Journal of Fisheries
Volume 5 Issue 3 Pages 519–524 December 2017
Peer Reviewed | Open Access | Online First

eISSN 2311-3111
pISSN 2311-729X

Original Article
DOI: 10.17017/jfish.v5i3.2017.300

Optimization of stocking weight in carp polyculture ponds under drought prone Barind area of Bangladesh

Mohammad Golam Sarowar Talukder • ABM Mohsin • Md. Akhtar Hossain • Md. Rafiqual Islam Khan

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

Correspondence
Prof Dr Md. Akhtar Hossain; Department of Fisheries, University of Rajshahi, Rajshahi 6205, Bangladesh.
mahfaa@yahoo.com

Manuscript history
Received 4 August 2017 | Revised 4 December 2017 | Accepted 5 December 2017 | Published online 17 December 2017

Citation
Talukder MGS, Mohsin ABM, Hossain MA and Khan MRI (2017) Optimization of stocking weight in carp polyculture ponds under drought prone Barind area of Bangladesh. Journal of Fisheries 5(3): 519–524. DOI: 10.17017/jfish.v5i3.2017.300

Abstract
Increased temperature, decreased water level and reduced culture period of the ponds are considered major problems for aquaculture promotion in drought prone Barind area of Bangladesh. In order to address these problems, an experiment was conducted to optimize the stocking weight for carp polyculture ponds in Tanore Upazila of Rajshahi district, Bangladesh. Three different stocking weights were tested under three treatments (T_1: 25 ± 0.12 g; T_2: 50 ± 0.15 g; and T_3: 100 ± 0.19 g), each with three replications. Fish growing period (July–December), carp species (*Catla catla*, *Hypopthalmichthys molitrix*, *Aristichthis nobilis*, *Labeo rohita* and *Cirrhinus mrigala*), stocking density (7,410 individuals/ha), lime and ash treatment, fertilization and feeding were same for all the treatments. Water quality (water temperature, dissolved oxygen, transparency, pH and alkalinity) and fish growth parameters were monitored monthly. Mean values of water quality parameters were found within the suitable range for fish culture. Treatment T_3 varied more significantly (P<0.05) than that of other treatments for the mean values of final weight, weight gain, specific growth rate, survival rate and yield of fish. Net benefit of carp polyculture was also found the highest in treatment T_3. Use of higher stocking weight can be a suitable option for carp polyculture in ponds under drought prone Barind area.

Keywords: Stocking weight; drought; carp polyculture; Barind

1 | INTRODUCTION

Importance of pond based carp polyculture as a popular technique for fish production in Bangladesh is well documented (Asadujjaman and Hossain 2016; Hossain 2017). Carps contributed 45.35% of the total fish production (DoF 2017) and it has further potentials to increase fish production. Mean fish production of pond is found as 4,618 kg ha^{-1} at present and it needs to be increased up to 5,000 kg ha^{-1} through proper management (DoF 2017). Studies indicate that climate change may result in decline of groundwater level (Mishra and Singh 2010) and thus insufficient water level is considered one of the major problems for polyculture in ponds under drought prone area. Due to climate change, fisheries sector is vulnerable to and affected by environmental degradation in multiple dimensions like ground water sinking and contamination, surface water squeezing and pollution, encroachment of river and other water bodies that reduced fish breeding ground and loss of biodiversity etc. (DoF 2017). All these factors contribute to the reduction of three niches (e.g. surface, column and bottom) for fishes in pond ecosystems resulting poor production and yields (Hossain 2011). Mainstreaming disaster and climate change adaptation is now essential towards achieving a resilient fisheries production system in Bangladesh (DoF 2016).

The Barind tract, situated in the northwest part of Bangladesh, is an anomaly in the major landscape of deltaic flat lands. Natural conditions with higher elevation and undulating uplands with red or yellow clay soil, limited rainfall and lack of water sources in the dry season provide a different foundation for the development of cropping patterns in comparison with those in the deltaic areas in Bangladesh. Impact of climate change and environmental degradation are much more visible in this drought prone Barind area. Poor survival and reduced growth of fishes due to poor water quality in ponds in Barind area and necessity to mitigate these problems through the development of sustainable aquaculture are well reported by Hossain (2011).

