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Research Article

Effect of Stocking Densities on Growth and Production Performance of Bheda (*Nandus nandus*) in Pond Aquaculture

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ABSTRACT

The current study's goal was to look at how stocking densities affected Bheda (*Nandus nandus*) growth and production over the course of a 120-day period. Three treatments were T_1 (20,000 fish ha^{-1}), T_2 (30,000 fish ha^{-1}), and T_3 (40,000 fish ha^{-1}), each with three replicates. Those fishes were fed daily with commercial sinking feed and a live food mixture at 9-3% fish body weight up to harvesting. Temperature, dissolved oxygen, pH, and other water quality indicators were measured every two weeks, along with the growth performance of Bheda fish. T_2 had the highest yield of Bheda (3439.08±207.31 kg ha^{-1}), followed by T_3 (3422.78±224.42 kg ha^{-1}), and T_1 (3136.62±150.00 kg ha^{-1}). The harvesting weight (g), individual weight gain (g), individual percent (%) weight gain (g), SGR (% per day), and survival rate (%) of fish were significantly higher ($p<0.05$) in T_1, followed by T_2 and T_3, respectively, where combined production of fishes was significantly higher at T_2 followed by T_3 and T_1. Net profit and benefit-cost ratio were significantly higher in T_1 than T_2 and T_3. Based on the results of this experiment, it can be concluded that stocking density of Bheda fingerlings at the rate of 20,000 fish ha^{-1} in T_1 showed the highest production performance for profitable pond aquaculture. However, further research on the standardisation of stocking density with economic profitability of this fish at the on-station or on-farm level in ponds may be required before widespread dissemination of this culture technology to farmers, particularly in Bangladesh and elsewhere.

Keywords: Stocking density, Growth, Production, Bheda

INTRODUCTION

The fishing industry adds substantially to Bangladesh's agro-based economy by supplying food and nutrition, reducing poverty, opening up employment possibilities, and gaining offshore money (Islam *et al*., 2016). In 2020–2021, there were 4.62 million metric tonnes (MT) of fish produced annually, with aquaculture output accounting for 57.10% of the total (DoF, 2022). In 2020–2021, this sector generated more than 26.50% of the agricultural Gross Domestic Product (GDP) and 3.57% of the national GDP. This industry's average growth rate during the previous ten years was close to 5.43%. The government of Bangladesh is working to maintain this growing performance, which has enabled the fisheries sector to reach this significant milestone (DoF, 2022). Bangladesh presently produces enough fish to meet its own needs, accounting for about 60% of the population's daily need for animal protein. More than 12% of Bangladesh's entire population work in this industry either full-time or part-time as a means of subsistence (DoF, 2022). Through fishing-related activities, more than 17 million people (BFTI, 2016), afford their living where more than 80% are women (DoF, 2015). According to an

FAO report, Bangladesh ranked third in inland open water capture production and in world aquaculture production. Bangladesh also ranked in tilapia production in the world and third in Asia (FAO, 2022; Pandit *et al.*, 2021).

The people of Bangladesh have relied on fish and fisheries for their nourishment, economics, culture, and traditions from the onset of time, and they strive to do so now (Arefin *et al.*, 2018). The production of fish per hectare in this country is still lower than in some fish-producing countries of the world (FAO, 2022). This is mainly due to a lack of knowledge of the scientific fish culture and management practises used by countries like China and Vietnam. To increase the productivity of water bodies efficiently, an understanding of the various aspects of scientific fish culture and management of fisheries resources is required.

