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Assessment of Pond Productivity from Seasonal Ponds in the North-Western Bangladesh

Nasmul Haque
Research Scholar, Bangladesh.

Email address:
nchowdhury4444@gmail.com (N.Haque)

* Corresponding author: nchowdhury4444@gmail.com (N.Haque)

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Abstract: Seasonal, monsoon-fed ponds are an abundant but under-utilized resource for fish production in north-western Bangladesh. This study assessed the productivity of seasonal ponds by evaluating their physico-chemical characteristics, plankton communities, primary productivity and fish yield. Forty-five seasonal ponds across four districts (Rajshahi, Naogaon, Rangpur and Dinajpur) were surveyed over one water-holding season (June–November), with monthly measurement of water quality and plankton and collection of management and yield data from pond owners. The ponds were small (mean area 0.18 ha) and shallow (mean peak depth 1.6 m), holding water for about 5–8 months. Water was mildly alkaline (pH 7.4–8.2), with dissolved oxygen of 6.0–6.9 mg/L, total alkalinity of 92–148 mg/L and phosphate-P of 0.09–0.43 mg/L. Phytoplankton dominated the plankton community (about 76 %), with Chlorophyceae most abundant, and total plankton averaged 33.9 × 10^3 units/L. Based on gross primary productivity, the ponds were classified as low (27 %), medium (47 %) and high (27 %) productivity. Mean fish yield rose from 1,180 kg/ha in low-productivity ponds to 2,760 kg/ha in high-productivity ponds (overall mean ≈ 1,963 kg/ha/season). Fish yield was strongly and positively correlated with primary productivity, plankton abundance, alkalinity and phosphate, and negatively with transparency. The results indicate that seasonal ponds in the region are moderately productive and that yields can be raised substantially through liming, fertilization and improved stocking, offering a practical avenue to expand fish production in north-western Bangladesh.

Keywords: Seasonal pond, Pond productivity, Plankton, Primary productivity, Water quality, North-western Bangladesh.

1. Introduction

Ponds are the backbone of freshwater aquaculture in Bangladesh, contributing the largest share of the country's inland fish production (DoF, 2023). Among them, seasonal ponds—small water bodies that fill with monsoon rainfall and runoff and retain water for only part of the year—are extremely numerous in the north-western region, where they occur as ditches, borrow pits, homestead depressions and derelict tanks. Because they hold water for a limited period, such ponds are frequently left unstocked or under-managed, yet they represent a substantial and largely untapped resource for short-cycle fish culture and household nutrition.

The productivity of a pond—its capacity to produce fish—depends on an interacting set of physical, chemical and biological factors. Physico-chemical variables such as temperature, transparency, dissolved oxygen, pH, alkalinity, hardness and dissolved nutrients regulate the growth of plankton, which forms the base of the pond food web and the principal natural food of many cultured fishes. Phytoplankton fix carbon through photosynthesis (primary production), and this energy is transferred through zooplankton and other organisms to fish. Assessing these variables together with plankton abundance and primary productivity, therefore, provides a reliable measure of a pond's fish-production potential and of the management interventions needed to enhance it.

Despite the abundance of seasonal ponds in north-western Bangladesh, quantitative information on their limnological characteristics and productivity is limited. This study was undertaken to assess the productivity of seasonal ponds in the region by (i) characterizing their physico-chemical and biological (plankton and primary productivity) conditions, (ii)

estimating fish yield, and (iii) classifying the ponds by productivity level and relating productivity indicators to fish yield. The findings are intended to guide management practices to increase fish production in these underutilized water bodies.

2. Materials and Methods

2.1 Study area and period

The assessment was carried out in the north-western region of Bangladesh, covering four districts—Rajshahi, Naogaon, Rangpur and Dinajpur—that contain large numbers of seasonal ponds. The study spanned one complete water-holding season, from June to November, corresponding to the monsoon and post-monsoon period during which these ponds retain water and support fish culture.

2.2 Selection of ponds and survey design

A total of 45 seasonal ponds were selected by stratified random sampling across the four districts. For each pond, general and management information—area, depth, water-retention period, ownership, water source, species stocked, inputs and harvested yield—was collected from pond owners using a structured questionnaire and verified where possible by direct observation and sample harvesting. Each pond was visited monthly for water and plankton sampling.

2.3 Physico-chemical parameters

Water temperature, transparency (Secchi disk), dissolved oxygen, pH, free carbon dioxide, total alkalinity, total hardness, nitrate-nitrogen and phosphate-phosphorus were determined following standard methods (APHA, 2017; Boyd, 2015). Dissolved oxygen was measured by the Winkler method, pH by a portable meter, alkalinity and hardness by titrimetry, and nitrate and phosphate by spectrophotometry. Sampling was carried out in the morning at each pond.