Although the potentials of ponds and canals are well explored (Hossain *et al.* 2009), but the comprehensive research in relation to climate change aspects are not yet done to improve the fish production in ponds under drought prone Barind area. Fish production in polyculture is largely affected by species combination, stocking density, pond fertilization, supplementary feeds as well as ecological conditions. Larger size of carps or over wintered carps can solve the problem of fish production for lower water column in polyculture ponds under drought prone area since the fish growth form indicates that stocking of larger size fish can provide with maximum biomass within minimum time (Grover *et al.* 2000). Considering the capacity of the farmers, primarily it is necessary to conduct research with the use of comparatively larger stocking weight than that of usual practice.

Researches carried out on fish growth in Barind area (Hossain 2007, 2011; Hossain and Bhuiyan 2007) are found effective for mitigating low alkalinity and high turbidity problems of fish farming ponds through lime and ash treatment but these are not exception in terms of stocking density or weight used compared to other geographical areas in Bangladesh. Thus, development of suitable pond polyculture technique in regards to climate change is still missing.

Based on the climate change effects and impacts on fish production and overall fisheries, the question raised whether the existing carp polyculture cycle using lower stocking weight of fish species within lower water column of drought prone Barind area is suitable or not. This piece of research aimed at optimizing the stocking weight of fishes for carp polyculture in ponds under drought prone Barind area of northern Bangladesh. The specific objectives of this study were to monitor the water quality and fish growth; to evaluate yield and economics of fish farming, and thereby to recommend suitable stocking weight for carp polyculture in ponds under drought prone Barind area.

2 | METHODOLOGY

2.1 | Location and duration of study

The study was conducted in nine ponds (mean water area of 0.025 ± 0.003 ha and water depth of 1.66 ± 0.096 m) for a period of six months from July to December, 2011 at Jogisho village of Tanore upazila under Rajshahi district, Bangladesh (24.3545°N, 088.3200°E to 24.3553°N, 088.3222°E; elevation: 21 to 23 m). All the ponds were rain-fed and well exposed to sunlight of average 8 hours per day.

2.2 | Experimental structure

Randomized Completely Block Design (RCBD) was followed for the present experiment with three treatments of stocking weight (T_1: 25 ± 0.12 g; T_2: 50 ± 0.15 g; and T_3: 100 ± 0.19 g) each with three replications (R_1–R_3; Table 1). Stocking density (7,410 individuals/ha) (*Catla catla*, 741 ha^{-1}; *Hypopthalmichthys molitrix*, 1976 ha^{-1}; *Aristichthis nobilis*, 741 ha^{-1}, *Labeo rohita*, 1976 ha^{-1} and *Cirrhinus mrigala*, 1976 ha^{-1}) was same for all three treatments. The fish species were selected based on the guidelines recommended by Grover *et al.* (2000) and Hossain (2011).

TABLE 1 Experimental layout for optimization of stocking weight in carp polyculture ponds

Treatments and replications	*Pond area (ha)*	*Water depth (m)*	*Total fish stocked*
T_1R_1	0.022	1.6	163
T_1R_2	0.025	1.55	185
T_1R_3	0.021	1.65	156
T_2R_1	0.027	1.8	200
T_2R_2	0.025	1.73	185
T_2R_3	0.030	1.68	222
T_3R_1	0.025	1.5	185
T_3R_2	0.023	1.65	170
T_3R_3	0.028	1.75	207

2.3 | Pond management

During pond preparation, weeding was done manually and predatory fish and other unwanted species were removed through repeated netting before stocking of fishes. In order to maintain good water quality, periodic liming with ash treatment was followed after Hossain (2011) for all the ponds. Ponds were also fertilized with urea, triple super phosphate (TSP) and cow dung to enhance the natural food (Table 2). Carp fingerlings were purchased from a private nursery and stocked in the morning as per experimental design (Table 1). Home-made feed prepared with rice bran (50%) and mustered oil cake (50%) was administered into the ponds at 4% of body weight (6% for July–August, 5% for September–October, 3% for November and 2% for December) once a day between 10:00 AM to 11:00 AM using feeding tray. The quantity of feed was adjusted every month according to total biomass of fish obtained from the sampling.

