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Impact of pen-culture technology on fish productivity of floodplain wetlands in Asom

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ABSTRACT

An impact study was carried out to know the extent of productivity increase after the adoption of pen culture technology for *in situ* seed production in four wetlands located in three districts of Asom. An impact pathway was designed to study the impact of technology intervention on the production and productivity of floodplain wetlands. Annual fish production of the wetlands increased significantly after the adoption of pen culture technology for stocking of fingerlings raised *in situ*. Fish productivity increased from 300, 417, 425, and 125 kg $ha^{-1}yr^{-1}$ to 1050, 1030, 850 and 415 kg $ha^{-1}yr^{-1}$ in Haribhanga, Damal, Raumari and Puthimari wetlands, respectively. The benefit cost ratio of fish production in wetland ranged between 2.85 and 3.94 for the selected wetlands. The weighted average compound annual growth rate of studied wetlands for the period from 2002–03 and 2007–08 was 25.39%. The direct impact of adoption of pen culture technology increased fish production and productivity of the selected wetlands of Asom, under participatory management.

Key words: Fixed cost, Impact pathway, Pen culture, Productivity, Technology, Variable cost, Wetlands

Floodplain wetlands, defined as low-lying areas bordering large rivers, which are seasonally inundated by the spill-over from the main river channel, are important fishery resources and contribute significantly to the inland fish production. The state of Asom is endowed with floodplain wetlands, extending over an area of nearly 1.08 lakh ha. These wetlands (locally known as beels), are the prime fishery resources in Asom, with high production potential (Dey 1981, Choudhury 1998, Sugunan and Bhattacharjya 2000, Chandra 2010, Chandra and Sharma 2011), providing livelihood support to a large section of the population next only to agriculture. The wetlands are distributed over the valleys of Brahmaputra (about 92000 ha) in the northern and central Asom and Barak valley (about 8000 ha) in southern Asom. The average productivity of floodplain wetlands of Asom is only 173 kg $ha^{-1}yr^{-1}$, against the productivity potential of 1000 to 1500 kg $ha^{-1}yr^{-1}$ as estimated by CIFRI (Sugunan and Bhattacharjya 2000). Adoption of culture-based fisheries in reservoirs and wetlands is the most important tool for increasing fish production, in developing countries in Asia and South America from reservoirs and wetlands (Thayaparan 1982, Lorenzen, *et al.* 1998, Welcomme and Bartley 1998, DeSilva 2003, Sugunan and Katiha 2004). Culture-based fisheries is less resource intensive and therefore more attractive (DeSilva 2003, Felsing *et al.* 2003). The floodplain wetlands in Asom are best suited for culture-based fishery development. They are productive in nature, rich in organic carbon and nutrients like available nitrogen and phosphorus besides having favourable thermal and oxygen regimes (Sugunan 1997).

The lower fish productivity in wetlands is mainly due to lack of stocking of fish seed of proper size (100–150 mm) and species at the right time. To tide over this situation, rearing of *in-situ* seed in pens could be a viable alternative. Pen culture technology developed by CIFRI has been found to be an effective tool for producing quality seed of right size critical for optimum survival and growth of fish in open waters. The stocking of *in situ* raised fingerlings of Indian major carps in pens can greatly help in bridging the gap between present and potential productivity of fish in wetlands. The fingerlings raised in pens have shown higher rate of survivability, better growth and are also found to be fairly resistant to diseases, being raised within the same ecological condition and having been already acclimatized (Gireesha *et al*. 2003). The present study involves an in-depth analysis of not only the pen culture operation but also total floodplain wetland fisheries management in its ambit to assess impact of stock enhancement measures with good management practice on the production and productivity increase in the floodplain wetlands. The objectives of the present study were to assess the (i) benefit cost analysis of

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pen culture technology adoption in floodplain wetlands, (ii) impact of pen culture on the productivity of the floodplain wetlands and (iii) to work out the economics of floodplain wetland fisheries management.

