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Productivity enhancement through enclosure culture in a sub-tropical wetland of Bundelkhand region, India

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Abstract

The enclosure culture *i.e.* pen culture for *in situ* raising of stocking material was demonstrated in the Loni wetland, a sub-tropical wetland of Bundelkhand region in central India. Pen stocked with 20000 fry of Indian major carps (IMCs), catla, rohu and mrigal in the ratio 1:2:1 with initial weight 2.1, 2.83 and 2.82 g respectively @20 m^2. The experiment was conducted during September 2018 to November 2018 for two months. Catla, rohu and mrigal exhibited substantial difference ($p<0.05$) in the growth pattern during the study with catla growing from 2.1±0.21 to 24.25±2.12 g, rohu from 2.83±0.25 to 19.58±1.81g whereas mrigal from 2.82±0.23 to 15.42±1.10 g. The specific growth rate (SGR) recorded was 124.6, 108.9 and 82.43% in catla, rohu and mrigal, respectively. The survival rate was maximum in rohu (76%), followed by catla (68%) and mrigal (42%). The benefit to cost ratio (BCR) estimated was 1.69 and proportion of return on investment was 0.69. Through this intervention, the productivity of fish yield reached up to 450 kg ha^{-1} yr^{-1} from 165 kg ha^{-1} yr^{-1} which can be further increased manifolds. Based on the results of the present experiment, it can be suggested that rearing of IMC fry to fingerlings in pen enclosures in wetlands is technically feasible and economically viable.

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Introduction

India is bestowed with vast freshwater wetland resources (0.55 million ha), locally known as beels, mauns, chaurs, pats, tals and jheels in various states of the country. The characteristic of having vegetation of aquatic plants is the main element that separates wetlands from other water bodies (Butler, 2010). Globally, 917 million ha to more than 1275 million ha area is occupied by wetland ecosystems (Lehner and Doll, 2004). As perestimates, the freshwater wetlands sustains approximately 20% of the known range of biodiversity in India (Deepa and Ramchandra, 2000). In India, the state of Uttar Pradesh has the second highest sizeable area of 1.52 lakh ha under wetlands (Pathak *et al.,* 2004), but the level of interventions to enhance the productivity of these water bodies remained almost nil or insufficient due to non-existence of location-specific management protocols (Alam *et al*., 2017). This huge biodiversity reserves provide necessary launching platforms for increasing fish production. The ecology and productivity of wetlands in different parts of the country and also from Uttar Pradesh has been widely deliberated (Pathak *et al.,* 1985, 2002, 2004; Jha, 1989, 1997; Pathak, 1989, 1990; Sugunan, 1995, 1997; Vass, 1997; Kumar and Joshi, 2008; Joshi and Kumar, 2009; Alam *et al.,* 2017; Das *et al*., 2017; Joshi *et al.,* 2022). The production potential of the wetlands from different locations of the country has been estimated, which is in the range between 1000 and 1500 kg ha^{-1} (Pathak *et al.,* 2004; Sharma *et al.,* 2010). Having such high potential from wetlands, we are still unable to harness it due to lack of understanding of the ecological principles, especially productivity characteristics and improper management which have resulted in relatively low yield (100 to 200 kg ha^{-1}) from most of the wetlands of the country

(Pathak *et al.,* 2004; Anon., 2011b). Low production may be due to reduced recruitment or auto stocking of fish seeds from tributaries and rivers (Anon., 2000). Hence, such wetlands are sensibly stocked with fish seeds of required size in sufficient number to enhance fish production. By stocking fry size in the water bodies, it is difficult to get targeted production and therefore ICAR-Central Inland Fisheries Research Institute (ICAR-CIFRI), Barrackpore has popularised pen culture technology for rearing fry to fingerling/advanced fingerling and then release it the water body for futher growth. Pen culture is an economically feasible technology for *in situ* raising of stocking material (Banerjee and Pandey, 1978; Katiha *et al.,* 2005; Gorai *et al.,* 2006; Aparna and Hassan, 2013; Chandra *et al.,* 2013). Releasing fingerlings raised in pen in open waters, have demonstrated better growth and survivability (Gireesha *et al.,* 2003; Aparna and Hassan, 2013; Alam *et al.,* 2017; Das *et al.,* 2017). In this backdrop, the present study was undertaken with an aim to enhance the fish productivity of the wetland ecosystem, by stocking fry of catla, rohu and mrigal that were reared to fingerling stage in a bamboo pen installed at Loni wetland, Rewa District, Madhya Pradesh, India with the support of the local wetland co-operative society.