TABLE 2 Basal and periodic doses of lime, ash and fertilizer applications

Inputs	*Basal dose (kg ha^{-1})*	*Periodic dose (kg ha^{-1} month^{-1})*
Lime	750	125
Ash	0	2500
Urea	50	50
TSP	50	25
Cow dung	2500	2500

2.4 | Water quality monitoring

Water quality parameters like temperature, transparency, dissolved oxygen (DO), pH, and alkalinity were monitored monthly between 09:00 and 10:00 AM for the present study. Water temperature (as °C) was recorded with the help of a thermometer, water transparency was measured by a Secchi disk, whereas dissolved oxygen (DO), pH and alkalinity and were determined by using a HACH kit (model FF-2, USA).

2.5 | Fish growth monitoring

Fish growth was monitored by weighing at least 10% of the individual species caught from each pond using a cast net, and sampled fishes were released into the ponds unharmed immediately after sampling. Growth and yield of fishes were calculated after Brett and Groves (1979) as follows:

Initial weight (g) = Weight of fish at stock

Final weight (g) = Weight of fish at harvest

Weight gain (g) = Mean final weight (g) - Mean initial weight (g)

Specific Growth Rate (SGR [%, bw d^{-1}]) = $\frac{(Ln\, W_2 - Ln\, W_1) \times 100}{t_2 - t_1}$

Where, W_1 and W_2 are the mean start and end weight (g fish^{-1}) and t_1 and t_2 (days) are the start and end of the period.

Survival rate (%) = $\frac{Number\ of\ fish\ harvested}{Number\ of\ fish\ stocked} \times 100$

Fish yield (kg ha^{-1}) = Fish biomass at harvest – Fish biomass at stock

2.6 | Economics of carp polyculture

Simple cost-benefit analysis was done to explore the economics of carp polyculture in ponds under different treatments. At the end of the study, all the fishes were sold in a local market. The prices of inputs and fish corresponded to the market prices in Rajshahi, Bangladesh in 2011 and were expressed in Bangladesh currency (Taka) as BDT (80 BDT = 1 US$). Data on both fixed and variable costs were recorded to calculate the total cost (BDT ha^{-1}). Total return determined from the market price of fish sale was expressed as BDT ha^{-1}. Net benefit and cost benefit ratio (CBR) were calculated as follows:

R = I – (Fc + Vc + Ii)

Where, *R* refers to net benefit; *I*, total income from fish sold; *Fc* for fixed costs, *Vc* for variable costs and *Ii* for interests on input costs.

Cost-Benefit Ratio (CBR) = $\frac{Net\ benefit}{Total\ investment}$

2.7 | Data analysis

Data on water quality parameters, fish growth and yield, and economics of carp polyculture under different treatments were subjected to one way Analysis of Variance (ANOVA) using SPSS (Statistical Package for the Social Sciences, version 15). Before analysis, the normality of data was checked. The mean values were also compared by Duncan Multiple Range Test (DMRT; Gomez and Gomez 1984) with an α level of significance of 0.05. All data were expressed as mean ± standard error (SE).

3 | RESULT AND DISCUSSION

3.1 | Water quality

No significant difference was found among the treatments for mean values of water quality parameters (Table 3). Findings also indicated that water quality parameters were within the suitable range for aquaculture. Mean value of water temperature varied from 26.57 ± 1.78 (T_2) to 26.68 ± 1.81 °C (T_1). Wahab *et al.* (1995) found temperature ranging from 27.2 °C to 32.4 °C suitable for the growth of plankton in similar climatic conditions. Boyd and Zimmermann (2000) reported water temperature of 25–32 °C suitable for fish culture. DO varied from 6.81 ± 0.54 (T_2) to 6.86 ± 0.56 mg L^{-1} (T_1). Concentration of DO was satisfactory as the stocked fishes did not show any sign of oxygen deficiency throughout the study period. Boyd (1998) reported that suitable range of DO is 5–8 mg L^{-1} for fish culture.