MATERIALS AND METHODS

Study area

For the present study, four floodplain wetlands viz. Haribhanga, Raumari, Puthimari and Damal in Brahmaputra valley of central Asom were selected (Fig. 1). These floodplain wetlands are perennial in nature and are managed by the lease holders (mostly fishermen). The property and water regimes of the selected wetlands under study are mentioned in table 1. The ownership of the floodplain wetlands was with Asom Fisheries Development Corporation (AFDC). The fishing right of the floodplain wetlands were leased out to the members of fisheries community or a fishermen cooperative society under the Asom Fisheries Act, 1953 after competitive bidding for a stipulated period of time (not less than five years) by the government. CIFRI also made demonstration of pen culture technology for seed production in Haribhanga and Raumari wetlands.

Fig. 1. location map of wetlands

Pen is an enclosure of any size shape and design and can be made of any suitable material. Pen culture of fishes involves holding fishes in an enclosure under human management for short or long duration. Pen is generally stationary having fixed walls. In pen culture, an area is enclosed with some effectively permeable barricade (nylon net, split bamboo screen etc.) wherein fishes are reared for fingerlings or table fish production.

Impact pathway: This impact study focused on prospective assessment, structured in terms of an analysis of pathways to research impact. This initiative is a relatively novel one in agricultural research, as impact assessment has mainly been conducted retrospectively or ex post (Evenson and Gollin 2003, Adato and Meinzen-Dick 2003). Impact pathway analysis is particularly useful in view of the new perspective on impact, which conceptualizes technical change in agriculture as a complex process involving feedback loops, and interactions between social, cultural and biophysical systems. This contrasts with the traditional characterization of agricultural research as involving a linear chain from output to impact, with minimal engagement between remote parts of the chain, i.e. researchers and final beneficiaries (Douthwaite *et al.* 2003, Springer-Heinz *et al.* 2003). It requires to define the changes at each stage, describing the linking processes, and to identify indicator to measure both content and process.

A new impact pathway was designed for studying the impact of technology intervention i.e. stock enhancement through pen culture on the production and productivity of the natural resources like floodplain wetland.

Table 1. Property and water regimes of selected floodplain wetlands under study

Floodplain wetland (location)	Avg. size (ha)	Owners	Lease rent per year (₹) (Per hectare value)	Period (Year)	Fishing regime	Water regime	Type of wetland
Haribhanga 26o31'15"N, 92o48'33"E	125	AFDC	5,75,000 (4,600)	7	Private	Perennial	Closed
Raumari 26o25'04"N, 92o42'59"E	25	AFDC	66,000 (2,640)	7	Private	Perennial	Open
Damal 26o12'61.9"N, 92o20'60"E	20	AFDC	51,000 (2,550)	7	Private	Perennial	Closed
Puthimari 26o30'35"N, 90o53'14.02"	60	AFDC	54,000 (900)	5	Private	Perennial	Closed

Impact flow diagram	Determinants
Stock enhancement through Pen enclosure:	Species ratio, stocking density, growth and economics of pen culture
↓	
Floodplain Wetland Productivity:	Fish production, productivity of floodplain wetland, annual trend of production, compound annual growth rate
↓	
Floodplain Wetland Economics:	Net return, wealth generation, price

Data collection and analysis

The present impact study was conducted during the year 2006-08. Detailed field visits were conducted and data were collected using structured questionnaire and focused discussion with the lessee. The data were analyzed using various parameters given in the above Impact pathways. The compound annual growth rate (CAGR) was calculated using the following formula:

$$\text{CAGR}\,(t_0, t_n) = \left\{ \left(\frac{V(t_n)}{V(t_0)} \right)^{\frac{1}{t_n - t_0}} \right\} - 1$$

Where $V(t_0)$, start value, productivity in the starting year 2002-03; $V(t_n)$, finish value, productivity in the year 2006-07; $t_n - t_0$, number of years.

RESULTS AND DISCUSSION

Species composition: The species selection varied from one wetland to another. This was because of raising fast growing and high priced exotic carp along with Indian major carp and minor carp. The species compositions of all the four floodplain wetlands were as follows:

Haribhanga : R:C:M:GC:SC:CC
Raumari : R:C:M:GO:CC
Damal : R:C:GC:SC:CC
Puthimari : R:C:M:GC:SC:B

(R: *Labeo rohita*, C: *Catla catla*, M: *Cirrhinus mrigala*, CC: *Cyprinus carpio*, GC: *Ctenopharyngodon idella*, B: *Labeo bata*, GO: *Labeo gonius*, SC: *Hypothalmichthys molitrix*)

The harvested fingerlings were used for further stocking of the floodplain wetlands.

