Integration of pen aquaculture in ecosystem-based enhancement of small-scale fisheries in a macrophyte dominated floodplain wetland of India

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Keywords: Wetland, pen aquaculture, macrophyte management, grass carp, small-scale fisheries

Posted Date: March 7th, 2022

DOI: <https://doi.org/10.21203/rs.3.rs-1329220/v1>

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Abstract

The rapid degradation, overexploitation and encroachment of floodplain wetlands have led to considerable decline in fish diversity and production from these invaluable aquatic resources threatening livelihood of the dependent fishers. The climate change evident in the fast few decades have further aggravated the problem of eutrophication causing water stress, sedimentation leading to rampant macrophyte proliferation affecting ecological and economic functioning of these ecosystems. Macrophyte control and management needs serious attention for sustaining ecosystem services provided by these resources. In this direction pen culture of grass carp, *Ctenopharyngodon idella* as a biocontrol for macrophytes along with Indian major carps was implemented in a co-management mode in Beledanga, a typical floodplain wetland, a gradually shrinking, macrophyte dominated floodplain wetland in lower Ganga basin. Indian major carps *Labeo catla* ($6.28 \pm 0.23\text{g}$), *Labeo rohita* ($5.1 \pm 0.12\text{g}$), *Cirrhinus mrigala* ($3.5 \pm 0.08\text{g}$) were stocked in the ratio 4:3:3 at the rate of 20 no./m² in pens (0.1ha each) in triplicate. Grass carp ($7.1 \pm 0.42\text{g}$) was stocked in pen at the rate of 20 no./m². The fishes were fed with pelleted feed twice a day at the rate of 2-3% of body weight per day. The seed was overwintered in pens for a period of 90 days from November 2019-January 2020. Average weight recorded at the end of culture period was $25.13 \pm 1.70\text{g}$, $18.11 \pm 0.63\text{g}$, $14.53 \pm 0.87\text{g}$ and $39.20 \pm 1.90\text{g}$ in *L. catla*, *L. rohita*, *C. mrigala* and *C. idella* respectively. The survival of fish ranged from 70 to 81%. Growth performance and feed utilization efficiency of grass carp was significantly higher ($p < 0.05$) compared to other carp species. The pen culture was found to be economically viable with a benefit cost ratio of 1.53. The fishes produced were released back into the open wetland as an input for culture based fisheries. The intervention led to 24% increase in the fish production from the wetland with grass carp contributing 20-22% of the total catch with 32% increase in revenue generated by the sale of fish with in a short span of one year. The study successfully demonstrated technological suitability and economic feasibility of pen culture in this wetland and role of grass carp as a potential biocontrol species for macrophyte management. Grass carp stocked grew to 0.8 to 1kg within 6 month and 2-2.3kg within a year and could utilise 40-45% of the submerged and emergent macrophytes. Integration and optimization of grass carp will not only aid in habitat management of macrophyte-choked wetlands but will also boost their small-scale fisheries by converting standing macrophyte biomass into protein rich fish biomass. The enhanced production will also cater to nutritional and livelihood security of the dependent fishers.

Introduction

India has vast floodplain wetland resources (0.5 million ha) distributed mainly in the Eastern and North Eastern States. These resources provide multiple goods and ecological services to resource poor fishers (MEA, 2005) besides providing habitat for fishes (Jude and Pappas 1992; Trebitz and Hoffman 2015) maintaining water quality (Sierszen et al. 2012) and acting as a carbon sink (Nag et al. 2019). They are one of the most productive fisheries resources having production potential of 1500-2000kg/ha/year (Sarkar et al. 2016). They harbor rich fish diversity (96 fish species) and are important spawning and

nursery ground to many commercially important riverine fish species and contribute significantly to the nutritional as well as livelihood security of the rural mass (Sarkar et al. 2021a).

In recent years, the fish production and diversity from wetlands has rapidly declined owing to anthropogenic and other environmental challenges (Sarkar and Borah 2018; Sarkar et al. 2020b) threatening livelihood of the dependent fishers (Sarkar et al. 2021a). The climatic variability and uncertainties have further aggravated the threats affecting fisheries production and profitability (Belhabib et al. 2016; Mabe and Asase 2020). Rapid degradation and shrinkage of wetland resources in the past few decades has led aquatic weed infestation. Aquatic macrophyte infestation in Indian floodplain wetlands is posing serious challenges to their ecological and economic functioning, necessitating serious attention for their control and management for sustaining ecosystem services provided by these resources (Sarkar et al. 2021b).