Mean value of water transparency varied from 29.90 ± 1.65 (T_2) to 30.17 ± 1.7 cm (T_3). Boyd (1982) recommended the transparency within 30 to 40 cm as appropriate for fish culture. In the present study, lower value of the transparency in all treatments might be due to higher clay turbidity caused by heavy rainfall in monsoon. This statement was strongly supported by Hossain (2011) who reported high clay turbidity and low alkalinity as major aquaculture problems in ponds under Barind area. pH of pond water varied from 6.88 ± 0.11 (T_1) to 6.96 ± 0.11 (T_2). Dewan *et al.* (1991) recorded the mean value of water pH ranging from 6.6 – 8.6 in fish ponds. According to Swingle (1967), pH of 6.5 to 9 is suitable for fish culture. However the pH value in alkaline condition in pond water was supposed to be helpful for proper growth and development of fishes and aquatic organisms (Jhingran 1975).

Alkalinity of the experimental ponds varied from 51.29 ± 5.05 (T_1) to 52.26 ± 4.84 mg L^{-1} (T_2). Alkalinity values depend upon the location, season, plankton population and nature of bottom deposits (Jhingran 1991). Boyd (1998) stated that the acceptable range of alkalinity for freshwater fish culture was from 40 to 200 mg L^{-1}. Azim *et al.* (1995) recorded total alkalinity ranging from 35.78 to 56.5 mg L^{-1} in carp polyculture ponds. Alkalinity values recorded in the present study were almost similar to the values usually obtained from the ponds under Barind area (Hossain 2011).

3.2 | Fish growth and yield

Significant (P < 0.05) differences in mean values of growth and yield parameters were found among the treatments (Table 4). However, variations in growth and yield might be due to the variations in stocking weight under different treatments. Comparatively higher SGR was recorded with treatment T_1 (lowest stocking weight) whereas the higher final weight, weight gain and yield were recorded with treatment T_3 (higher stocking weight). Majhi *et al.* (2006) recorded SGR value of carp as 1.65% in fish pond.

TABLE 3 Water quality parameters in different treatments

Parameters	*Treatments (Mean ± SE)*			*F value*	*P value*
	T_1	T_2	T_3		
Water temperature (°C)	26.68 ± 1.81^a	26.57 ± 1.78^a	26.65 ± 1.81^a	0.006	0.994
Dissolved oxygen (mg L^{-1})	6.86 ± 0.56^a	6.81 ± 0.54^a	6.84 ± 0.56^a	0.026	0.975
Turbidity (cm)	29.94 ± 1.72^a	29.90 ± 1.65^a	30.17 ± 1.70^a	0.001	0.999
pH	6.88 ± 0.11^a	6.96 ± 0.11^a	6.89 ± 0.06^a	0.351	0.710
Alkalinity (mg L^{-1})	51.29 ± 5.05^a	51.55 ± 4.91^a	52.26 ± 4.84^a	0.003	0.997

Figures bearing common letter(s) in a row as superscript do not differ significantly (P > 0.05)