Materials and methods

The present study conducted in Loni wetland, a seasonal open type wetland spread over 129 ha water area with mean depth of 3.6 m. The wetland is located in the Suti Village of Rewa District in Bundelkhand region (25°08'18" N and 81° 34'14" E) Madhya Pradesh, India (Fig. 1). The present experiment was conducted from September 2018 to November 2018 for production of suitable sizes of seed for stocking in the wetland, by rearing catla, rohu and mrigal fry in pen.

Pen construction and stocking

Baseline data on various aspects such as water spread area, fish yield (kg ha^{-1}), seed stocking, the intensity of weed infestation and fisheries in respect of the wetland were collected initially. Fish diversity was studied by collection of fishes through experimental fishing using different types of gears including gillnets, cast net and dragnets of different mesh sizes and other locally available gears. The pen prepared for the present study had a total area of 1000 m^2 (50 x 20 m) and were constructed by using different materials such as; fencing screen of nylon material having width 1.83 m with 0 mm mesh size; bamboo poles of length 2.7 m; nylon footrope of 3 mm dia and twine of 1 mm thickness. The site for the installation of the pen was selected during the previous year considering water availability for experimenting with duration of four to six months. In the dry season, the selected area was marked and measured with the help of measuring tape, and subsequently four bamboo poles were fixed in four corners. The measured area was ploughed to make the surface even and manuring was also done to boost the growth of plankton as well as for soil correction. Straight, freshly harvested bamboos having 5-6 cm diameter were used for pen construction. A total 180 such bamboos were selected and base portion (up to 2.5 m) was used for pen structure and the rest of the portion was used for frame preparation. Each frame was of 2.6 X 5 m dimension and a total of 28 such frames were used for pen making. At 5 m interval, sliced bamboo splits were planted (1.5 feet deep) and then the frames so constructed were fixed with the help of wires (50 X 20 m). When the water started filling in the wetland, the nylon net was fixed to the pen structure and the net was fixed one foot deep in the bottom to avoid escape of the stocked fish from the pen as well as to restrict entry of unwanted organisms from outside the pen. When suitable water level reached in the pen, pre-stocking management such as weed removal, liming