Grass carp (*Ctenopharyngodon idella*) is a large, herbivorous fish native to eastern Asia (Froese and Pauly 2005). It is the most produced freshwater species globally, providing inexpensive and high-quality animal protein for consumers (Tian et al. 2020). Grass carp has been widely introduced throughout the world for aquatic weed control (Pipalova 2006). In natural systems, they feed almost exclusively on macrophytes from one month of age (Cudmore and Mandrak 2004). Daily macrophyte consumption can be as high as 100% of body weight per day (van der Lee et al. 2017). About 65% of the weeds are digested and rest released as dense pellets that act as “green manure” for the water body (Thomas 2007). Grass carp has been effectively used as biocontrol agent of aquatic weed species such as *Potamogeton* sp, *Myriophyllum* sp and *Hydrilla* sp (Cooke et al. 2005). In most instances, young grass carp are introduced (Hanlon et al. 2000) and are effective in eradication even in relatively low densities of 50 juvenile carp/ha (van Dyke et al. 1984). The benefits of using grass carp as biocontrol include its ability to control a wide variety of submersed and floating vegetation, longevity of the method owing to constant feeding activity for long duration, low investments and additional income from conversion of weed biomass to protein food in form of fish (Kirkagac and Demir 2004). In India though several studies explore carp based composite fish culture in ponds and tanks, however its importance and efficacy in wetland fisheries and enclosures have not been explored systematically.

Beledanga wetland is an oxbow lake located in lower Gangetic basin of North 24 Parganas district in West Bengal. Fisheries of the wetland is governed by a locally managed Fishermen Co-Operative Society (FCS). The fishing activities are the main source of income for 176 families. The area of the wetland has significantly decreased from 161.40acre (65.15ha) in 1980 to 113.67 (46.0ha) in 2020 over the last two decade owing to encroachment, water stress, macrophyte infestation and sedimentation aggravated by the climate change scenario in the State. The shrinkage of area, habitat modification and closure of link channel owing to reduced flows and sedimentation has significantly affected fish diversity and production from the wetland. To sustain livelihood of the fishers, FCS is practicing culture-based fisheries with Indian and exotic carps.

Pen culture is an effective climate resilient adaptation strategy and an ideal technology for insitu seed raising for culture based fisheries (CBF) as well as table fish production in floodplain wetlands of India (Das et al. 2017a,b; Sarkar et al. 2021a; Paul et al. 2019, 2020). The strategic plan for inland fisheries development emphasizes on sustainable enhancement through implementation of region specific technologies in India (Das et al. 2021). The insitu raising of seed can address the issues of absence of rearing facilities near open water bodies and mortality in transporting bigger size fingerlings required for CBF. Insitu rearing of seed in pens and simultaneous release in wetlands lead to better survival (Roy and Hassan 2013). In this backdrop pen culture of grass carp along with Indian Major Carps (IMCs) was undertaken in the Beledanga wetland in participatory mode with the FCS. The aim of the study was to demonstrate efficacy of the pen culture in the wetland for raising advanced fingerlings of carps as stocking material for CBF and to integrate grass carp as important component of CBF as effective biocontrol for macrophyte management and enhanced fish production through biological conversion of macrophyte to protein food.

Material And Methods

Study area

The pen culture was demonstrated in a seasonally open wetland Beledanga, a cut off meander of River Ichamati situated in North 24 Parganas district of West Bengal. The GIS map was prepared using Arc GIS-10.2.1 for land use patterns taking images from Google Earth. The effective water area of the wetland is 46 ha (Fig. 1). The fish stocking, production and revenue data was procured from records maintained by Beledanga FCS.