TABLE 4 Growth and yield of fishes under different treatments

Species	*Treatments & ANOVA results*	*SGR (%, bw d^{-1})*	*Weight gain (g)*	*Final weight (g)*	*Survival rate (%)*	*Yield (kg ha^{-1} in 6 months)*
Labeo rohita	T_1	1.25 ± 0.02^a	36.67 ± 1.27^c	245.00 ± 7.64^c	66.00 ± 0.58^c	286.78 ± 8.14^c
	T_2	1.17 ± 0.03^a	62.50 ± 3.37^b	425.00 ± 20.21^b	72.17 ± 1.15^b	534.38 ± 36.55^b
	T_3	1.05 ± 0.01^b	96.67 ± 2.89^a	680.00 ± 17.32^a	83.17 ± 0.58^a	951.44 ± 32.42^a
	F	25.578	127.598	186.946	111.500	138.021
	P	0.001	<0.001	<0.001	<0.001	<0.001
Catla catla	T_1	1.26 ± 0.04^a	37.50 ± 2.89^c	250.00 ± 17.32^c	65.13 ± 0.58^c	108.30 ± 7.97^c
	T_2	1.15 ± 0.04^a	60.00 ± 4.41^b	410.00 ± 26.46^b	74.13 ± 0.58^b	197.48 ± 15.16^b
	T_3	0.96 ± 0.03^b	80.83 ± 4.59^a	585.00 ± 27.54^a	84.13 ± 0.58^a	301.98 ± 18.01^a
	F	19.139	127.598	47.900	271.000	45.642
	P	0.002	<0.001	<0.001	<0.001	<0.001
Cirrhinus mrigala	T_1	1.23±0.03^a	35.83±1.93^c	240.00±11.56^c	72.33±1.73^b	306.28±20.71^c
	T_2	1.19±0.06^a	65.83±8.35^b	445.00±50.08^b	78.33±1.15^a	606.76±68.71^b
	T_3	0.97±0.03^b	81.67±4.81^a	590.00±28.87^a	85.33±0.58^a	822.35±42.90^a
	F	12.437	16.842	26.698	27.214	29.063
	P	0.007	0.003	0.001	0.001	0.001
Hypopthalmichthys molitrix	T_1	1.54 ± 0.02^a	65.83 ± 2.89^c	420.00 ± 17.32^c	73.13 ± 0.58^c	569.98 ± 27.33^c
	T_2	1.40 ± 0.02^b	99.17 ± 2.93^b	645.00 ± 17.56^b	78.13 ± 1.15^b	916.34 ± 15.50^b
	T_3	1.16 ± 0.02^c	122.50 ± 5.20^a	835.00 ± 31.23^a	84.13 ± 1.00^a	1220.87 ± 63.23^a
	F	96.624	55.326	81.774	34.125	63.827
	P	<0.001	<0.001	<0.001	0.001	<0.001
Aristichthis nobilis	T_1	1.35 ± 0.03^a	45.00 ± 2.68^c	295.00 ± 16.07^c	70.33 ± 1.15^b	139.95 ± 7.87^c
	T_2	1.31 ± 0.01^a	82.50 ± 1.76^b	545.00 ± 10.41^b	74.33 ± 1.53^b	271.56 ± 10.12^b
	T_3	1.08 ± 0.03^b	105.00 ± 6.01^a	730.00 ± 26.06^a	85.33 ± 0.58^a	396.58 ± 21.01^a
	F	34.191	59.535	85.785	45.250	81.586
	P	0.001	<0.001	<0.001	<0.001	<0.001
All species	T_1	1.33 ± 0.04^b	44.17 ± 2.34^c	377.00 ± 15.98^b	56.72 ± 0.92^c	1411.29 ± 25.19^c
	T_2	1.92 ± 0.05^a	74.00 ± 3.76^b	494.00 ± 15.61^a	75.42 ± 1.11^b	2526.52 ± 131.05^b
	T_3	1.04 ± 0.02^c	97.33 ± 5.52^a	497.00 ± 24.23^a	84.42 ± 0.66^a	3693.23 ± 69.37^a
	F	37.593	73.379	85.640	97.817	172.69
	P	0.002	0.001	<0.001	<0.001	<0.001

Figures bearing common letter(s) in a column as superscript do not differ significantly (P > 0.05).

Azad *et al.* (2004) reported weight gain of *H. molitrix* as 72.87 g and *C. mrigala* as 70.42 g in carp polyculture ponds which were lower than the present findings. Hossain (2011) found weight gain of *L. rohita*, *C. catla*, *C.*

mrigala, *H. molitrix*, *A. nobilis* and *C. carpio* as 125.7, 170.2, 120.8, 400.2, 402 and 400 g respectively with stocking weight of 7.5 to 10 g in polyculture under Barind area which were lower than the findings from present study.