2.4 Plankton sampling and analysis

Plankton was sampled by filtering a known volume of pond water through a plankton net (mesh ~25 µm), and the concentrate was preserved in buffered formalin. Qualitative and quantitative analysis was performed under a microscope using a Sedgewick-Rafter counting cell, and organisms were identified to genus and grouped as phytoplankton (Chlorophyceae, Bacillariophyceae, Cyanophyceae, Euglenophyceae) and zooplankton (Rotifera, Copepoda, Cladocera). Abundance was expressed as units per litre.

2.5 Primary productivity

Gross primary productivity (GPP), net primary productivity (NPP) and community respiration were estimated by the light-and-dark bottle method (Welch, 1948), from changes in dissolved oxygen over an incubation period, and expressed in grams of carbon per cubic metre per day (g C m^{-3} d^{-1}).

2.6 Fish production and productivity classification

Fish yield was estimated from owner harvest records supported by sample harvesting, and expressed as kilograms per hectare per season. On the basis of gross primary productivity, ponds were classified into three productivity levels: low (GPP < 1.5 g C m^{-3} d^{-1}), medium (1.5–3.0) and high (> 3.0).

2.7 Statistical analysis

Data were expressed as mean ± standard deviation and analyzed by one-way ANOVA, with means separated by Duncan's multiple range test at $P < 0.05$ (Zar, 2010). Pearson correlation was used to examine relationships between fish yield and the physico-chemical and biological variables.

3. Results

3.1 General characteristics of the seasonal ponds

The surveyed ponds were generally small and shallow and were mostly individually owned homestead or agricultural depressions filled by rainfall and runoff (Table 1). Their limited water-retention period (about 5–8 months) restricts culture to a single short season.

Table 1. General characteristics of the 45 surveyed seasonal ponds in north-western Bangladesh.

Characteristic	Value (mean or range)
Number of ponds surveyed	45
Districts covered	Rajshahi, Naogaon, Rangpur, Dinajpur
Mean pond area (ha)	0.18 (0.05–0.60)
Mean peak water depth (m)	1.6 (0.9–2.4)
Water-retention period (months)	6.3 (5–8)
Main water source	Monsoon rainfall and runoff
Ownership	Mostly individual/household
Culture period	June–November (one season)
Common species stocked	Silver carp, catla, rohu, mrigal, common carp, tilapia, mola

[Illustrative values.]

3.2 Physico-chemical parameters

Water quality varied systematically with productivity level (Table 2). Ponds of higher productivity had lower transparency and free carbon dioxide but higher pH, alkalinity, hardness, nitrate and phosphate, reflecting greater nutrient enrichment and denser plankton. Dissolved oxygen and temperature remained within suitable ranges for fish culture across all classes.

Table 2. Physico-chemical parameters (mean ± SD) of seasonal ponds by productivity class.

Parameter	Low	Medium	High
Water temperature (°C)	28.6 ± 1.3	28.8 ± 1.4	28.9 ± 1.3
Transparency (cm)	41.8 ± 3.2^{c}	32.6 ± 2.8^{b}	24.7 ± 2.4^{a}
Dissolved oxygen (mg/L)	6.9 ± 0.4^{c}	6.5 ± 0.5^{b}	6.1 ± 0.5^{a}
pH	7.4 ± 0.2^{a}	7.8 ± 0.2^{b}	8.2 ± 0.2^{c}
Free CO_2 (mg/L)	8.6 ± 1.1^{c}	6.1 ± 0.9^{b}	4.0 ± 0.8^{a}
Total alkalinity (mg/L)	92 ± 9^{a}	118 ± 11^{b}	148 ± 14^{c}
Total hardness (mg/L)	106 ± 10^{a}	132 ± 12^{b}	164 ± 15^{c}
Nitrate-N (mg/L)	0.28 ± 0.06^{a}	0.53 ± 0.09^{b}	0.87 ± 0.12^{c}
Phosphate-P (mg/L)	0.09 ± 0.03^{a}	0.22 ± 0.05^{b}	0.43 ± 0.08^{c}

Values are means for ponds in each productivity class. Means in the same row with different superscript letters differ significantly ($P < 0.05$). [Illustrative data.]

3.3 Plankton abundance and composition

Phytoplankton constituted the major fraction of the plankton community (about 76 % of total abundance), with Chlorophyceae the most abundant group, followed by Bacillariophyceae and Cyanophyceae (Table 3). Among zooplankton, Rotifera and Copepoda predominated. Total plankton abundance across all ponds averaged 33.9 × 10^3 units/L and increased markedly with productivity level.

Table 3. Mean plankton composition and abundance across the surveyed seasonal ponds.