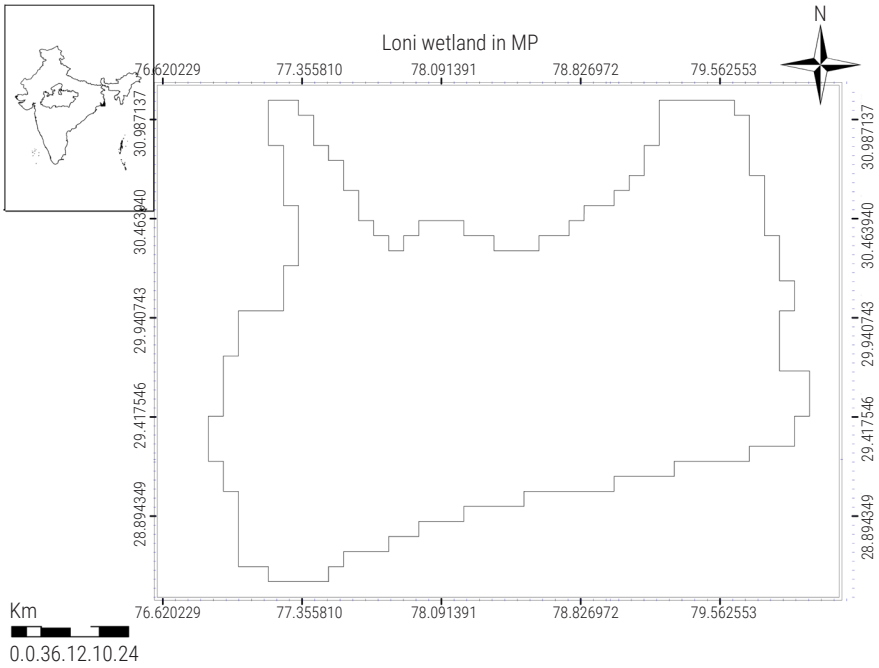

Fig. 1. Location of Loni wetland in Madhya Pradesh, India

and removal of predatory as well as weed fishes by repeated netting operations were undertaken. The pen was stocked with 20000 fry of catla, rohu and mrigal in the ratio of 1:2:1 with initial weight 2.1, 2.83 and 2.82 g respectively @20 m^{-2}.

Sampling and feeding

The fish samples were collected randomly from the pen at 30 days interval using cast net and length and weight measured, to evaluate the growth of stocked fishes, to determine health status and also to adjust feeding rate. At the same time, samples for water, soil and plankton were also collected from inside as well as outside the pen and analysed following standard methods (APHA, 2005). The fishes stocked in the pen were fed with mahua oil cake (MOC) and rice polish in the 1:1 ratio @ 3-5% of the bodyweight as supplementary diet in addition to natural food available in the pen. Growth during the culture period was assessed with the help of the following formulas:

Bodyweight gain (g per months) = (Final weight-Initial weight)/ culture period in terms of months

Specific growth rate (SGR) = (ln mean final weight - ln mean initial weight)/Culture duration in months) x 100

Feed conversion ratio (FCR) = (Total feed given/Weight gain) x 100

Carp juveniles were harvested post 60 days culture period and further released into the wetland for stock enhancement.

Statistical analysis

Length and weight of the sampled fishes were recorded and the growth pattern was statistically tested using one way ANOVA. Mean of the physico-chemical parameters and the plankton abundance inside and outside the pen were subjected to t-test at 5% level of significance.

Results and discussion

Loni is an open wetland and maintains its connection with Loni River during monsoon season and has total water spread area of 129 ha with an average depth of approximately 3.6 m. It has been observed that the wetland is highly infested with submerged aquatic weeds, such as *Hydrilla* sp., *Chara* sp., *Valliesnaria* sp. and *Potamogeton* sp. The fish yield recorded during the present study was around 165 kg ha^{-1}, even though there was high production potential estimations of 638-1327 kg ha^{-1} from wetlands of Uttar Pradesh (Pathak *et al.,* 2004).

From Loni wetland, predatory fishes such as *Heteropneustes fossilis*, *Channa marulius, Notopterus chitala* and *Wallago attu* and miscellaneous group of fishes *viz*., *Rasbora daniconius, Pethia conchonius*, *Puntius sophore, Chanda nama, Salmostoma bacaila, Xenentodon cancila, Amblypharyngodon mola* and *Glossogobius giuris* contributed significantly to the catch.

Water and sediment quality

Before conducting the experiment, the water, as well as soil quality parameters, were examined and depicted in Table. 1. The important variables of water *viz.,* temperature, pH, dissolved oxygen (DO_2), carbon dioxide (CO_2) and alkalinity were in optimum level required for culture. Since all the above parameters were observed to be within adequate range in Loni wetland, it can be placed under a moderately productive class. The results indicate that the wetland was productive and suitable for undertaking pen aquaculture. During the culture, monthly water and soil quality was examined both from inside and outside of the pen and the same has been shown in Table 2. The range of $DO_2$was more than 5 mg^{-1} which was in the optimal range required by cyprinids suggested by Dulic *et al.* (2010). The temperature of the water was in the range from 22 to 28ºC and which falls in the range considered to be suitable for fish culture (Sugunan, 2011). The pH of the water sampled from the Loni wetland was found to be in the range of 8.2-8.5 which was in the acceptable range (7-8.5) as recommended by Boyd *et al.* (1998). The values for total alkalinity was in the range of 45-64 mg l^{-1} and the total hardness was in the acceptable limit for fish culture *i.e.* 54-42 mg l^{-1} during the study period.