Pen culture

Haribhanga wetland: One pen of 5 000 m^2 was constructed at Haribhanga wetland. Three to five cm size of carry-over seeds of three Indian major carps and three exotic carps viz grass carp, silver carp and common carp raised in hatcheries were released in pen. The growth of exotic carps was faster than the three major carps. Moreover the survival rate of the fingerlings was ninety % in floodplain wetland condition (Table 2).

Raumari wetland: In Raumari, one pen of 2 000 m^2 size was constructed in 2004-05 and four to six cm size of carryover seed (fry) of carps purchased from the local hatcheries in Nagaon was stocked. The results revealed that the growth of catla and common carp species were better than other species (Table 3).

Damal wetland: The lessee used only net screen to construct the pen thereby reducing the cost of bamboo screens. The species composition was rohu, catla, grass carp, silver carp and common carp. The species ratio was

Table 2. Fish species stocked and harvested in pen culture in Haribhanga beel

Fish Species	Number stocked	Stocking length (cm)	Stocking weight (g)	Number harvested	Harvested length (cm)	Harvested weight (g)	Production (kg)
Rohu	10000	5	5	9000	13	50	450
Catla	2000	5	5	1800	14	100	180
Mrigal	2000	5	5	1800	13	50	90
G. carp	2000	8	7	1800	21	200	360
S. carp	10000	8	7	9000	17	100	900
C. carp	10000	8	7	9000	20	200	1800

Table 3. Fish species stocked and harvested in pen culture in Raumari beel

Fish Species	Number stocked	Stocking length (cm)	Stocking weight (g)	Number harvested	Harvested length (cm)	Harvested weight (g)	Production (kg)
Rohu	10000	4	5	8900	13	50	445
Catla	10000	4	5	9000	15	100	900
Mrigal	5000	4	5	4000	14	50	200
C. carp	1500	6	7	1350	19	150	202
L. gonius	5000	6	7	4350	15	50	435

Table 4. Fish species stocked and harvested in pen culture in Damal beel

Fish Species	Number stocked	Stocking length (cm)	Stocking weight (g)	Number harvested	Harvested length (cm)	Harvested weight (g)	Production (kg)
Rohu	12000	5	5	10700	17	50	535
Catla	4000	5	5	3700	18	100	370
G. carp	4000	8	7	3500	25	200	700
S. carp	10000	8	7	9000	25	100	900
C. carp	12000	8	7	10800	28	300	3240

Table 5. Fish species stocked and harvested in pen culture in Puthimari beel

Fish Species	Number stocked	Stocking length (cm)	Stocking weight (g)	Number harvested	Harvested length (cm)	Harvested weight (g)	Production (kg)
R							
Rohu	10000	3	4	8300	12	40	332
Catla	6000	3	4	5100	14	60	306
Mrigal	4000	3	4	3500	12	40	140
G. carp	4000	5	6	3500	22	200	700
S. carp	5000	5	6	4300	20	100	430
L. bata	6000	4	4	4800	13	40	192

approximately 30:10:10:20:30. The growth of exotic carp was better than Indian major carp (Table 4).

Puthimari beel: The species composition was rohu, catla, mrigal, grass carp, silver carp and bata, three to six cm size of carryover seed was stocked. The results revealed that the growth of catla and common carp species were better than other species (Table 5).

Economics of Pen culture: Four seed crops were grown in two-year life span of pen enclosure. The average cost of pen per crop estimated approximately 31 % of total expenditure, whereas mean variable cost calculated to around sixty nine %. Approximately 40 % of the cost of pen culture was accounted for by seed. In all the floodplain wetlands, the benefit cost ratio of pen culture was in the range of 1.78 to 2.23. The benefit cost ratio shows that adoption of pen culture can give a benefit equal to double the expenditure (Table 6).

