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Assessment of economic feasibility of pen aquaculture technology in floodplain wetlands (beels) of Assam, India

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ABSTRACT

Floodplain wetlands (beels) constitute one of the most important fishery resources amenable for culture-based fisheries development in Assam, both in terms of large resource size (100,815 ha) and high fish production potential (1000-1500 kg ha^{-1} yr^{-1}). Pen aquaculture technology standardised by ICAR-Central Inland Fisheries Research Institute (ICAR-CIFRI), Barrackpore, India for *in situ* rearing of carp seed for stocking in beels was demonstrated in 21 beels located in 9 districts of Assam in collaboration with the Assam Fisheries Development Corporation Limited (AFDC Ltd.) and Bodoland Territorial Council (BTC) for pilot-scale validation of economic feasibility of the technology. Large pen enclosures (2400-4990 m^2) were erected in the beels for the validation; which were grouped into four size groups *viz*., P1 (2400-2499 m^2), P2 (2500-3499 m^2), P3 (3500-4499 m^2) and P4 (4500-4999 m^2 area) to determine the most economic size of pens for the beels of Assam. Cost of bamboo (main construction material) ranged from 30.47 (P4) to 48.74% (P3) of the capital cost. Labour cost for pen construction was found to be the major contributor of capital cost ranging from 33.73 (P3) to 52.22% (P4), followed by the cost of LDPE netting (10.56-13.74%) and coir rope (3.28-5.83%). Major share of recurring cost was spent on fish seed (54.93-61.04%), followed by feed (17.01-22.63%) and towards labour for culture operations (8.48-14.51%). The total cost per crop was the highest in P3 (₹87,211/-) followed by that in P4 (₹52,606/-) and P2 (₹50,933/-), whereas it was the lowest in P1 (₹49,511/-). The percentage expenditure of recurring costs per crop to total cost was 72.48-82.25% and a much smaller percentage (17.74-27.51%) of total cost was contributed by the cost on fixed expenditure. The average quantity of fish seed produced in the pens in P1, P2, P3 and P4 groups was 885.94, 875.08, 1,356.73 and 1,104.62 kg, respectively. The P1 group was found to be the most economically viable pen size yielding the highest benefit-cost ratio (3.04), followed by pen sizes P4 (2.78), P2 (2.50) and P3 (2.28). The study showed that pen aquaculture technology using pen sizes in the range of 2400-5000 m^2 were economically viable for *in situ* carp seed rearing in the beels of Assam, with highest profitability in the pen size range of 2400-2499 m^2.

Keywords: Assam, Beels, Benefit-cost ratio, Economic viability, Floodplain wetlands, Pen aquaculture

Introduction

Major share of fish production from inland open water fisheries in India comes from reservoirs and floodplain wetlands, which are managed on the basis of culture-based fisheries or various other forms of enhancements (Ayyappan, 2005). Floodplain wetlands of India cover an area of over 3.54 lakh ha and constitute an important fishery resource in the states of Uttar Pradesh, Assam, West Bengal, Bihar and Manipur (Bhattacharjya, 2011). Assam has the largest area (1, 00,815 ha) under floodplain wetlands (locally called beels) in the north-eastern region of India (Bhattacharjya *et al.*, 2015a). These wetlands can produce 8 times more benefits than that of a paddy field of an equivalent area (Jhingran, 1989), as they are rich in nutrient load with availability of wide range of fish food organisms. The floodplain wetlands are productive ecosystems with an estimated fish production potential of 1000-1500 kg ha^{-1} yr^{-1} as against the actual average fish yield of 173 kg ha^{-1} yr^{-1} (Sugunan and Bhattacharjya, 2000). This is because of poor recruitment from their parent/ adjoining rivers, as most of the wetlands have lost their riverine connections. Since beels present diverse ecological conditions, they are amenable to development of capture fisheries and various forms of fisheries enhancements including culture-based fisheries (Bhattacharjya and Sarma,

2010). Fisheries enhancements refer to the process by which qualitative and quantitative improvement is achieved from waterbodies by exercising specific management options (Welcomme and Bartley, 1998). Studies have shown that fish yield rates from selected floodplain wetlands of Barak Valley of Assam ranged from 250-1500 kg ha^{-1} yr^{-1} where fish stock enhancement (supplementary stocking with carp fingerlings) was practiced (Bhattacharjya and Sarma, 2010). However, non-availability of carp fingerlings of desired size (10 cm and above) in required quantities at the beel site as well as high cost of carp fingerlings with associated high mortality during transportation are major constraints in practicing large-scale fish stock enhancement in these water bodies.