Small indigenous species (SIS) of fish have huge culture potential in Bangladesh. There are about 150 different SIS available in Bangladesh, such as *Anabas testudineus* (Bloch, 1792), *Channa striata* (Bloch, 1793), *C. punctata* (Bloch, 1793), *Nandus nandus* (Hamilton, 1822), *Ompok pabda* (Bloch, 1794), *Salmostoma phulo* (Hamilton, 1822), etc. Some of them have high nutritional value in terms of proteins, vitamins, and minerals which are not commonly available in other foods (Sharmin *et al.*, 2016; Mustafi *et al.*, 2022; Kawsar *et al.*, 2023). Among the available SIS, Bheda (*N. nandus*), locally called Meni or Nondoi, is an indigenous, near threatened, and small food fish in Bangladesh. *N. nandus* exclusively a bottom and column feeder (carnivorous) (Mustafa *et al.*, 1980; Saha *et al.*, 2000; Kawsar *et al.*, 2023) which is widely distributed in India, Pakistan, Nepal, Myanmar, and Thailand (Froese and Pauly, 2019; Gupta, 2018). Muddy streams, rivers, pools, and marshes are its main habitats (Bhuiyan, 1964) and it inhabits both fresh and brackish waters (Hossain and Afrose, 1991) and uses the floodplains as its breeding, nursing, and rearing grounds (Sharmin *et al.*, 2016). It is a high-priced fish despite its spiny fins and ugly black bands and blotches all over its body (Talwar and Jhingan, 1991). It has a breeding period from April to September (Hossain and Afrose, 1991).

However, indiscriminate fishing, unplanned construction of bridges and flood protection embankments, destruction of breeding grounds, rapid habitat degradation, siltation, and anthropogenic induced climate change are decreasing its population in rivers and wetlands (Sarkar *et al.*, 2020; Kawsar *et al.*, 2023). The International Union for Conservation of Nature (IUCN) categorises Bheda as lower risk least concern, though it is a near threatened species in Bangladesh (IUCN, 2015); Kawsar *et al.*, 2023). An induced breeding technique that is successful and culture technology development can offer cultivation of these fish in shallow waterways like rice fields, which would play a significant part in Bangladeshi people's total nutrition, especially the poor and lower middle-class inhabitants of rural Bangladesh. By boosting its yield, induced breeding, rearing, or the creation of culture techniques for *N. nandus* can contribute significantly to its conservation and rehabilitation.

There is little research on Bheda artificial breeding for the purpose of producing its fry and raising it in cisterns in Bangladesh (Das *et al.*, 2022) in order to save this slightly grey and dark brown striped fish from extinction. As stocking density plays an important role in the growth and production of fish in fish culture (Backiel and Le Cren, 1978; Kunda *et al.*, 2021), nevertheless, stocking densities have not yet been standardised for the successful rearing or culture of *N. nandus* in earthen ponds so far. Therefore, this experiment was undertaken for the successful rearing or culture of *N. nandus* to assess the growth performance and economics of this fish at different stocking densities in earthen ponds.

MATERIALS AND METHODS

Location and duration of study

The experiment was carried out by the Bangladesh Fisheries Research Institute of Floodplain Sub-station, Santahar, Bogura (Figure 1) during the period from 01 August to 31 November 2020.

Experimental design and stocking of fishes

A randomised complete block design (RCBD) was followed for this assessment with three different stocking densities viz. T_1 (20,000 fish ha^{-1}), T_2 (30,000 fish ha^{-1}), and T_3 (40,000 fish ha^{-1}), each with three replicates (Table 1). All fish were stocked at the same weight (an average of 3.64 g) for all treatments. Fish seeds from the *N. nandus* species were mostly procured at the Bangladesh Fisheries Research Institute's Flood-plain Sub-station hatchery. The fries were maintained in a nursery pond at a high stocking density after being collected. Fries were relocated and provisioned in nine experimental grow-out ponds after three days in accordance with the research setup. During the discharge of the fry into the ponds, proper procedures and hygienic conditions were upheld.

Pond management

The ponds' water was drawn out and left to dry in the sun for approximately a week, or until the bottom finally cracked or hardened enough to keep a man standing without sinking more than 1 cm. Draining and drying eradicate competitor predatory (*Channa* spp., *Wallago attu*, *Clarias batrachus* and *Notopterus chitala*) and weed fishes (*Puntius* spp., *Colisa* spp. and *Ambassis* spp.). The pond's bottom was then dug up and dried. In addition to eradicating undesired species and burrowing predators like mudfish, ploughing makes underlying nutrients accessible at the surface for the development of fish food in the pond. Then the bottom of the pond was levelled. To keep predators and pests out of the pond system, dikes and all gates were fixed. Additionally, pipelines were examined for cracked slabs and other damage. They were cleansed to get rid of any obstruction-causing material. Aquatic weeds were removed (*Colocasia esculenta*, *Enhydra fluctuans, Marsileaquadri folia, Eichhornia crassipes* and *Ipomaea aquatica*) manually from the ponds. Additionally, the

Table 1. Experimental blueprint (mean±SD).