Growth parameters

The net production mainly rests on the growth and survival of species cultured in the system. In the present study catla, rohu and mrigal have shown significant difference ($p<0.05$) in the growth pattern, wherein catla attained a growth from 2.1±0.21 to 24.25±2.12 g, rohu 2.83±0.25 to 19.58±1.81g whereas mrigal from 2.82±0.23 to 15.42±1.10 g (Fig. 2.). Higher weight gain was observed in case of catla and rohu in comparison to mrigal (Table 3). In the present study, catla showed higher net production than the other two species as well as exhibited the fastest growth amongst IMC, which is in agreement with the results of Jhingran and Pullin (1985). The present study showed a significant difference ($p<0.05$) in the growth pattern of catla, rohu and mrigal. On the commencement of the investigation, the preliminary weight of catla was considerably

Table 1. Water and sediment quality parameters in Loni wetland

Parameters	Mean±SE
Air temperature(ºC)	32.4±0.47
Water temperature (ºC)	31.7±0.22
Transparency (cm)	28.3±3.05
pH	8.6±0.21
Carbon dioxide (ppm)	00±00
Carbonate (ppm)	14.5±1.09
Bicarbonate (ppm)	57.48±10.48
Dissolved oxygen (ppm)	9.3±0.55
Total hardness (ppm)	47.5±5.49
Phosphate (ppm)	0.032±0.01
Silicate (ppm)	3.7±0.33
D.O.M (ppm)	1.7±0.23
Sediments quality	
pH	7.9±0.07
Free CaCO3 (%)	2.3±0.13
Free OC (%)	2.4±0.09
Phosphate (mg P 100 g $soil^{-1}$)	3.6±0.06
Nitrate (mg N 100 g $soil^{-1}$)	24.2±0.61

Table 2. water and sediment quality parameters inside and outside of pen

Parameters	Inside pen	Outside pen
Water quality		
Air temperature (°C)	29.2±1.9	30.8±2.0
Water temperature (°C)	28.4±2.6	28.7±2.6
Transparency (cm)	48.3±12.9	56.3±26.6
pH	8.2±0.2	8.5±0.4
Carbon dioxide (ppm)	2.7±2.2	3.0±2.4
Carbonate (ppm)	8.7±3.6	10.7±4.5
Bicarbonate(ppm)	36.7±6.8	53.7±17.7
Dissolved oxygen (ppm)	8.8±0.0	9.7±0.7
Total hardness (ppm)	54.7±2.2	42.0±4.9
Phosphate (ppm)	0.024±0.05	0.029±0.05
Silicate (ppm)	2.5±0.7	2.7±1.1
D.O.M (ppm)	2.1±0.6	2.5±0.5
Sediment quality		
pH	7.97±0.05	7.7±0.1
Free CaCO3 (%)	2.83±0.49	2.1±0.2
Free OC (%)	2.3±0.29	2.3±0.1
Phosphate (mg P 100 g soil^{-1})	4.63±0.77	4.0±0.4
Nitrate (mg N 100 g soil^{-1})	16.51±6.22	17.7±5.4

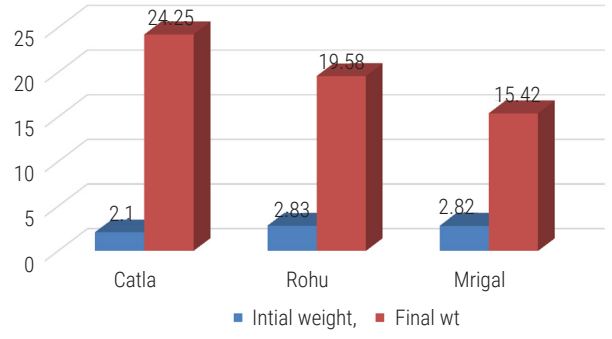

Fig. 2. Mean increase in total body weight (g) of catla, rohu and mrigal in Loni wetland during 60 days culture period

($p<0.05$) lower as compared to rohu and mrigal, respectively. The specific growth rate (SGR) at the end of culture period was 124.6, 108.9 and 82.43% in catla, rohu and mrigal respectively. The survival recorded were 76, 68 and 42% for rohu, catla and mrigal respectively (Table 3).