Pen culture is raising of fish in confinements of water areas in large water bodies, which is gaining importance for enhancement of fish production from open waters (Beveridge, 1984; Baluyut, 1989). Published literature on pen culture in India is limited (Banerjee and Pandey, 1978; Abraham, 1980, 1990; Yadava *et al*., 1983; Gorai *et al.*, 2006a, b; Chandra *et al.*, 2013). *In situ* rearing of fingerlings in pens in the floodplain wetlands appears to be a feasible option to overcome constraints faced during stock enhancement in beels (Bhattacharjya *et al.*, 2015b). Pen aquaculture technology was successfully demonstrated and perfected by ICAR-Central Inland Fisheries Research Institute (ICAR-CIFRI), Barrackpore, India as an avenue for additional fish production in floodplain wetlands parallel to enhancement of their capture fisheries/fish stock enhancement, wherein a manageable part of marginal areas of the wetland are encircled with net-lined split-bamboo screens (*bana*) for rearing of carp fingerlings/table fishes. Pen aquaculture is a good management option for macrophyte-choked shallow and unproductive wetlands that solves the problems created by gear restrictions and catchability (Bhattacharjya, 2003). Carp fingerlings raised in pens have shown better survivability and growthwhen released in open water (Roy and Hassan, 2013). It is a low-cost and simple technology for fish culture in enclosures erected in marginal/ shallow areas of wetlands.

Pen aquaculture in the floodplain wetlands of Assam has proven to be economically viable with positive benefit-cost ratios (Bhattacharjya, 2003, 2011; Katiha *et al.*, 2005, Gorai *et al.*, 2006a, b; Chandra, 2010; Bhattacharjya *et al.*, 2015a). However, the benefit-cost ratios in the previous experiments and field trials ranged from 1.35-2.15. In the present study, we increased the pen size to 2400-5000 m^2 from the size of 500-1000 m^2 employed in the previous trials/demonstrations, to overcome the increasing costs of bamboo and labour in Assam in recent years and also attempted to determine the most economic size of pens for the beels of the state.

Materials and methods

The present study was conducted in 21 pens erected in 21 floodplain wetlands (beels) located in nine districts of Assam spread across both the Brahmaputra and Barak valleys of the state. These pen aquaculture demonstrations were carried out for pilot-scale validation of the ICAR-CIFRI technology in collaboration with Assam Fisheries Development Corporation Limited (AFDC Ltd.), Guwahati and Bodoland Territorial Council (BTC) Kokrajhar. The size of the pens constructed ranged from 2415 to 4990 m^2, which were categorised in to four size groups *viz.*, 2400-2499 m^2 (P1), 2500-3499 m^2 (P2), 3500-4499 m^2 (P3) and 4500-4999 m^2 (P4). Field visits were undertaken for data collection using pre-structured questionnaire and focused discussion with the stakeholders (beel lessees, members of fishers' cooperative societies and beel managers) during September 2013 to March 2014.

The collected data from the respondents during the study period were edited, scored, tabulated and analysed by simple tabular and functional analysis for estimating cost and return of pen aquaculture. Different farm business plan, cost and income measures were estimated following Salim and Biradar (2001). Different components of fixed and recurring costs that are area-normalised, were subjected to one-way ANOVA using SPSS at 5% level of significance. To evaluate economic feasibility of pen aquaculture technology, benefit-cost ratio (BCR) was computed following Goswami *et al.* (2011). The fixed capital cost per crop was calculated considering 3 crops per year. The rental value was calculated for different pen sizes as per the lease amount per year for the beels, where the demonstrations were conducted. The interest on fixed capital cost was calculated at 10.5%.