Variables	Treatments		
	T_1	T_2	T_3
Pond dimension (m^3)	720±10	720±15	720±20
Pond profundity (m)	1.2±0.5	1.2±0.6	1.2±0.3
Stocking density (fish ha^{-1})	20,000	30,000	40,000

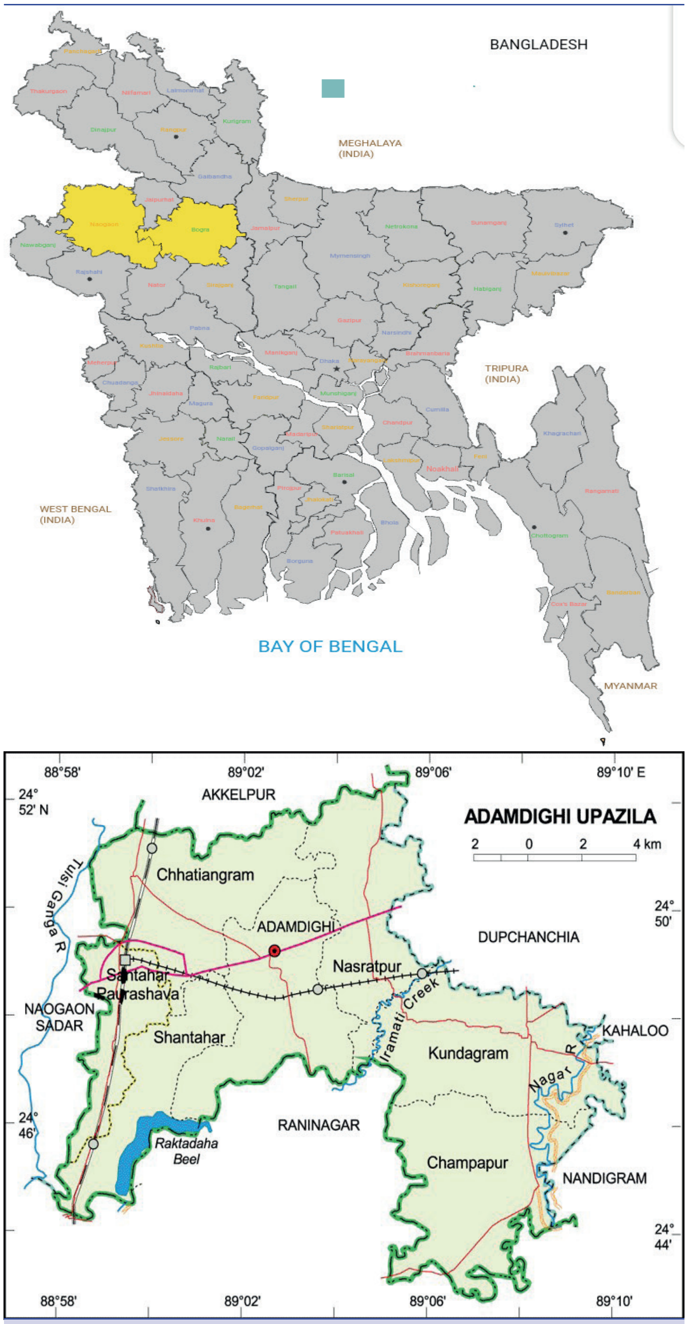

Figure 1. Experimental site.

grasses on the pond dike were carefully pruned down to an extremely tiny size. A deep tubewell was utilised when necessary to maintain the water depth of 1.20 m in all of the ponds utilising ground water. To keep the proper water level, each pond has a well-designed input and outflow system. Lime was applied at a rate of 250 kg ha^{-1} after 3 days. Lime was put in the pond water and embankment after being liquefied in an earthen pot. $CaCO_3$ (agricultural lime) and CaO (quicklime) were utilised for this. The ponds were fertilised with cow dung, urea, and triple superphosphate (TSP) at the rates of 500 kg ha^{-1}, 50 kg ha^{-1}, and 25 kg ha^{-1}, respectively, after 5 days of liming. The water was examined for natural food after a week of fertilising. To improve fish development performance, additional feed continued to be used on a regular basis.