Table 6. Economics of pen culture in wetlands of Asom

Items	Haribhanga	Raumari	Damal	Puthimari
Total cost of pen construction (₹)	41520	24500	28000	24000
Cost of pen/crop (₹)	10380 (25.08)	6125 (38.68)	7000 (19.50)	6000 (35.86)
Variable cost (₹)	31000 (74.92)	9710 (61.32)	28900 (80.50)	10730 (64.14)
Total cost of pen culture (₹)	41380 (100)	15835 (100)	35900 (100)	16730 (100)
Return (₹)	89100	30500	80000	31580
Profit (₹)	47720	14665	44100	14850
B:C ratio	2.15	1.93	2.23	1.89

Figures in parentheses are values in terms of %age

Fish production of floodplain wetlands: The production of the selected wetlands increased sharply after adoption of stock enhancement measures. The highest production of 1, 31,250 kg was achieved in Haribhanga wetland, followed by 24900 kg in Puthimari wetland. The production per kg per hectare increased sharply in all of these floodplain wetlands. The highest productivity has been achieved in Haribhanga wetland, followed by Damal, Raumari, and Puthimari. Productivity from selected wetlands were 1050, 1030, 850 and 415 kg $ha^{-1}yr^{-1}$ for Haribhanga, Damal, Raumari and Puthimari respectively (Fig. 2). Mean weighted average productivity of these four wetlands was 861.11 kg ha^{-1} yr^{-1}.

Annual trends in production and productivity: Time series data from 2002-03 revealed that the production and productivity of the wetlands increased sharply within a period