However, in this study catla exhibited higher monthly average growth compared to rohu and mrigal throughout the whole investigation. The growth of rohu and mrigal were found very close to each other and not significantly ($p>0.05$) different during the last month of the investigation. There are very few reports on the culture of IMCs for raising fry to fingerlings in the wetlands (Banerjee and Pandey, 1978; Bhattacharya *et al.*, 2010). In the study conducted by Bhaumik et al. (2000) they observed that rohu, mrigal and silver carp grew from 50 to 71.5 g, 60 to 74 g and 30 to 75 g, respectively in 59 days of culture period with supplementary feeding at 4% of body weight in the wetland. Gorai *et al.* (2006) from Goruchora wetland of Assam reported that catla, rohu and mrigal grew from an initial body weight of 1.8, 1.15 and 1.15 g to 85.1, 52.8 and 42.9 g respectively in 145 days rearing period. Whereas Alam *et al.* (2017) showed that rohu grew from 2.88±1.41 to 57.72±13.84 g while catla grew from 2.1±1.16 to 67.38±25.79 g during 120 days of culture period in Sareni Jheel, Uttar Pradesh and Das *et al.* (2017) from Alwara Taal of Uttar Pradesh showed that catla, rohu and mrigal fry grew from 6.85 g ±0.48, 3.77 g ± 0.31 and 5.03 g ± 0.26 to 123.10 g ± 5.53, 85.4 g ± 4.91 and 72.3 g ± 2.42 in 110 days culture period.

Benefit-cost ratio (BCR)

For the present study benefit cost ratio (BCR) estimated was 1.69 (Table 4) and return on investment was 0.69. Benefit-cost ratio from present study was in agreement with that reported by Gorai *et al.* (2006) and Chandra *et al.* (2013) in the wetlands of Assam, which indicate comparatively higher profitability than any other private enterprise. Production of stocking material and their subsequent release greatly increased fish yield and productivity of the wetland providing nutritional security and livelihood to the people of the Bundelkhand region of India.

From the present experiment, it can be suggested that rearing of IMC from fry to fingerlings stage in the pen enclosures in wetlands is economically feasible. Through this intervention, the productivity of fish yield reached up to 450 kg ha^{-1} yr^{-1} from 165 kg ha^{-1} yr^{-1} which can be further increased to manifolds. Release of reared fingerlings can significantly help in bridging the gap between actual and potential productivity of fish yield in wetlands and also have potential to enhance productivity levels in the floodplain wetlands of Bundelkhand region.

Table 3. Growth and survival of *C. catla, L. rohita* and *C. mrigala* in the pen installed in Loni wetland during 60 days of culture period

Days	0	30	60
Catla catla			
Temperature (°C)	31.7	29.2	21
Mean weight (g)	2.1±0.21	12.15±1.23	24.25±2.12
Weight gain (g)		10.05	14.2
Specific growth rate (SGR)		115.5	124.6
Survival (%)			68
Labeo rohita			
Mean weight (g)	2.83±0.25	10.75±1.15	19.58±1.81
Weight gain (g)		7.92	8.83
Specific growth rate (SGR)		103.4	108.9
Survival (%)			76
Cirrhinus mrigala			
Mean weight (g)	2.82±0.23	10.22±1.06	15.42±1.10
Weight gain (g)		7.4	5.2
Specific growth rate (SGR)		100.0	82.43
Survival (%)			42

Table 4. Economics of pen culture in Loni wetland for raising advance fry to fingerling

Particulars	Rate (₹)	Unit	Amount (₹)
Capital costs			
Cost of full-length mature bamboo poles (No.)	55	200	9900
Cost of Nylon net (per bundle)	1000	08	8000
Sub total			17900
Capital costs per crop (assuming that the materials will last for 3 crops)			5966
Operational costs			
Cost of IMC fingerlings (kg)	950	20	19000
Cost of rice bran + MOC (kg)	15	750	11225
Labour charges for construction of pen	300	5	1500
Labour charges for stocking and harvesting	200	5	1000
Labour charges for watch and ward and daily feeding for 2 months	2500	2	5000
Miscellaneous expenses			1000
Sub total			38725
Total Cost			56625
Sale price of advanced fingerlings (per kg)	350	275 kg	96250
Sub-total			
Net income (Gross income - Total costs)			39625
Benefit-cost ratio			1.69
Return on investment			0.69

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