Feeding of Bheda

After stocking, Bheda fish were fed with commercial sinking feed and a live food mixture at 9-3% of the body weight of stocked fish and supplied twice daily. Commercial sinking feed (Quality Feed Co. LTD.) contains 27.94% crude protein, 12.14% moisture, 7.95% crude fat, 8% crude fibre, 15.38% ash, and 36.59% nitrogen free extract. Throughout the period of cultivation, three different types of commercial fish feeds were used, including starter, grower, and finisher feeds. From the time of stocking until three weeks later, starter feed was administered at 6% of the body weight of the fish. Grower feed was then applied until 14 weeks at 4% of the body weight of the fish. Finisher feed was used the last two weeks at 2% of the body weight of the fish. At first, a live food mixture was given at 3% of the body weight of the stocked fish, and the amount was decreased to 1% in the last month according to the different types of commercial feed.

The mixture of live foods contained 75% trash fish fry (*Lepidocephalus guntea*, *Esomus danricus*, *Channa punctata*) and 25% zooplankton (*Notonectidae*, *Cyclops* sp., *Daphnia* sp.).

Growth sampling of *N. nandus*

A seine net and a scoop net were employed during sampling at intervals of 15 days to track Bheda's growth performance and to alter the feeding rate in light of this fish's body weight. To evaluate the health, growth, and even some hazy growth tendencies of the Bheda fish, individual weights of at least 10% of the initially supplied fish were obtained. The weight of the fish in each sampling was determined using a portable balance (OHAUS, model No. CT-1200-S). Throughout the culture phase, pond conditions in general and fish health were regularly checked. Because the sampled fish are sensitive to handling stress, care was taken when handling them.

Harvesting

All fishes were entirely taken at the conclusion of the experiment (after a 120-day culture period). Bheda fish were mostly caught by repetitive netting using a fine-mesh net towed over the pond. After that, a shallow pump was used to entirely drain the water out of each pond individually. The remaining Bheda fish were then taken separately from each pond. In order to determine the survival rate and productivity, each Bheda fish was then numbered, measured, and weighted separately for each pond.

Monitoring of water quality parameters

Throughout the study period, water quality parameters were sampled between the hours of 9:00 and 10:00 a.m. in the morning on each sampling day at intervals of 15 days. A Celsius thermometer was placed 20–30 cm under the water's surface to measure the water's temperature. A black and white veiled Secchi disk was used to measure water transparency (cm). Alkalinity (mg/l) and ammonianitrogen (mg/l) were dogged with a HACH kit (FF2, USA). Dissolved oxygen (mg/l) was listed through a dissolved oxygen metre (DO-5509), pH was recorded with a pH metre (HANNA instruments, HI 98107), and total dissolved solids (TDS) were analysed with a Multimeter (HQ 40 D, HACH, USA).

Fish growth monitoring

Data were gathered every two weeks, with 10% of the supplied fish from each pond being sampled using a seine net on each sampling day. The fish were then weighed in a computerised electronic scale with a 0.01 g precision before being immediately released into the ponds without inflicting any discernible harm to the fish. Following some previous research (Brett and Groves, 1979; Kunda *et al.*, 2021, 2022), the growth, survival, and production abilities of fish were examined as follows:

Initial weight (g) = Fish stock weight

Final weight (g) = Fish harvest weight

$$\text{Weight gain} = \frac{\text{Mean final fish weight (g)} - \text{mean initial fish weight (g)}}{\text{mean initial fish weight (g)}} \times 100$$

Specific growth rate (SGR) (% day^{-1}) = $\frac{\text{Log}_e W_2 - \text{Log}_e W_1}{T_2 - T_1} \times 100$ (Brown, 1957)

Where,

W_1 = The initial body weight (g) at time T_1 (day)

W_2 = The final live body weight (g) at time T_2 (day)

T_2 - T_1 = Duration of fish rearing (days)

$$\text{Survival (\%)} = \frac{\textit{No. of fish harvested}}{\textit{No. of fish stocked}} \times 100$$

Gross production = No of fish harvested × Final mean weight of fish

Net production = No of fish harvested × Mean weight gain of fish

Economic analysis

On the basis of the expenses (cost of fish fry, energy, lime, fertiliser, labour, and harvest) and the revenue from selling fish, cost-benefit analyses of the treatments were developed. The cost of goods and fish sales are indicated in Bangladeshi Taka (BDT) (1 USD = 85 BDT, November 2020). Due to the varying sizes, the average selling prices of fish at T_1, T_2, and T_3 were 300, 280, and 250 BDT/kg, respectively.