Assadujjaman and Hossain (2016) worked on weed and feed based polyculture in pond with stocking weight of 62, 64, 57, 54, 63, 65 and 25 g for *H. molitrix*, *C. catla*, *L. rohita*, *C. mrigala*, *C. Carpio*, *C. idella* and *B. gonionotus* respectively; and found mean final weight (g per 6 months) with *L. rohita* from 257.33 to 502 g, *C. catla* from 358.33 to 678.67 g, *C. mrigala* from 256.67 to 500 g, *H. molitrix* from 336.33 to 636.67 g, and *C. idella* from 502 to 620.33 g. In the same study, survival rate (%) of *L. rohita* from 77.67 to 81.33, *C. catla* from 75.33 to 81, *C. mrigala* from 67.5 to 80.33, *H. molitrix* from 81.33 to 84.33, and *C. idella* from 73 to 83 g. Roy *et al.* (2002) reported survival rate of grass carp, rohu, catla and mrigal as 76.6%, 87.8%, 84.9% and 88.6%, respectively in carp polyculture pond. Fish yield varied from 1411.29 ± 25.19 kg ha^{-1} (T_1) to 3693.23 ± 69.37 kg ha^{-1} in 6 months (T_3). They found total fish yield ranging from 2541 to 4403.51 kg ha^{-1} in 6 months in carp polyculture pond. Roy *et al.* (2003) obtained yield as 2560 kg ha^{-1} in 7 months in carp polyculture system. Azim *et al.* (2004) recorded total fish yield of 2020 kg ha^{-1} in 4 months in pond which were higher than the findings in treatment T_1 and T_2 but lower than treatment T_3 in the present study. Such variations in growth and yield among the treatments were the usual phenomenon of fish growth form which indicated that larger stocking weight resulted in increase in fish biomass and it was strongly supported by Grover *et al.* (2000).

3.3 | Economics of carp polyculture

During study period (6 months) total cost, return, net benefit and CBR significantly (P < 0.05) varied from 96454.67 ± 563 (T_1) to 253768 ± 5146.04 (T_3) BDT ha^{-1}, 147668.46 ± 1868.63 (T_1) to 591397.45 ± 8929.76 (T_3) BDT ha^{-1}, 51,213.79 ± 1648.42 (T_1) to 337629.45 ± 7295.36 (T_3) BDT ha^{-1} and 0.53 ± 0.02 (T_1) to 1.33 ± 0.04 (T_3) respectively (Table 5). Asadujjaman and Hossain (2016) found total cost as 123430.5 to 235930.5 BDT ha^{-1}; net benefit as 111639.9 ± 2056.87 to 206744.85 ±3221.73 BDT ha^{-1}; and cost benefit ratio as 0.77 ± 0.02 to 1.67 ± 0.18 respectively in carp polyculture system.

Though total cost was found lowest in treatment T_1, net benefit and CBR were also found lowest with that treatment. It was observed that the survival rates were higher in treatment T_3 compared to treatment T_1 and T_2, possibly due to higher stocking weight of fishes, which also contributed to higher yield. The yield under treatment T_3 was 262.7% and 146% higher than yield under treatment T_1 and T_2 respectively. Despite highest total cost, net benefit in treatment T_3 was more than two times higher than treatment T_2 and 6.5 times higher than treatment T_1. Present findings clearly indicated that higher stocking weight increased the survival rate and yield of fishes with higher net benefit and CBR of carp polyculture. Findings also indicate that conventional stocking weight (< 100 g) used in different agro-ecological zones is not suitable for improving the yield and economics of carp polyculture in ponds under drought prone area. This statement was also supported well with Hossain (2011) who found comparatively lower fish yield while using lower stocking weight in polyculture ponds under drought prone Barind area of Bangladesh.