Pen culture

In the present study, HDPE knotless webbing net (3mm mesh size) was used for constructing pen wall. Polypropylene ropes of 6 mm diameter were used for holding the net walls in shape supported by 10 feet long round strong and rigid FRP poles with perforations at regular intervals for tying with net wall. No bamboo was used in the pen structure and construction for increased longevity of the structure in water. The pen was installed in marginal area of the wetland where minimum water depth was 1m. The size of each pen unit was 0.1 ha. Indian major carps *Labeo catla*, *L. rohita* and *Cirrhinus mrigala* of initial size 6.28 ± 0.23 g, 5.1 ± 0.12 g and 3.5 ± 0.08 g respectively were stocked at the ratio of 4:3:3 at the rate of 20 no./m² each in pens in triplicate. Grass carp of initial size 7.1 ± 0.42 g were stocked at the rate of 20 no./m² in duplicate. The fishes were fed with pelleted feed (crude protein 28%, fat 5%) twice a day at the rate of 2-3% of body weight per day. The seed was overwintered in pen culture duration was 90 days from November 2019-January 2020. After 90 days the advanced fingerlings produced were released in the wetland proper

The cost of pen, feed, seed and advanced fingerlings produced in the pens were estimated and benefit cost ratio (BC ratio) were used to estimate the economic viability of the pen culture.

B: C ratio = [Total benefits / Total cost]

Growth parameters

Survival rate in each pen was calculated as:

Survival (%) = [Total number of fingerlings harvested/ Total number of fingerlings stocked] x 100

Weight gain, specific growth rate (SGR), feed conversion ratio (FCR), feed conversion efficiency (FCE) and protein efficiency ratio (PER) were estimated as:

Weight gain = [Final weight (g) – Initial weight (g)]

SGR (%/day) = [ln (Final weight) – ln (Initial weight)]/ Culture duration in days] x 100

ADG= [Wet weight gain (g)/Culture duration in days]

FCR= [Feed fed (dry weight)/ Wet weight gain]

FCE= [Wet weight gain/ Feed fed (dry weight)]

PER= [Net wet weight gain / Crude protein fed]

Since it was difficult to estimate the amount of feed consumed by different species in pens, the combined feeding efficiency (FCR, FER) were calculated for IMCs.

Environmental parameters

The climate data (air temperature and rainfall) for the study area (North 24 Parganas) was procured from Indian Meteorological Department (IMD). The water quality parameters were monitored monthly from pens, outside and 100m away from pen site (n=3) following the standard methods (APHA, 2012) to study impact of pen culture activities on wetland ecology.

Statistical analysis

All growth data were analysed in SPSS software (Version 14) for Windows. Average value pertaining to growth of a species in each pen was treated as independent treatment and mean±SE was estimated. The water quality data were analysed using one-way ANOVA. Significant differences between means of water quality parameters were evaluated using Duncan's multiple range test at 5% level of significance (p<0.05).

Results

The growth performance of the IMCs during the experimental period is presented in Table 1. Among IMCs *L. catla* showed maximum growth in terms of weight gain, average daily growth and specific growth rate followed by *L. rohita* and *C. mrigala*. The survival rate showed ranged from 70% in *C. mrigala* to 81% in *L. catla*. The overall survival rate for IMCs was 76.8% in the pens. The FCR, PER and FCE calculated based

on total feed given and total biomass achieved from each IMC culture pen were 2.76 ± 0.15 , 1.30 ± 0.06 , 0.37 ± 0.02 respectively. Among IMCs, the growth performance and survival rate of *L. catla* was significantly higher than *L. rohita* and *C. mrigala*. Grass carp *C. idella* attained average weight of 39.20 ± 1.90 during the 90-day culture period with survival rate of 78.3%. The feed utilization efficiency in terms of FCR, PER and FCE was 0.92 ± 0.02 , 3.50 ± 0.17 and 1.14 ± 0.03 respectively. The growth performance and feed utilization efficiency of grass carp in pens was significantly better than IMCs (Table 1).