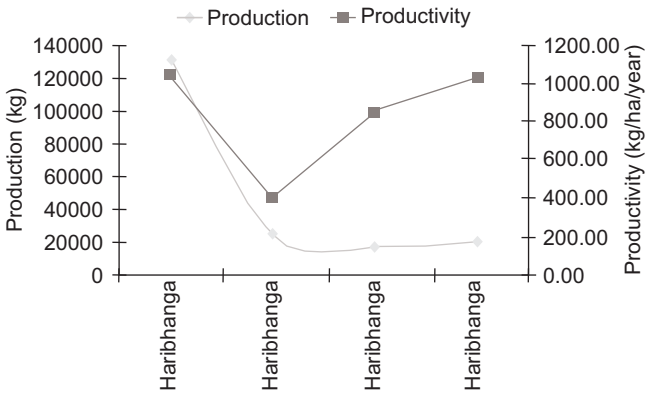

Fig. 2. Fish Production and Productivity of Selected Wetlands

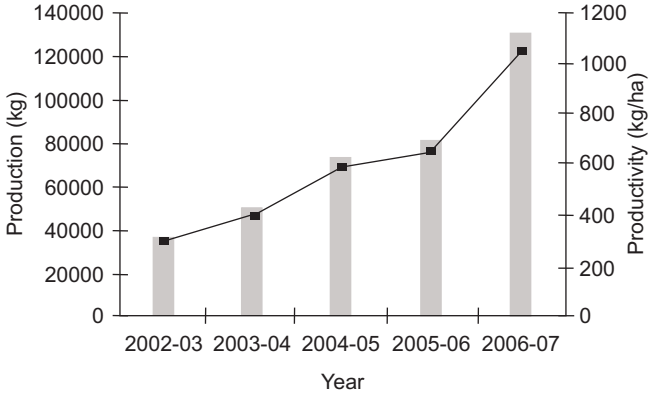

Fig. 3. Annual trend of production and productivity in Haribhanga wetland

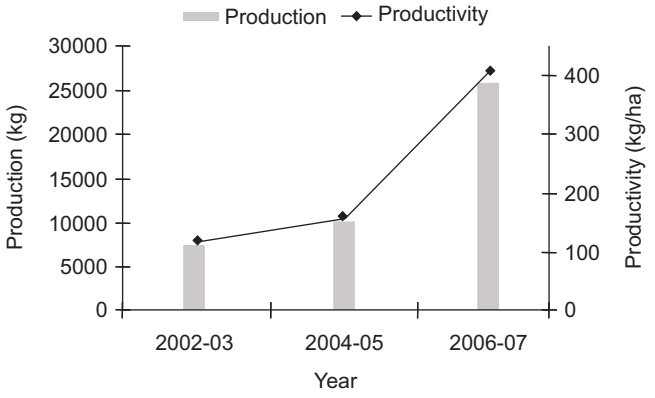

Fig. 4. Annual trend of production and productivity in Puthimari wetland

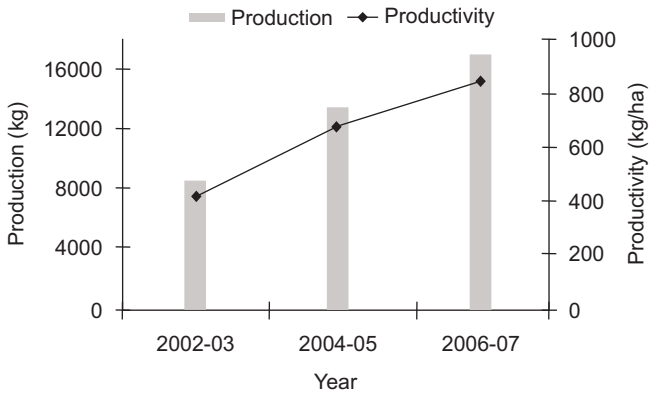

Fig. 5. Annual trend of production and productivity in Raumari wetland

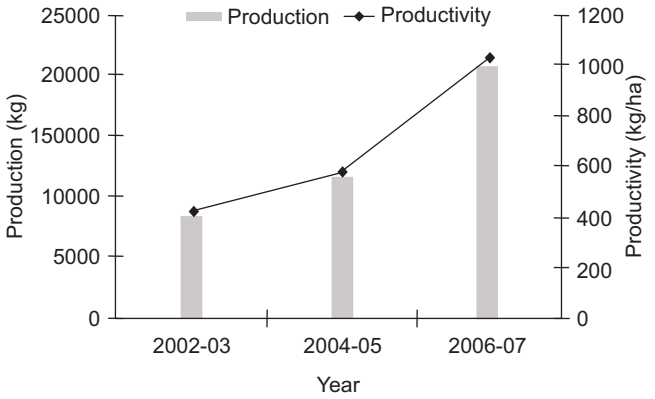

Fig. 6. Annual trend of production and productivity in Damal wetland

of three to five years. With the adoption of stock enhancement practices through pen culture, the productivity showed a considerable shift and consequently production increased. Annual trend revealed that the productivity of Haribhanga and Puthimari wetland just trebled in these five years (Figs 3, 4). In 2002-03 it was 300 kg ha^{-1} yr^{-1} which increased to 1 050 kg ha^{-1} yr^{-1} in 2006-07 in Haribhanga wetland. In Raumari and Damal wetland, the production got doubled in four years (Figs 5, 6).

The present study shows that pen culture has given appreciable increase in the fish production of floodplain wetlands, after stocking of fingerlings of 100-150 mm size. Earlier studies have also revealed that the realization of production potential from floodplain wetlands was dependent on stocking of fish seed (advance fingerlings of 100-150 mm) for achieving higher survival in wetland situation and growth in production (Natrajan 1976, Selvaraj *et al*. 1990, Murugeshan *et al.* 2005). Ayyappan and Venkateswarlu (2002) also emphasised that the pen-culture, especially for raising stocking materials, offers a great scope for the effective utilization of the available floodplain wetland resources for fisheries enhancement; leading to significant improvement in the socioeconomic status of fishers. Seed production in pens reduces the cost of production of advance fingerlings than the conventional system of hatchery or nursery pond.

In the north eastern region in particular rearing of fingerlings for effective stocking from land nursery and their transport to respective sites have not been found economically viable. Raising of required quantity of stocking materials of 100-150 mm size within the same system by installing pens a viable option to address the cause of rational stocking in floodplain wetlands so as to convert them into culture based systems for better economic returns (Gorai et al. 2006).

Although there is increasing trend in total production and productivity after stocking of advanced fingerlings raised in pens (mean productivity 861 kg/ha), individual differences do exist (415kg/ha to 1050 kg/ha). The maximum productivity was found in Haribhanga (1050 kg/ha), followed by Damal (1030 kg/ha), Raumari (850 kg/ha) and lowest in Puthimari (415 kg/ha). The low fish productivity in Puthimari beel can be attributed to low alkalinity (18-23mg/l), phosphate (<0.01mg/l) and nitrate (0.005 to 0.06 mg/l) levels (CIFRI 2008).