Results and discussion

Fixed/capital cost

Fixed/capital cost (*i.e.* cost of pen construction and maintenance) per crop was the highest for P3 (₹15,474/-) followed by P2 (₹14,013/-), P1 (₹13,198/-) and P4 (₹11,343/-) and overall average cost of all the size categories was ₹13,844/- (Table 1). Fixed cost per crop contributed to 17.74 to 27.51% of total cost per crop in the present trials. Chandra *et al.* (2013) reported it to be 19.50 to 38.68% in four pens/beels of Assam. Apparently increasing the pen size resulted in lowering of proportion of capital cost to total cost in the present study. Cost of bamboo (main construction material) ranged from 30.47 (P4) to 48.74% (P3) of capital cost. Labour cost for pen construction was found to be the major contributor of capital cost ranging from 33.73 (P3) to 52.22% (P4), followed by the cost of LDPE netting (10.56-13.74%)

Table 1. Expenditure on fixed capital (₹for various size categories of pens installed in different floodplain wetlands of Assam

Pen size category	Annual depreciation	Rental value	Repair/ maintenance per year	Interest on fixed cost (10.5%)	Cost of labour per year	Fixed cost per year	Fixed cost per crop
P1	15,295	3,325	3,500	1,973	15,500	39,593	13,198
	(38.63)	(8.39)	(8.83)	(4.98)	(39.14)		
P2	20,452	1,762	2,911	2,453	14,459	42,038	14,013
	(48.65)	(4.19)	(6.92)	(5.83)	(34.39)		
P3	23,335	5,523	2,417	2,704	12,445	46,423	15,474
	(50.26)	(11.89)	(5.20)	(5.82)	(26.80)		
P4	12,848	1,733	2,375	1,598	15,475	34,030	11,343
	(37.75)	(5.09)	(6.97)	(4.69)	(45.47)		
Overall average (3463.52 m^2)*	19,336	2,980	2,724	2,316	14,176	41,533	13,844
	(46.55)	(7.17)	(6.55)	(5.57)	(34.13)		
2500 m^2 **	15,085	2,213	2,203	1,815	10,976	32,292	10,778
	(46.71)	(6.85)	(6.82)	(5.62)	(33.98)		

Figures in parentheses indicate percentage of the fixed cost per year
*Overall average cost of pen aquaculture was calculated for all beels where pen culture demonstrations were conducted in Assam
**Cost of the respective items per pen was calculated for 2500 m^2
Fraction of rupees is converted into nearest whole number

and coir rope (3.28-5.83%) (Table 2). In many cases, extra bamboo poles were used for making a taller bamboo screen (anticipating increase in water level during the rainy season). Higher number of bamboo poles were also used in some beels for giving extra support to the screens (anticipating wind action), which accounted for higher percentage of fixed cost being spent on bamboo. Overall average expenditure across different pen sizes showed that approximately 60% of the expenditure is towards material cost and approximately 40% towards cost of labour.

The percentage expenditure incurred on bamboo for P3 pen size (3500-4499 m^2) was significantly higher ($p<0.05$) compared to that of P4 (Table 2), even though it had no significant difference with the other two pen size groups. It can be partially attributed to the fact that cost of bamboo was different in different localities. It was evident from the present study that the largest pen size of 4500-4999 m^2 was the cheapest to construct. The cost of construction per unit area logically comes down in large pens because the cost of internal partitions is reduced here. In the P1, P2 and P3 pen size categories, the expenditure on repair/maintenance was lower compared to other costs mainly due to high quality of bamboo and *bana* used during the construction, while in P4 category, the low quality of construction and construction materials used led to a higher maintenance cost. This was also reflected in higher labour cost (52% of total capital cost) for this pen size category. The overall expenditure on fixed cost per crop was only 22.51% of the total cost. Previous reports on pen aquaculture in the state showed that the expenditure on fixed cost was 25.08% in Haribhanga beel of Assam (Chandra, 2010). Another study showed it to be 34.58% in the same beel and 35.74% in Kumri beel of Assam (Katiha *et al.,* 2005). The results showed that the negative effects of increasing bamboo costs in the study region could be offset by increasing the individual pen size from 1000 m^2 to 2415-4990 m^2 in the present trials.