The net return was calculated using the following formula: R = I − (FC + VC + Ii)

where, R = net return, I = fish sale revenue, FC = fixed costs (costs that apply to all treatments equally), VC = variable costs and Ii = interest on inputs.

Benefit-cost ratio (BCR) = Fish selling revenue / Total input costs

Statistical analysis

One-way analysis of variance (ANOVA) was used to examine the relationship between stocking densities and the growth and production performances of Bheda in pond aquaculture. While a mean impact was significant, Duncan New Multiple Range Test (Duncan, 1955) was conducted after the ANOVA at a 5% level of significance (Gomez and Gomez, 1984). After the arcsine transformation, the percentages and ratio data were examined. Prior to analysis, the assumptions of a normal distribution and variance homogeneity were verified. Version 20.0 of SPSS (Statistical Package for Social Science) was used for all analyses (IBM Corporation, Armonk, NY, USA).

RESULTS

Hydrological properties of the pond water

Water quality parameters of the pond water were analysed in this experiment to observe any appreciable variation among the treatments (Table 2). Water quality parameters viz. temperature (°C), dissolved oxygen (mg/l), pH, transparency (cm), total alkalinity (mg/l) and NH_3 (mg/l) did not vary significantly (p>0.05) among the treatments.

Growth and yield parameters of *N. nandus*

Table 3 displays growth and yield metrics of Bheda. Fish stocking density has a noticeable impact on the overall growth presentation of this fish (Table 3 and Figure 2). Individual harvesting weight (g), weight growth (g), weight gain percentage (%), and survival rate (%) of Bheda were all significantly greater in T_1 treatment than in T_2 and T_3 treatments, respectively. As a general rule, a higher specific growth rate (% bw d^{-1}) was also observed in T_1, despite the fish being stocked in that treatment at a much lower rate than those in the other treatments. The fish at T_1 had a considerably (p<0.05) greater survival rate than the others (Table 3).

Table 2. Water quality variables (mean±SD) recorded under different treatments during the study period of August-November, 2020.

Months	Treatments	Temp. (°C)	pH	Dissolved oxygen (mg/l)	Transparency (cm)	Total alkalinity (mg/l)	NH_3 (mg/l)
Aug.	T_1	28±1.11	7.88±0.5	5.81±0.50	36.88±3.22	82.10 ± 2.47	0.49±0.10
	T_2	28.18±1.3	7.93±0.5	5.91±0.39	34.5±2.8	83.11 ± 2.85	0.50±0.13
	T_3	28.21±1.5	7.96±0.5	5.96±0.37	34.8±4.45	85.20 ± 2.95	0.47±0.18
Sept.	T_1	31.99±1.2	7.3±0.8	6.2±0.31	36.33±4.22	84.10 ± 1.23	0.48±0.11
	T_2	32.23±0.7	7.6±0.4	5.4±0.31	35.6±2.5	81.11 ± 2.11	0.49±0.12
	T_3	30.22±1.2	7.2±0.14	5.9±0.55	34.66±5.1	81.25 ± 2.31	0.51±0.11
Oct.	T_1	31.88±2.3	7.2±0.41	6.2±0.11	36.33±2.01	82.10 ± 2.94	0.50±0.09
	T_2	29.88±2.1	6.9±0.42	5.81±014	33.99±4.22	83.11 ± 2.92	0.54±0.12
	T_3	30.44±1.8	7.3±0.32	5.74±0.35	34.88±4.31	82.20 ± 1.99	0.49±0.10
Nov.	T_1	27.19±1.1	7.1±0.81	6.64±0.41	36.66±3.33	85.10 ± 3.25	0.50±0.10
	T_2	29.55±1.0	6.9±0.28	5.64±0.55	36.33±3.18	80.11 ± 2.23	0.48±0.07
	T_3	25.09±1.0	7.3±0.47	5.51±0.19	35.5±5.50	79.20 ± 2.99	0.49±0.08

Feed utilisation

N. nandus stocking at different stocking densities had a significant impact on the FCR (Table 3). FCR was lowest at treatment T_1's lowest stocking density, and subsequent increases in stocking density at treatments T_2 and T_3 resulted in a considerable drop in feed consumption, which was shown by a magnified FCR value.