Table 1
Growth performance of carps in Pens at Beledanga wetland

Species	<i>Labeo catla</i>	<i>Labeo rohita</i>	<i>Cirrhinus mrigala</i>	<i>Ctenopharyngodon idella</i>
Initial weight (g)	6.28 ± 0.23	5.1 ± 0.12	3.5 ± 0.08	7.1 ± 0.42
Final weight (g)	25.13 ± 1.70^b	18.11 ± 0.63^a	14.53 ± 0.87^a	39.20 ± 1.90^c
Weight gain (g)	18.85 ± 1.72^b	12.99 ± 0.65^a	10.97 ± 0.80^a	32.12 ± 1.68^c
Weight gain (%)	300.2 ± 27.1^a	253.8 ± 12.3^a	300.8 ± 24.5^a	451.9 ± 23.8^b
Survival (%)	81.77 ± 0.66^b	76.67 ± 2.02^{ab}	70.66 ± 2.92^a	78.33 ± 1.85^b
ADG	0.21 ± 0.01^b	0.14 ± 0.01^a	0.12 ± 0.01^a	0.35 ± 0.02^c
SGR	1.53 ± 0.07^a	1.40 ± 0.04^a	1.56 ± 0.06^a	1.90 ± 0.05^b
FCR	2.76 ± 0.15^b	2.76 ± 0.15^b	2.76 ± 0.15^b	0.92 ± 0.02^a
PER	1.30 ± 0.06^a	1.30 ± 0.06^a	1.30 ± 0.06^a	3.50 ± 0.17^b
FCE	0.37 ± 0.02^a	0.37 ± 0.02^a	0.37 ± 0.02^a	1.14 ± 0.03^b
Net Yield (kg)	164.03 ± 10.04^b	83.43 ± 4.45^a	61.73 ± 5.55^a	617.5 ± 13.10^c
Values are Mean $\pm$ SD, (n=3)				
Different superscript in same row signify statistical differences at 95% confidence interval ($p < 0.05$)				

A net yield of 309.2kg per pen (*L. catla*: 164.03 ± 10.04 kg; *L. rohita*: 83.43 ± 4.45 kg; *C. mrigala*: 61.73 ± 5.55 kg) was achieved from IMC pens while net yield per pen for grass carp was significantly higher (617.5 ± 13.10 kg). The economics have been worked out taking into account possibility of three crops (seed) per year. The BC ratio for the culture was estimated to be 1.53 indicating its profitability. Feed accounted for 55% of recurring and 51.7% of the total cost per crop. Feed and seed cost formed over 93% of the total cost per crop (Table 2).

Table 2
The water quality parameters during the seed raising

Parameters	IMC pens	Grass carp pens	Reference site	p-Value
Atmospheric temperature (°C)	25.23±4.20	25.23±4.12	25.43±4.05	0.988
Water temperature (°C)	22.17±4.05	22.40±3.90	22.33±4.11	0.997
pH	7.43±0.25	7.30±0.26	7.63±0.25	0.342
Dissolved oxygen (mgL ⁻¹)	7.13±0.30	7.06±0.20	7.53±0.31	0.163
Conductivity (µScm ⁻¹)	464.67±15.82	467.0±15.01	474.33±18.00	0.761
Total dissolved solids (mgL ⁻¹)	335.67±29.67	334.64±29.28	336.56±21.33	0.997
Free Ammonia (mgL ⁻¹)	0.004±0.001	0.004±0.001	0.002±0.001	0.567
Turbidity (NTU)	34.06±1.59	34.84±1.56	34.92±1.56	0.770
Total Hardness (mgL ⁻¹)	197.33±11.54	202.0±10.58	196.67±11.2	0.746
Alkalinity (mgL ⁻¹)	236.0±8.71	238.0±10.58	224.67±12.84	0.590
Total nitrogen (mgL ⁻¹)	0.042±0.003	0.045±0.002	0.041±0.001	0.996
Nitrate (mgL ⁻¹)	0.014±0.002	0.016±0.003	0.011±0.004	0.388
Phosphate-P (mgL ⁻¹)	0.131±0.034	0.146±0.025	0.127±0.031	0.730
Calcium (mgL ⁻¹)	32.86±1.38	32.22±0.78	33.80±1.85	0.079
Magnesium (mgL ⁻¹)	27.63±1.93	26.30±1.27	25.87±1.66	0.444
Sulfate (mgL ⁻¹)	0.33±0.03	0.32±0.04	0.30±0.05	0.786
Silicate-Si (mgL ⁻¹)	11.83±2.54	12.33±2.97	12.88±2.16	0.884
Chlorophyll-a (µgL ⁻¹)	17.63±1.47	18.63±1.37	20.31±1.86	0.191
Values are Mean ± SD, (n=3)				