Recurring cost

The recurring cost pattern for various size categories of pens per crop is presented in Table 3. In the present study, the recurring costs increased from small to large pen size categories *i.e.,* ₹36,314, ₹36,920 and ₹71,737 in pen size P1, P2 and P3 respectively. Among the components of recurring cost, seed and feed generally account for the major

Table 2. Components of fixed capital (%) for various size categories of pens installed in different floodplain wetlands of Assam

Pen size category	Bamboo (₹)	LDPE netting (₹)	Rope (₹)	Labour (₹)
P1	37.06^{ab} ±4.67	10.56±3.17	3.28 ± 0.60	49.10^{a} ±7.24
P2	40.22^{ab} ±2.25	13.74±1.53	5.83 ± 1.04	40.21^{ab}±2.49
P3	48.74^{a}±4.65	13.57±1.84	3.97 ± 0.80	33.73^{b}±3.37
P4	30.47^{b}±2.14	11.83±4.57	5.50 ± 1.01	52.22^{a} ±5.87

Data expressed as mean±SE; Different superscripts in the same column denote statistical significance ($p\leq0.05$)

Table 3. Recurring cost pattern for various size categories of pens installed in different floodplain wetlands of Assam

	Cost (₹)										
Pen size category	Lime	Seed	Feed	Disease	Labour	Macrophyte control	Control of unwanted organisms	Other costs	Interest (@ 9%)	Total recurring cost per crop	Total recurring cost per year
P1	467	21,000	7,050	0	5,250	458	458	831	799	36,314	1,08,941
	(1.28)	(57.82)	(19.41)	(0.00)	(14.45)	(1.26)	(1.26)	(2.28)	(2.20)		
P2	762	23,000	5926	0	4958	595	361	506	812	36,920	1,10,761
	(2.06)	(62.29)	(16.04)	(0.00)	(13.42)	(1.61)	(0.97)	(1.37)	(2.20)		
P3	1,412	47,025	14,017	440	5,359	878	444	583	1579	71,737	2,15,210
	(1.96)	(65.55)	(19.53)	(0.61)	(7.47)	(1.22)	(0.61)	(0.81)	(2.20)		
P4	591	24,500	7,756	50	5,052	950	742	713	908	41,263	1,23,788
	(1.43)	(59.37)	(18.79)	(0.12)	(12.24)	(2.30)	(1.79)	(1.72)	(2.20)		
Overall average (3463.52 m^2)*	887	29,960	8,693	135	5,118	730	467	598	1398	47,987	1,43,960
	(1.85)	(62.43)	(18.12)	(0.28)	(10.67)	(1.52)	(0.97)	(1.25)	(2.92)		
2500 m^2 **	661	21,973	6,517	86	3,960	536	350	461	777	35,321	1,05,963
	(1.87)	(62.21)	(18.45)	(0.24)	(11.21)	(1.51)	(0.99)	(1.30)	(2.20)		

Figures in parentheses indicate percentage of the total recurring cost per crop
*Overall average cost of pen aquaculture was calculated for all beels where pen culture demonstrations were conducted in Assam
**Cost of the respective items per pen was calculated for 2500 m^2
Fraction of rupees is converted into nearest whole number

share. Seed cost was the highest that ranged from 57.82 to 65.55%, feed cost was the second highest that ranged from 16.04 to 19.53% and cost of labour was the third highest that ranged from 7.47 to 14.45%. It was evident from the results that the recurring cost was higher in larger pens than that of first two size categories mainly because of higher fish seed and feed cost. In earlier studies on pen aquaculture, expenditure on seed cost was reported to be 58% of recurring cost in Haribhanga beel of Assam (Chandra, 2010) and 43.25% in Kumri beel, 40.41% in Samaguri beel and 47.56% in Haribhanga beel of Assam (Katiha *et al*., 2005).

When percentage expenditure on various components of variable costs was worked out, no significant difference was observed among size categories except for 'other costs' (Table 4).