Economic analysis

Economic illustration of *N. nandus* under various stocking density is given in Table 4. In this experiment, fish fry cost was an important item for being a SIS among the treatments. Only few hatcheries do induced breeding of this species. The greatest feed cost was determined at treatment T_3, despite the fact that feed cost for treatments T_2 and T_1 also fluctuated considerably over the research period due to the large influence of stocking density that was seen in the experimental ponds. Feed costs made up the majority of the study's costs, accounting for 42.07, 50.34, and 55.87% of the total costs for T_1, T_2, and T_3, respectively. In addition to this, a few other expenses had fixed prices, most

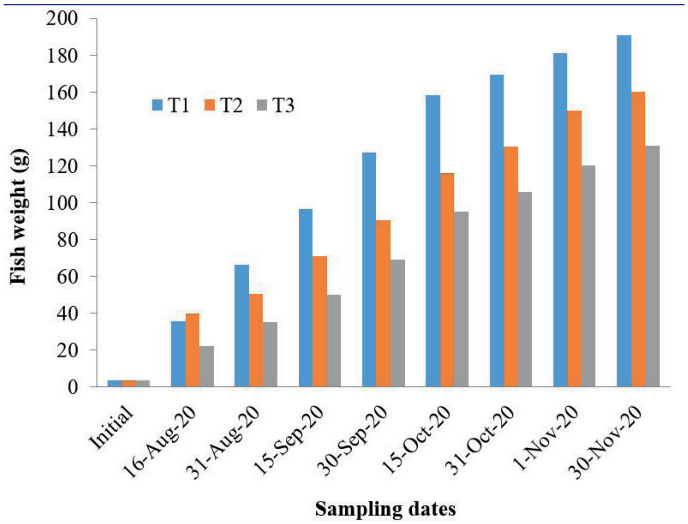

Figure 2. Fish growth in different stocking density.

Table 3. Growth and yield parameters (mean±SD) of Bheda fish in different treatments during study period.

Growth parameters	Treatments		
	T_1	T_2	T_3
Initial weight (g)	3.64±0.31^{a}	3.64±0.23^{a}	3.64±0.16^{a}
Final weight (g)	190.56±0.49^{a}	160.33±1.26^{b}	130.84±3.46^{c}
Weight gain (g)	186.92±1.80^{a}	156.69±1.30^{b}	127.2±2.30^{c}
% weight gain	5135.17±0.58^{a}	4304.67±0.31^{b}	3494.51±1.50^{c}
Specific growth rate (% bwd $^{-1}$)	2.12±0.05^{a}	2.41±1.70^{b}	2.81±0.07^{c}
Survival rate (%)	82.3±0.45^{a}	71.50±0.65^{b}	65.40±0.03^{c}
FCR	1.09±0.51^{a}	1.29±0.55^{b}	1.46±0.99^{c}
Total yield (kg ha^{-1} 120 d^{-1})	3136.62±150^{b}	3439.08±207.3^{a}	3422.78±224.4^{a}
Net yield (kg ha^{-1} 120 d^{-1})	3076.70±200^{b}	3361.00±250.80^{a}	3327.55±278.30^{a}

*Mean values with different superscripts letters in the same row indicate a significant difference (p<0.05).

Table 4. Costs associated with carp fattening at various pond stocking densities.

Items	Treatments (mean ± SD)		
Fixed costs (BDT/ha)	T_1	T_1	T_1
Pond lease	120000	120000	120000
Variable cost (BDT/ha)			
Fish fry	40000	60000	80000
Feed	200000	300000	400000
Electricity bill (Pump)	13000	13000	13000
Labour	60000	60000	60000
Fertilizer	20000	20000	20000
Harvest	13000	13000	13000
Total cost (BDT/ ha)	476000±2000^{c}	596000±2250^{b}	716000±1500^{a}
Total return (BDT/ ha)	940985.28±2000^{a}	962941.98±2000^{a}	855693.6±2000^{a}
Net benefit/profit (BDT/ ha)	464985.28±2000^{a}	366941.98±2000^{b}	139693.6±2000^{c}
BCR	1.97^{a}	1.62^{b}	1.19^{c}