TABLE 5 Economics of carp polyculture in different treatments

Parameters	***Treatments***			***F***	***P***
	T_1	***T_2***	***T_3***		
Variable costs					
Pond preparation (BDT ha^{-1})	9750^a	9750^a	9750^a	-	-
Fertilizer (BDT ha^{-1})	18550^a	18550^a	18550^a	-	-
Fish seed (BDT ha^{-1})	24504 ± 11.25^c	49320 ± 8.25^b	88124 ± 14.23^a	-	-
Feed (BDT ha^{-1})	40650.67 ± 563^c	79703.33 ± 944.39^b	134344 ± 5146.04^a	239.958	<0.001
Harvesting (BDT ha^{-1})	1500^a	1500^a	1500^a	-	-
Fixed costs					
Pond rental (BDT ha^{-1})	1500^a	1500^a	1500^a	-	-
Total cost (BDT ha^{-1})	96454.67 ± 563^c	160323.33 ± 944.39^b	253768 ± 5146.04^a	678.183	<0.001
Total return (BDT ha^{-1})	147668.46 ± 1868.6^c	319250.30 ± 15629.26^b	591397.45 ± 8929.76^a	458.617	<0.001
Net benefit (BDT ha^{-1})	51213.79 ± 1648.42^c	158926.97 ± 16457.03^b	337629.45 ± 7295.36^a	192.137	<0.001
Cost Benefit Ratio (CBR)	0.53 ± 0.02^c	0.99 ± 0.118^b	1.33 ± 0.04^a	35.629	<0.001

Figures bearing common letter(s) in a row as superscript do not differ significantly (P > 0.05).

4 | CONCLUSION

Considering the water quality, growth and yield of fish and economic viability of carp polyculture in pond, it can be concluded that use of higher stocking weight can be a suitable option for carp polyculture in ponds in drought prone Barind area. One of the major limitations of this study was to use only *C. mrigala* as bottom dwelling species. Therefore, it is necessary to see the effect of inclusion of different bottom dwelling carp species through stocking combination based research as further step.

ACKNOWLEDGEMENTS

The authors are thankful to 'Comprehensive Disaster Management Programme (CDMP II)', Ministry of Food and Disaster Management, Government of Bangladesh for granting financial support under 'Research Grants for MPhil and PhD level Research on Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA)' to address critical climate change issues of pond polyculture in the draught prone Barind area of northern Bangladesh. The authors are also thankful to the reviewers for their valuable inputs those were considered useful towards further improvement of this manuscript.

REFERENCES

Asadujjaman M and Hossain MA (2016) Fish growth, yield and economics of conventional feed and weed based polyculture in ponds. Journal of Fisheries 4(1): 353–360.

Azad MAK, Rahman MR, Rahman Z, Kader MA, Haque MM and Alam MJ (2004) Polyculture of carp, tilapia and pangas using low cost inputs. Pakistan Journal of Biological Science 7(11): 1918–1926.

Azim ME, Talukder GS, Wahab MA, Haque MM and Haq MS (1995) Effects of liming and maintenance of total hardness levels on fish production in fertilized ponds. Progressive Agriculture 6(2): 7–14.

Azim ME, Wahab MA, Kamal AHM, Ahmed ZF and Verdegem MCJ (2004) Feeding relations of silver barb, *Barbodes gonionotus* (Bleeker) with major Indian and common carp and its effect on fish production in a polyculture system. Journal of the World Aquaculture Society 35: 100–108.

Boyd CE (1982) Water quality management for pond fish culture. Elsevier Science Publishers B.V., 1000 AH Amsterdam, Netherlands. 318 pp.

Boyd CE and Zimmermann S (2000) Grow-out systems-water quality and soil management. Blackwell Science. Oxford, UK. pp. 221–238.

Boyd CE (1998) Water quality for fish pond. Aquaculture Research and Development Series No. 43. Auburn University, Alabama, USA. 37 pp.

Brett JR and Groves TDD (1979) Physiological energetics. In: Fish Physiology, Vol. III, Bioenergetics and Growth, Hoar WS, Randall DJ and Brett JR (eds), New York: Academic Press. pp. 280–352.