Different components of variable costs in pen aquaculture normally vary with the area of pens. That is why the cost per unit area remains unchanged among different categories of pen sizes. The percentage expenditure (per m^2) on 'other costs' (though a small percentage of total recurring cost) for pen size P2 and P3 was similar but it was lower compared to other two categories of pens.

Total cost of pen aquaculture

Total cost of pen aquaculture per crop for P1 was the lowest (₹49,511/-) compared to all other size categories (Table 5). However, it was similar to that of next pen size category, *i.e.,* P2 (₹50,933/-). The total cost per crop was highest in P3 (₹87,211/-). Our study revealed that in all the pen size categories, the expenditure on total recurring cost per crop (that is 72.48-82.25% of the total cost) was higher than that of the fixed cost per crop (17.74-27.51%).

Table 4. Percentage average expenditure (₹ per m^2 of pen) on different components of recurring cost incurred for various size categories of pens installed in different floodplain wetlands of Assam

Pen size category	Lime	Seed	Feed	Disease	Labour	Macrophyte control	Control of unwanted organism	Other costs	Interest (9%)
P1	1.31±0.77	55.96±19.05	21.25±17.51	0.00±0.00	14.51±0.80	1.23±0.03	1.23±0.03	2.26^{a}±0.09	2.20±0.00
P2	1.93±0.52	61.04±6.52	17.01±5.09	0.00±0.00	13.62±1.99	1.64±0.24	1.13±0.31	1.40^{b}±0.18	2.20±0.01
P3	2.43±0.71	60.61±8.68	22.63±6.51	0.49±0.25	8.48±1.54	1.50±0.45	0.66±0.20	0.95^{b}±0.24	2.20±0.00
P4	1.39±0.11	54.93±11.74	21.23±7.52	0.15±0.15	13.62±3.08	2.53±0.99	2.16±1.15	1.75^{ab} ±0.13	2.20±0.01

Data expressed as mean ± SE; Different superscripts in the same column denote statistical significance (p≤0.0)

Table 5. Economics (per crop) of pen aquaculture demonstrations conducted in selected beels of Assam

Operation	P1	P2	P3	P4	Overall
Fixed costs (₹)					
Depreciation on fixed assets	15,295	20,452	23,335	12,848	19,336
Repair/maintenance cost	3,500	2,911	2,417	2,375	2,724
Rental value of land	3,325	1,762	5,523	1,733	2,980
Interest on fixed assets	1,973	2,453	2,704	1,598	2,316
Labour cost for pen construction per year	15,500	14,459	12,445	15,475	14,176
Total fixed cost per year	39,593	42,038	46,423	34,030	41,533
Total fixed cost per crop (A)	13,198 (26.65)	14,013 (27.51)	15,474 (17.74)	11,343 (21.56)	13,955 (22.51)
Variable costs (₹)					
Liming	467	762	1,412	591	887
Fish seed	21,000	23,000	47,025	24,500	29,960
Feed	7,050	5,926	14,017	7,756	8,693
Medication	0	0	440	50	135
Macrophyte control	458	595	878	950	730
Control of unwanted organisms	458	361	444	742	467
Labour	5,250	4,958	5,359	5,052	5,118
Harvesting, marketing and others	831	506	583	713	598
Interest on working capital	799	812	1,579	908	1,048
Total variable cost (B)	36,314 (73.34)	36,920 (72.48)	71,737 (82.25)	41,263 (78.43)	47,637 (77.48)
Total cost (A+B)	49,511	50,933	87,211	52,606	61,481
Total cost per m^2 (₹)	20.45	18.39	22.68	11.04	17.75
Total production (kg)	885.94	875.08	1,356.73	1,104.62	1,064
Production (kg ha^{-1})	3659.17	3160.40	3528.78	2317.37	3072.01
Average price of fish (₹)	170	145.55	146.67	132.50	145.71
Gross income (₹)	1,50,609	1,27,374	1,98,988	1,46,362	1,55,062
Net income	1,01,098	76,440	1,11,777	93,742	93,562
B C ratio	3.04	2.5	2.28	2.78	2.52
Return on investment	204.19	150.08	128.17	178.15	152.13

Similar findings were also reported from Haribhanga beel (Chandra, 2010) and Dek beel (Gorai *et al.*, 2006b) of Assam and Jandaha beel of Bihar (Patial and Hassan, 2013).

