO3–N, TDS, and alkalinity, as their values were lower in July which was previously reported by several researchers [41–45]. The higher concentration of nitrate and phosphate in March could be due to the atmospheric deposition, inflow of organic maters and microbial activity. PO4–P and NO3–N showed positive correlation with phytoplankton density, zooplankton abundance and fish biomass. According to Khan et al. [46], the average concentration of PO4–P in the water of Kaptai Lake is 0.367 mg/L, however it rises significantly for the dry season compared to the wet season. The total alkalinity decreased from 135.14 ± 3.57 mg/L in June to 77.97 ± 0.82 mg/L in July. The mean alkalinity of the Korotoa River water (122.05 mg/L) was similar

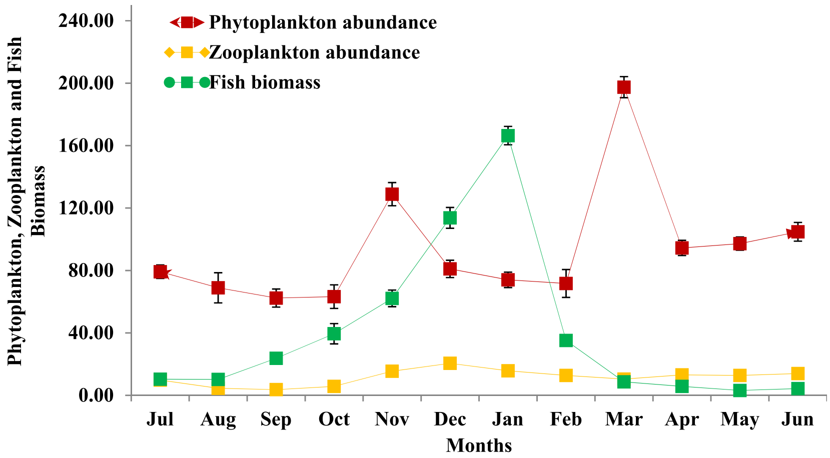

Fig. 8. Relation between plankton and fish.

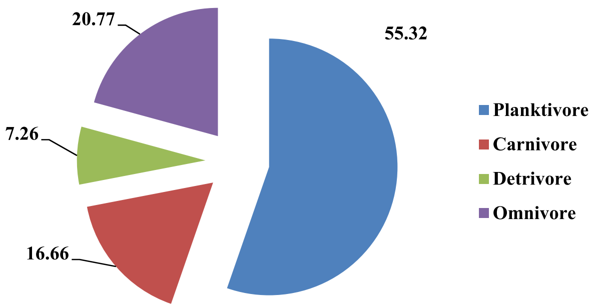

Fig. 9. Trophic group of fish species at Mithamoin Haor.

to the current study [47]. TDS levels in the haor ranged from a peak of 140.45 ± 1.30 mg/L in May to a low of 83.77 ± 1.79 mg/L in July. TDS values in this study ranged from 80.75 to 184.0 mg/L, with a mean concentration of 132.38 mg/L, which is quite similar to those obtained in Hakaluki haor [37]. The variations in the pH, DO, alkalinity and trace metals are having a major impact on phytoplankton productivity [48].

During the investigation period, the Chlorophyceae species group was found to be the dominant quantitative component of phytoplankton. The recorded stable hydrographical features were largely responsible for the good production of Chlorophyceae algae, as reported by earlier researchers [49,50]. The role of light and temperature in determining the density of phytoplankton promotion has been reported earlier by Nazneen [51]. Presently, the temperature and nutrients are positively correlated with the total density of phytoplankton. Available literature indicates that temperature is an important determining factor for phytoplankton productivity [52]. In this study recorded maximum density of phytoplankton in March might be due to the maximum sunlight besides conducive temperature and triggered nutrient retention in the water column. Kondowe et al. [53] described that phytoplankton abundance highest in March and lowest in November which was identical to the current study. Increased phytoplankton productivity during the dry months was probably due to the favorable environmental conditions related to light, temperature, and nutrient availability Hilaluddin et al., [54]. The monsoonal heavy rainfall caused water stratification along with turbidity and reduced temperature was the reason for the recorded lesser phytoplankton productivity in November. Daoudi et al. [55] highlighted the significant relationship between the phytoplankton density and nutrient concentration especially during summer months. Higher chlorophyll *a* concentration in April is most likely due to a higher concentration of nitrate and phosphate concentration and the availability of sufficient amount of solar radiation in this month. Such type of variation was also observed by Prabhahar et al. [56] and Sardessai et al. [57].