The water quality parameters recorded from pen culture site and reference wetland site are presented in Table 3. In the present study, most of the environmental parameters were well within range suitable for carp culture. The water quality parameters studies did not vary significantly ($p>0.05$) between pen and reference sites. The dissolved oxygen, chlorophyll a and primary productivity levels in the pen culture sites were comparatively lower to reference site. The mean annual temperature in the study area (North 24 Parganas) shows increasing trend (Fig. 2) while mean annual precipitation shows decreasing trend (Fig. 3) in the last two decades. The land use pattern of the catchment of the Beledanga beel is presented

pictorially in Fig. 1 and percentage utilization is presented in Fig. 4. The land use is dominated by agriculture (52%), followed by natural vegetation (39%).

Table 3
Economics of pen culture for raising advanced fingerlings of Carps

Sl. No	Particulars	Amount (INR)
1	<i>Fixed cost</i>	
1.1	Pen cost (0.5ha CIFRI HDPE pen) @ 47685/0.1ha unit	2,38,375
1.6	Maintenance charges/crop	500
1.7	Fixed cost/crop (@3 crops/year) (life span: 5years)	15892
2	<i>Recurring cost</i>	
2.1	Cost of seed @160INR/kg	106380
2.2	Cost of feed @35 INR/kg (CIFRI CAGE GROW)	131250
2.3	Miscellaneous (Lime, prophylactics)	500
2.5	Total recurring cost	238130
3	Total cost per crop	254022
4	<i>Estimated cost of produced fingerlings</i>	388600
5	<i>Net profit</i>	134578
6	<i>Benefit Cost Ratio (BC)</i>	1.53

The assessment of fish production from the Beledanga wetland before and after the intervention showed a jump of 24% from 21372.45kg in 2019-20 to 28307.75kg in 2020-21. The productivity of the wetland has increased from 356-472kg/ha/year. The revenue has increased from 18.79 lakh INR in 2019-20 to 27.66 lakh INR in 2020-2021 registering a growth of 32% (Fig. 5). Grass carp contributed 20-22% of the total CBF production in the wetland in 2020-2021.

Discussion

The growth performance of the IMCs in pens varied species wise with *C. idella* showing maximum growth in terms of weight gain, average daily growth and specific growth rate followed by *L. catla*, *L. rohita* and *C. mrigala*. The survival rate was highest for *L. catla*. The higher growth rate and low FCR (<1) of grass carp in pens might be attributed to utilization of macrophyte growth in the pens. The macrophyte growth in pens with IMC was much higher than in pens with grass carp. The growth and survival of carps in pen showed similar trend to growth of carps reported in pens installed in Assam and Uttar Pradesh (Bhattacharjya et al. 2015; Alam et al. 2017). The comparatively lower growth might be probably due to low temperature regime in the present study, as the aim was to overwinter the seed to release them in the open wetland to utilise primary productivity and achieve compensatory growth in the productive wetland

in growing season. The growth performance of the seed may be better during warmer temperature regime due to higher metabolic rate, feed utilization and shorted culture period.

A net yield realized viz 309.2kg advanced fingerlings per pen from IMC culture and 617.5 ± 13.10 kg per pen from grass carp culture was released into wetland proper as an input for CBF. Carp seed can easily be reared in high stocking densities in pens with using supplementary feeding with artificial feed to achieve high production rates (Das et al. 2017b). The additional benefit for in situ raising of seed for CBF is lower mortality, low production cost. Moreover, carp fingerlings grown in pens and subsequently released into wetlands show better survival (Roy and Hassan 2013). The present study highlighted the efficacy of pen enclosure for seed raising in these weed choked, shallow wetlands in absence of nursery facilities. This pen culture technique has also been deemed useful for grow out of carps and conservation of auto-recruiting small indigenous species in the wetlands of eastern and north-eastern India (Sarkar et al. 2019).