Values in the same row with different superscripts are significantly different (p<0.05).

notably the cost of electricity (for the pump), lime, fertiliser, and harvesting for all treatments. However, the full refund from the fish vending industry claimed a different setup of total costs, and treatment T_1, where the stocking density was lower, filed for a substantially larger total reimbursement. Additionally, treatment T_1 generated a much bigger net benefit; hence, the economic analysis revealed a higher BCR at a lower stocking density for treatment T_1. Additionally, for T_1, T_2, and T_3, the net benefit was 97.68%, 61.56%, and 19.51%, respectively. The growth of Meni/ Bheda was confirmed to be considerably more lucrative for the farmer and to be economically beneficial at a lower stocking density, and higher stocking density was always lacking in number of multiplication in comparison with the lower stocking density ponds.

DISCUSSION

The most significant elements influencing fish growth and productivity in aquaculture ponds are fish stocking size and density (Mazlum, 2007; Zhu *et al*., 2011; Garr *et al*., 2011; Kunda *et al*., 2021). Fish growth and survival were negatively impacted by higher stocking density (40,000/ha) at treatment T_3. Additionally, it has been confirmed by Pouey *et al*. (2011), Sorphea *et al*. (2010), Mohanty *et al*. (2004), Rahman and Verdegem (2010), and Mridha *et al*. (2014) that fish at higher stocking density are subjected to a relatively higher struggle for food and space, which causes physiological stress to fish and results in lower growth, while some can tolerate extreme crowding, competition for food, and DO (Stickney, 1994).

The significant impact of stocking density on FCR is shown in Table 3. As shown by the FCR value, treatment T_1's lower stocking density resulted in greater feed consumption. Whereas Buentello *et al*. (2000) reported that low dissolved oxygen resulted in a stress situation that altered the food intake of fish, higher stocking density at treatment T_3 may produce overcrowding and a consequent decrease in oxygen consumption. Several studies have also documented a detrimental negative impact of increasing stocking density on the aquaculture feed efficiency of farmed fish. Haque *et al*. (2018) and Rahman *et al*. (2010) reported that the individual final weight of cultured fish may be reduced with the increase of their stocking density due to intra-specific competition for the same resources. In this experiment, the mean values of individual weight gain of Bheda fish were significantly higher ($p<0.05$) in T_1 than in T_2 and T_3, where stocking density was low, which could be due to high competition for feed and space, which slows down weight gain. This finding, however, was nearly identical to that of Begum *et al*. (2017b), who discovered better individual weight gain in Bheda at a lower stocking density fed with artemia. Bheda's individual percent (%) weight gain was significantly higher ($p<0.05$) in T_1 and T_2 than in T_3. This could be attributed to the T_1 treatment's higher individual harvesting weight and weight gain, followed by the T_2 and T_3 treatments. The result also indicated that the growth rates varied due to different stocking densities, which coincides with the findings of Kunda *et al*. (2021), Begum *et al*. (2017b), Begum (2009), Rubel (2008), and Rashid (2008). The specific growth rate of the fish was significantly higher *($p<0.05$)* in the T_1 treatment than in the T_2 and T_3 treatments, respectively. This finding was more or less similar to the findings of Haque *et al*. (2018), Begum *et al*. (2017b), and Ronald *et al*. (2014). However, the highest gross and net yields of Bheda were found in T_2 compared to T_3 and T_1, respectively. Although the individual harvesting weight (g), individual weight gain (g), individual percent (%) weight gain, specific growth rate (% bw d^{-1}) and survival rate (%) were higher in T_1 than T_2 and T_3, respectively, production does not depend only on the average individual weight, individual weight gain, specific growth rate (SGR), and survival rate (%) of fish but also on the number of individuals stocked (Rahman *et al*., 2010). Backiel and le Cren (1978) stated that stocking density has a direct effect on growth and hence on production. They also mentioned that the growth rate progressively increases as the stocking density decreases and vice-versa. However, the findings of gross and net production support the findings of Haque *et al*. (2018), Rahman *et al*. (2016), and Sarker (2016). Considering the overall growth performance, weight gain, percentage weight gain, specific growth rate (% bw d^{-1}), survival rate (%) gross and net production, the best result was obtained in T_1 with lower stocking density.