Zooplankton consumes phytoplankton and then transfers the energy to higher level organisms like fishes. Further, some of the zooplankters are considered to be good indicator species (to assess the health of the aquatic ecosystems). The abundance of zooplanktonic population of an area largely depends upon the density of phytoplankton coupled with conducive hydrographical factors, and thus, the zooplankton coordinates a food chain between the fishes and phytoplankton. In this study, the high abundance of zooplankton was recorded at Mithamoin Haor in the month of December when the species diversity of zooplankton was high because of nutrients elements possibly triggered during this month and increased phytoplankton production, consequently resulting in higher zooplankton abundance. Correlations between zooplankton abundance and water temperature and transparency were previously obtained by Hart [58], Akbulut [59], Shurin et al. [60], Messner et al. [61]and Akindele [62]. The zooplankton abundance in the

Table 2

Correlation between phytoplankton abundance and zooplankton and fish biomass, as well as other water quality parameters.

	WT	Trans	Depth	pH	DO	NH3	NO3	PO4	Alk	TDS	Cha	Phyto	Zoo
Trans	−0.012	1											
Depth	.298[a]	−.824[a]	1										
pH	−.481[a]	−.364[a]	−0.026	1									
DO	−.773[a]	−.303[a]	−0.054	.792[a]	1								
NH3	−.411[a]	.416[a]	−.613[a]	.217[b]	.305[a]	1							
NO3	−0.055	.914[a]	−.805[a]	−.457[a]	−.340[a]	.431[a]	1						
PO4	0.016	.898[a]	−.785[a]	−.434[a]	−.361[a]	.402[a]	.919[a]	1					
Alk	−0.028	.669[a]	−.838[a]	0.026	−0.115	.509[a]	.716[a]	.618[a]	1				
TDS	0.04	.779[a]	−.858[a]	−0.14	−.239[b]	.490[a]	.826[a]	.751[a]	.953[a]	1			
Cha	−0.032	.922[a]	−.791[a]	−.317[a]	−.308[a]	.392[a]	.875[a]	.803[a]	.735[a]	.818[a]	1		
Phyto	.262[a]	.606[a]	−.437[a]	−0.121	−0.163	.217[b]	.491[a]	.546[a]	.327[a]	.451[a]	.442[a]	1	
Zoo	−.437[a]	.500[a]	−.590[a]	.346[a]	.380[a]	.447[a]	.346[a]	.249[a]	.515[a]	.420[a]	.546[a]	.206[b]	1
Fish	−.813[a]	−0.07	−.204[b]	.644[a]	.750[a]	.329[a]	−0.142	−.203[b]	0.009	−0.112	−0.029	−.213[b]	.525[a]

[a] Correlation is significant at the 0.01 level (2-tailed).

[b] Correlation is significant at the 0.05 level (2-tailed).

present study appeared to be controlled by water temperature and transparency.

In the present study Cypriniformes was the dominant order compared to other order because of the ideal environmental conditions and lateral connection of the Danu Rivers, allows fishes to migrate into this Haor ecosystem [63]. Freshwater bodies of Bangladesh are mainly dominated by Cypriniformes as previously reported [64–69]. Dominance of planktivore species was correnpond to the findings of Ehshan and Bhuiyan [70] and Saha [71] who also reported the dominance of planktivore from the other open water bodies of Bangladesh. A total of 56 fish species recorded during the present investigation was also more or less similar by the findings of Islam et al. [72] who reported 57 species of fishes in their study. January showed the highest biomass (166.41 ± 5.89 kg), with the lowest (3.13 ± 0.43 kg) in May. Rahman et al. [73] also reported that the highest fish biomass in January and lowest in May. This variation of fish biomass occurred due to the variation of water level, current and flood condition and also fishing pressure in these months. Fish biodiversity and fish habitats are declining in the Haor region and the nearby beels due to a variety of human and natural factors, generating major concern for the sustainability of fish biodiversity. Overfishing by illegal and lethal gears, which damaged the breeding, feeding and nursery ground of the indigenous fish of the haor ecosystem, are to blame for the loss of species diversity in the studied Haor [74]. The widespread application of poisonous pesticides on the farms bordering wetland areas has also led to catastrophic water pollution in these areas.The most significant anthropogenic impact reducing species diversity in the Mithamoin Haor is the unplanned construction of dams, embankments, roads, and bridges, which isolate the shallow water section from the deeper portion of wetland and nearby rivers.**Factors influencing the diversity**.