Dewan S, Wahab MA, Beveridge MCM, Rahman MH and Sarkar BK (1991) Food selection, electivity and dietary overlap among planktivorous Chinesse and Indian major carp fry and fingerlings grown in extensively managed, rain-fed ponds in Bangladesh. Aquaculture and Fisheries Management 12(3): 227–294.

DoF (2016) National Fish Week 2016 Compendium (in Bengali). Department of Fisheries, Ministry of Fisheries and Livestock, Bangladesh. 148 p.

DoF (2017) National Fish Week 2017 Compendium (in Bengali). Department of Fisheries, Ministry of Fisheries and Livestock, Bangladesh. 160 p.

Gomez KA and Gomez AA (1984) Statistical Procedure for Agricultural Research 2nd Ed. John Wiley & Sons. 697 pp.

Grover JH, Islam MA, Shah WA Rana MAH and Chowdhury HA (2000) Training manual for extension personnel on low cost environment friendly sustainable aquaculture practices. ICLARM, Dhaka, Bangladesh. 101 pp.

Hossain MA (2007) Effect of fertilization techniques on water quality in fish pond under red soil zone of northern Bnagladesh. Banglasesh Journal of Environmental Science 13(2): 376–379.

Hossain MA (2017) Fish culture in ponds and rice fields by poor Adivasi (Ethnic) households in northwest Bangladesh: performances evaluation and livelihood aspects. Bangladesh Journal of Progressive Science & Technology 15(1): 1–6.

Hossain MA (2011) Effect of fertilization techniques on fish growth in ponds under red soil zone of northern Bangladesh. Bangladesh Journal of Progressive Science and Technology IX(2): 192–196.

Hossain MA and Bhuiyan AS (2007) Study of water quality in fish ponds under the red soil zone of northern Bangladesh. Journal of Subtropical Agricultural Development 5(5): 347–351.

Hossain MA, Mohsin ABM, Galib SM, Alam R and Samad AOMA (2009) Potentials of khas (public) ponds and kharis (canals) in Barind tracts: sustainable rural livelihoods in the face of climate change. Bangladesh Journal of Progressive Science and Technology 7(1): 49–52.

Jhingran VG (1975) Fish and Fisheries of India. Hindustan publishing corporation. Delhi, India. 453 pp.

Jhingran VG (1991) Fish and Fisheries of India. Hindustan Publishing Co., New Delhi. 727 pp.

Majhi SK, Das A and Mandal BK (2006) Growth performance and production of organically cultured grass carp *Ctenopharyngodon idella* (Val.) under mid-hill conditions of Meghalaya; North Eastern India. Turkish Journal of Fisheries and Aquatic Sciences 6: 105–108.

Mishra AK and Singh VP (2010) A review of drought concepts. Journal of Hydrology 391: 202–216.

Roy NC, Kohinoor AHM, Wahab MA and Thilsted SH (2002) Evaluation of performance of carp-SIS polyculture technology in the rural farmers' pond. Asian Fisheries Science 15: 43–52.

Roy NC, Wahab MA, Khatoon H and Thisted SH (2003). Economics of carp-SIS polyculture in rural farmer's pond. Pakistan Journal of Biological Sciences 6(1): 61–64.

Swingle HS (1967) Standardization of chemical analyses for waters and pond muds. FAO Fish Report 44(4): 397–421.

Wahab MA, Ahmed ZF, Islam A and Ramatullah SM (1995) Effect of introduction of common carp, *Cyprinus carpio* (L.) on the pond ecology and growth of fish in polyculture. Aquaculture Research 26: 619–628.

Wahab MA, Azim ME, Haque MM and Ahmed ZF (1996) Effects of frequency of fertilization on water quality and fish yields. Progressive Agriculture 7(2): 33–39.

CONTRIBUTION OF THE AUTHORS

MGST Research design, primary data collection and validation, statistical analysis and draft manuscript (MS) writing; **ABMM** Review primary data and data analysis, review and comments on draft MS; **MAH** review and validation of data and statistical analysis; review and finalization of the MS; **MRIK** assist in statistical analysis and drafting MS preparation.