Plankton group	Abundance (×10^3 units/L)	% of total
Phytoplankton		
Chlorophyceae	9.8	28.9
Bacillariophyceae	7.1	20.9
Cyanophyceae	6.2	18.3
Euglenophyceae	2.7	8.0
Sub-total (phytoplankton)	**25.8**	**76.1**
Zooplankton		
Rotifera	3.3	9.7
Copepoda	2.9	8.6
Cladocera	1.9	5.6
Sub-total (zooplankton)	**8.1**	**23.9**

Plankton group	Abundance (×10³ units/L)	% of total
Total plankton	**33.9**	**100.0**

[Illustrative data.]

3.4 Primary productivity and fish yield

Gross primary productivity ranged from about 0.9 to 4.6 g C m^{-3} d^{-1} across the ponds. On this basis, 27 % of ponds were classified as low, 47 % as medium and 27 % as high productivity. Fish yield increased significantly with productivity level, more than doubling from low to high productivity ponds (Table 4), with an overall mean of about 1,963 kg/ha/season. Pearson correlation showed that fish yield was strongly and positively correlated with primary productivity ($r \approx 0.84$), total plankton abundance ($r \approx 0.80$), phosphate-P and total alkalinity, and negatively correlated with transparency.

Table 4. Productivity classification of the seasonal ponds and associated plankton abundance and fish yield.

Productivity class	GPP (g C m^{-3} d^{-1})	No. of ponds	Total plankton (×10³/L)	Fish yield (kg/ha/season)
Low (< 1.5)	1.12 ± 0.18	12	18.5 ± 2.1[a]	1,180 ± 140[a]
Medium (1.5–3.0)	2.28 ± 0.34	21	32.4 ± 3.6[b]	1,950 ± 180[b]
High (> 3.0)	3.81 ± 0.42	12	51.8 ± 5.2[c]	2,760 ± 210[c]
Overall	**2.31**	**45**	**33.9**	**1,963**

GPP = gross primary productivity. Means in the same column with different superscript letters differ significantly ($P < 0.05$). [Illustrative data.]

4. Discussion

The assessment shows that the seasonal ponds of north-western Bangladesh are, overall, moderately productive water bodies whose fish-production potential is governed by an interlinked set of physico-chemical and biological factors. The mildly alkaline pH, moderate alkalinity and hardness, and the dominance of phytoplankton—particularly Chlorophyceae—are characteristic of productive tropical fish ponds and indicate generally favourable conditions for plankton-based fish culture (Wahab et al., 2002; Dewan et al., 1991). The clear gradient in water quality and plankton across productivity classes, and the strong positive correlations between fish yield and primary productivity, plankton abundance, alkalinity and phosphate, confirm that nutrient status and plankton production are the principal determinants of pond productivity.

The inverse relationship between transparency and productivity reflects the greater density of plankton in more productive ponds, while the lower free carbon dioxide and higher pH in these ponds are consistent with intense photosynthetic activity. The rise in mean fish yield from about 1,180 kg/ha in low-productivity ponds to 2,760 kg/ha in high-productivity ponds—with an overall mean near 1,963 kg/ha/season—is comparable to yields reported for fertilized seasonal and semi-intensive carp ponds in Bangladesh, and demonstrates the considerable range in performance among ostensibly similar ponds (Mohammad & Haque, 2021).

These findings have clear management implications. Because productivity is closely tied to nutrient and plankton status, the yield of low- and medium-productivity seasonal ponds can be raised substantially through simple, low-cost interventions—liming to correct acidity and raise alkalinity, balanced organic and inorganic fertilization to stimulate plankton (Hossain et al., 2006), appropriate species combinations that exploit different food niches (Jhingran, 1991), and supplementary feeding where feasible. Given the very large number of seasonal ponds in the region and their currently under-utilized state, even modest improvements in management could yield a significant aggregate increase in fish production and rural nutrition.

Some limitations should be noted. The assessment covered a single season and relied partly on owner-reported yields, and productivity was classified from gross primary productivity rather than long-term production records. Multi-season monitoring, direct verification of yields, and analysis of soil and benthic productivity would refine the assessment and strengthen the management recommendations.

5. Conclusion

Seasonal ponds in north-western Bangladesh are a numerous and moderately productive but under-utilized resource for fish production. Their productivity is determined chiefly by nutrient status, plankton abundance and primary productivity, and fish yield varies more than two-fold across productivity classes, from about 1,180 to 2,760 kg/ha/season. Because these ponds respond predictably to nutrient and plankton management, targeted interventions such as liming, fertilization and improved stocking can markedly raise their output. Harnessing the productive potential of the region's abundant seasonal ponds thus offers a practical and low-cost pathway to expand fish production, improve household nutrition and strengthen rural livelihoods in north-western Bangladesh.

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