Fish species have been steadily decreasing in number. Islam et al. [75], found 79 species of fishes during 2017–2018 in their study in Mithamoin Haor. Fish biodiversity and fish habitats are declining in the Haor region and the nearby beels due to a variety of human and natural factors, generating major concern for the sustainability of fish biodiversity. Dewatering beels for fishing, Damage to the wetland habitat caused by illegal and unregulated fishing practices. The widespread application of poisonous pesticides on the farms bordering wetland areas has led to catastrophic water pollution in these areas. The most significant anthropogenic impact reducing species diversity in the Mithamoin Haor is the unplanned construction of dams, embankments, roads, and bridges, which isolate the shallow water section from the deeper portion of wetland and nearby rivers. Another important factor is drought.

4.1. *Conservation measures*

Several initiatives have been taken to protect fish populations in the Mithamoin Haor, these efforts are insufficient and additional conservation strategies are required. This research would serve as a foundation for assessing the current state of fisheries resources. This updated information is critical for choosing effective conservation management techniques. The development of protected areas is also important for mitigating habitat loss and degradation. Saunders et al. advocated for the establishment of freshwater protected zones as a means of directly conserving freshwater species and habitats. Fish sanctuaries always increase fish production, biodiversity, and fishers' economic and social well-being [76–78]. Revenue- oriented leasing scheme should be stopped or requires the terms of leasing system for development of Haor ecosystem. In order to allow juvenile fish to mature, fishing is banned for three months each year, from April to July, during peak breeding season. Artificial Recruitment/Stocking: Planktivore: Stocking less than 25 %, Carnivore stocking at least 15 %, Omnivore stocking at least 10 % is suggested for the Haor in order to sustain fish populations and ensure the continued viability of the fisheries production. Hijol and koros trees, among others, are crucial to have planted in haor dyke regions. The construction of fish-friendly structures facilitates the migration of all species of fish throughout the year. Furthermore, conserving endangered fish species through the use of a live fish gene bank may be a viable option. Thousands of the poor, and especially fishermen, rely on the region's fisheries for their survival; to secure the potential growth of production in the Kishoregonj districts' haor area, the government should institute a comprehensive conservation policy.

5. Conclusion

Haors are important ecosystems and significant natural resources due to their diversity and high productivity. Due to the productive conditions of the Haor, the Chlorophyceae and Bacillariophyte families of phytoplankton are the most abundant, whereas Rotifera dominate the zooplankton species. During the course of the study, 56 different fish species representing 7 different orders were documented. The Cypriniformes family is the most common group of fish. This study reveals trophic dynamics whereby the results showed that the planktivores were the most common, followed by the omnivores, the carnivores, and the detritivores. Among the environmental parameters temperature, transparency have significantly positive relation with the phytoplankton and zooplankton abundance and negatively relation with fish biomass. Although the numbers of fish species are steadily decreasing, this research reveals that the Mithamoin Haor is still a productive ecosystem and bio-diverse inland open water body. Establishment of fish protected area; ban of fishing from April to July during peak breeding season, live gene bank creation and ecological based fisheries management can be the effective actions to ensure sustainable production in Mithamoin haor in Kishoregonj districts in future.

Data availability statement

Data included in article/supp. material/referenced in article.

CRediT authorship contribution statement

Md Nahiduzzaman: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Writing – original draft. **Ehsanul Karim:** Funding acquisition, Project administration, Writing – review & editing. **Nazia Naheen Nisheeth:** Writing – review & editing. **Anuradha Bhadra:** Writing – review & editing. **Yahia Mahmud:** Funding acquisition, Project administration, Writing – review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:The study was conducted by self-funding of authors.

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Appendix A. Supplementary data

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