Compound annual growth rate: This technique is used frequently in financial management lexicon for the

calculation of growth over a period of time. Compound annual growth rate implies fish productivity over a period of time. The present study was used to understand the productivity changes of the selected wetlands during post adoption of pen culture technology. The results indicated highest CAGR in Puthimari wetland (34.98 %), followed by Haribhanga (28.43 %), Damal (25.36 %) and Raumari (18.92 %). The mean CAGR was calculated as 25.39 %.

Economics of floodplain wetland fisheries management: The total capital expenditure incurred by the fisher and the income received after selling of their catch is the inbuilt component of economics of floodplain wetland fisheries management. The fixed cost includes the lease amount paid to the government whereas the variable cost includes the expenditure incurred in fishing operation, cost of weed clearance, seed cost and other practices. Better managed small wetlands like Raumari showed high B: C ratio of 3.98. The increase in production of Puthimari wetland in 2006-07 after stock enhancement as indicated in annual trend has led to increase of B: C ratio to 3.64. One of the noteworthy achievements was seen in Haribhanga wetland despite its large size, the fishers had achieved benefit cost ratio of 3.23. The mean fixed cost of the four floodplain wetlands was approximately 21% of the total cost (Table 7).

The average farm gate price of different fish species were in the range of ₹ 25-30/kg for small indigenous fishes, ₹ 40-45 for Silver carp, ₹ 50-55/kg for other exotic carps, ₹ 60-70/kg for rohu, catla and mrigal, and ₹ 100-200/kg for catfishes like *Wallago attu*, *Chitla chitla*, etc. for the year of study (2006-07). The price of these fishes almost doubled around thirteenth January every year due to the Bhogali Bihu festival. Almost one harvest was done on this time every year for ripping higher profit.

Table 7. Economics of wetland fisheries management

Items	Haribhanga	Raumari	Damal	Puthimari
Lease amount (₹)	575000	66000	51000	54000
	(23.96)	(26.29)	(14.08)	(19.71)
weed clearance (₹)	280000	15000	61214	35000
	(11.67)	(5.98)	(16.09)	(12.77)
Fishing operation	700000	100000	178572	100000
including Katal (₹)	(29.17)	(39.84)	(49.3)	(36.50)
Seed (₹)	400000	45000	40822	40000
	(16.67)	(17.93)	(11.27)	(14.60)
Other (₹)	425000	15000	25500	30000
	(17.71)	(5.98)	(7.04)	(10.95)
Transportation (₹)	20000	10000	3658	15000
	(0.83)	(3.98)	(1.01)	(5.47)
Total recurring (₹)	1825000	185000	311216	220000
	(76.04)	(73.71)	(85.92)	(80.29)
Total cost of Beel	2400000	251000	362216	274000
management (₹)	(100)	(100)	(100)	(100)
Fish production (kg)	131250	17000	20600	24900
Return (₹)	7750000	935000	1030000	996000
Profit (₹)	5350000	684000	667784	722000
B: C ratio	3.23	3.73	2.84	3.64

Figures in parentheses are values in terms of percentage.

The present study proves that floodplain wetlands in Asom offer immense scope for increasing fish production, besides generating additional employment and income to the fishers. For stock enhancement of desirable fish species of 100- 150 mm size, advance fingerling remains the single most important management tool towards this end. The transformation of the four wetlands under study from low productive to high productive one has been achieved through adoption of pen culture technology and also due to the risk bearing capacity of the fishers.

The direct impact of adoption of pen culture technology was visible in increaseing fish production and productivity of these wetlands of Asom, which directly helped in raising the income of the fisher's household and livelihood security. The indirect impact of adoption of the technology could be seen in the increase of total fish productivity from the wetlands and increase in the per capita fish availability of the state. The increase in production will also contribute to the income of state because the lease rent of these wetlands would automatically increase after the expiry of present lease of seven years. Lease rent in Asom is fixed on the basis of the total production of the wetland one year prior to the expiry.

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