The appropriateness of water for the growth and existence of fish in fish farming is the standard definition of water quality. In T_1, T_2, and T_3, the mean water temperatures were 28±1.11˚C, 28.17±1.3˚C, and 28.21±1.58˚C, respectively. The fact that there were no clouds in the sky and a strong sun on October 3 may have contributed to the highest temperature of 30.4°C that was recorded in T_1. It is possible that the low intensity of sunshine and some rain on August 19 led to the lowest water temperature (25.7 °C) ever recorded in T_3. Begum *et al*. (2017a) noted a temperature range of 28.50°C to 28.60°C for the water, which is somewhat comparable to the present findings. The dissolved oxygen concentration of the water in treatments T_1, T_2, and T_3 in the current investigation had mean values of 5.81±0.50, 5.91±0.39, and 5.96±0.37 mg/l, respectively. On August 19, T_1 had the greatest dissolved oxygen level (6.23 mg/l), whereas on 3 December, it had the lowest dissolved oxygen content (5 mg/l). Rahman *et al*. (2018) in primary nursing of bata (*Labeo bata*), Rayhan *et al*. (2018) in recirculating aquaponic system of monosex tilapia (*Oreochromis niloticas*), and Yasmin *et al*. (2019) in primary nursing of Mahseer (*Tor putitora*) all found decreased DO with higher stocking density.

Another potential explanation for treatment T_3's decreased DO concentration was the considerable decline in total plankton population brought on by the presence of more fish (Monir and Rahman, 2015). According to Boyd (1998), the ideal range for dissolved oxygen content in water is 5 to 15 mg/l. The DO values below 3.5 mg/l are not acceptable for fish farming, according to Neill and Bryan (1991) and Daniel *et al*. (2005). In order to support fish life in freshwaters, 5.0 mg/l of dissolved oxygen is necessary, according to Chapman and Kimstach (1996). According to Mallasen *et al*. (2012), oxygen concentrations below 4.0 mg/l are necessary for tropical fish growth. As a result, the experiment's DO values support the conclusions of the authors mentioned above. The water in tests T_1, T_2, and T_3 had mean pH values of 7.9, 7.91, and 7.92, respectively. Boyd (1979) asserted that an ideal pH range for enhancing fish output is between 6 and 9. According to Hepher and Pruginin (1981), fish culture is best in a pH range of 6.5 to 9.0. In pond water, Dinesh *et al*. (2017) discovered a pH range of 7.1 to 8.0. The pH readings from this investigation, however, were consistent with the findings of the authors mentioned above. Therefore, it could be argued that the water quality standards were satisfactory for *N. nandus* culture or upbringing.

According to the study, net profit declined as stocking density increased, which was consistent with Dasuki *et al*. (2013) and Hossain *et al*. (2022). The BCR for every treatment exhibits a significant heterogeneity in density. The 20,000 fish ha^{-1} stocking density of Bheda was therefore found to be the best among the three treatments in terms of growth, survival rate, output, and economic return, according to the overall findings of the current study. The BCR calculated for this trial run was between 1.19 and 1.97. The T_1 had the significantly highest BCR compared to the T_2 (1.62) and the T_3 (1.19), respectively (Table 4). Benefit cost ratio demonstrated the substantial *($p<0.05$)* differences across treatments. The BCR values that Kunda *et al*. (2021) and Hossain *et al*. (2022) acquired were significantly lower than our latest findings.

CONCLUSION

In this study, the stocking density of Bheda fingerlings at 20,000 fish ha^{-1} significantly improved *($p<0.05$)* the growth performance of fish in terms of individual harvesting weight, individual weight gain (g), individual percent (%) weight gain, specific growth rate (% bw d^{-1}), survival rate (%), and BCR. Despite T_1 having the lowest overall output, it has a more favourable BCR than other regimens. Therefore, it can be said that stocking fingerlings of the Bheda fish (*N. nandus*) at a density of 20,000 fish ha^{-1} has a significant impact on their growth and production performance in ponds. However, more research on standardising the stocking density of this fish at the on-station and on-farm levels may be necessary before this culture technology is widely distributed to farmers, particularly in Bangladesh and other areas in this region.

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