The total cost per m^2 per crop was calculated for the overall average pen size (*i.e.,* 3463.52 m^2) as ₹17.75/-. The highest cost was incurred (₹22.68 m^{-2}) for P3 followed by P1 (₹20.45 m^{-2}) and P2 (₹18.39 m^{-2}) while the lowest was for P4 (₹11.04 m^{-2}). Though the pen size category P4 (*i.e.* pens having area between 4500-4999 m^2) was the largest, the total cost was lower than that incurred in P3, because some of the components of fixed (bamboo and LDPE netting) and recurring costs (fish seed, fish feed and lime) were lower in the former as compared to the latter.

Economics of pen aquaculture

The economic analysis of the pen aquaculture demonstrations is presented in Table 5. Data on the fish husbandry practices followed in the pens was collected that was vital for calculating various economic parameters. The pens were stocked with different sizes of fish seed (fry, fingerlings and stunted yearlings) that ranged from 30-127 mm in length. The stocking density ranged from 2.98-4.49 nos. m^{-2}. Size of the fish at the time of stocking ranged from 50-85 mm which were cultured for a period of 3 months. The survival rate of the fish ranged between 72.77 and 87.5% and the harvest weight varied from 95.55-135 g.

Production rate from the pen size category P1 was the highest (3659.17 kg ha^{-1} $crop^{-1}$), followed by P3 (3528.78 kg ha^{-1} $crop^{-1}$), P2 (3160.40 kg ha^{-1} $crop^{-1}$) and P4 (2317.37 kg ha^{-1} $crop^{-1}$). Higher production per hectare was recorded in the present study compared to that reported in earlier studies. It is perceived to be an outcome of size of fish stocked in the pens. The levels of production reported in earlier studies where size of fish seed was 4.8-5.4 cm were, 1797; 1870 and 2659 kg ha^{-1} in the pen sizes of 0.9, 0.12 and 0.12 ha, respectively (Gorai *et al*., 2006b) and 1858, 1795 and 1390 kg ha^{-1} in the pen sizes of 2250; 2875 and 2000 m^2, respectively (Katiha *et al*., 2005).

Pen aquaculture demonstrations in the present study registered a positive benefit cost ratio (BCR) of 2.28 to 3.04

and return on investment of 128.17 to 204.19% indicating the economic viability of the technology. The highest BCR (3.04) was observed in the smallest pen size (P1). This could be attributed to lower total cost of culture (₹49,511/-) and also to proper management of the stock compared to all other pen size categories. The second highest BCR (2.78) was obtained in the largest pen size (P4) indicating higher return on investment. The return on investment was found to be highest in the smallest pen size, followed by that of P4, P2 and lowest in P3 . Earlier studies reported benefit-cost ratios of 1.13-3.01, with an average of 1.90 for one crop (Gorai *et al*., 2006b), 1.89 in 2002, 2.01 in 2003, 2.15 in 2005 (Chandra, 2010) and 1.35-1.94 with an average of 1.74 for one crop (Katiha *et al*., 2005). In a recent study, we demonstrated that rearing of carried over carp seed in a pen of 741 m^2 installed in Damal beel of Assam yielded a BCR of 1.8 (Bhattacharjya *et al.,* 2015a). In the present study, we observed an overall BCR of 2.52, which is far higher than the values reported in the past.

The economic analysis of pen aquaculture in different pen size categories suggested that the pen size of <2500 m^2 was the most economically viable size of pen offering the highest BCR. However, all other pen size categories also showed high BCR ranging from 2.28 to 3.04. The results suggested that the pen sizes of <2500 m^2 (P1) and 4500-4999 m^2 (P4) were better for pen aquaculture considering the benefit-cost ratios compared to other two pen size categories *i.e.,* P2 (2500-3499 m^2) and P3 (3500-4499 m^2). The overall results suggested that pen aquaculture in floodplain wetlands (beels) of Assam was an economically feasible enterprise that can be adopted by the beel lessees as well as fishers.

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