Marginal fishers are more likely to adopt an adaptation strategy if it is economically viable (Kijima et al. 2011). The economics have been worked out considering possibility of three crops (seed) per year and culturing IMCs in all three pens and grass carp in two pens. The BC ratio for the culture (1.53) indicated its economic viability. Feed and seed cost formed over 90% of the recurring cost. Utilizing all the pens for grass carp will give higher benefit cost ratio. The technological feasibility and economic viability of pen culture have been previously reported in wetlands of Uttar Pradesh, West Bengal, Assam and Manipur with BC ratio varying from 1.4 to 1.8 (Gorai et al. 2006; Roy and Hassan 2013; Bhattacharjya et al. 2015; Alam et al. 2017; Das et al. 2017a,b; Yengkokpam et al. 2019). The variation in profitability may be attributed to difference in seed size stocked, culture period and duration, type of feed used, habitat characteristics and climatic conditions.

In the present study, most of the water quality parameters did not vary significantly ($p > 0.05$) between pens and reference sites. This may be due to small-scale farming. The lower plankton abundance and chlorophyll a level in the pens may be due to grazing of plankton by the stocked fishes and lower dissolved oxygen can be related to respiration. Most of the environmental parameters were well within range suitable for carp culture.

The mean annual temperature in the district of North 24 Parganas shows increasing trend while precipitation shows decreasing trend in the last two decades. Climate change trends along 4 major river basins viz. Ganga, Brahmaputra, Mahanadi, Cauvery show similar climatic trend (ICAR-CIFRI 2016; Sharma et al. 2015; Sarkar et al. 2019) in the last three decades. The climatic parameters have direct bearing on growth of species in floodplain wetlands affecting its production (Karnatak et al. 2020). The climatic variations along with overexploitation and habitat may be some of the major reasons for declining natural fish production and diminishing fish diversity in this wetland. The catchment is dominated by agriculture activities, which might be major source of nutrients through runoff reflected in the nutrient status (eutrophic) and primary productivity. The agriculture in the catchment is also one of the major cause of water abstraction from the wetland (Sarkar et al. 2020a). Paddy and Jute are major

water intensive crops cultivated in the catchment fulfilling 30-40% of the water requirement from the wetland. Further jute retting in the wetland causes deterioration of water quality during monsoon months (July-September) (Fig. 6). This requires integrated wetland management interventions like use of water efficient irrigation system (drip, sprinkler) to reduce water abstraction and cropping of low water requiring crops like oil seeds, pulse and other cash crops. Promotion of organic farming in the catchment can control eutrophication of the wetland and promote food safety (Hassan et al. 2015).

The fish production from the studied wetland before and after the intervention showed a jump of 24% within one year. The productivity of the wetland has increased significantly from 356-472kg/ha/year, while revenue increased to the tune of 32%. Grass carp contribution to total catch increased from 8-10% to 20-22%. The stakeholders involved in routine monitoring of the wetland resources and fishing activities state that 80-85% of the wetland is infested with aquatic macrophytes including floating, submerged and emergent varieties. They opined that the grass carp stocked could utilise 40-45% of the macrophytes. The growth of the stocked grass carp was 0.8 to 1kg within 6 month and 2-2.3kg within a year. Grass carp feeds preferably on submerged, rooted emergent vegetation (Swanson and Bergersen 1988) and can consume macrophytes up to 100% of body weight per day (van der Lee et al. 2017). Although in pond ecosystems they effectively control macrophytes at relatively low densities of 50 juvenile carp/ha (van Dyke et al. 1984); however the densities required to manage weed choked floodplain wetlands may be far more. In the present study grass carp stocking at the rate of 360 fish/ha could aid in utilization of approximately 40-45% of the macrophyte biomass, leaving further scope for fisheries enhancement through incorporation of herbivorous and macrophyte utilizing fish species like grass carp. There is a need to optimize their stocking densities based on area of wetland, type of macrophyte infestation, ecosystem type and their market demand. The production of these fishes in pens and its subsequent release in wetlands will not only boost carp fish production from the wetland but will not only reduce cost of seed for CBF. The growth performance and survival of grass carp indicate suitability of pens for their culture. Evidently, integration of grass carp will not only aid in ecofriendly macrophyte management in the wetlands but will also cater to nutritional and livelihood security of the fishers in face of changing climate by utilizing natural productivity converting weed biomass to protein food in form of fish.

Declarations

Ethics approval and consent to participate

The Institute Research Committee (IRC) of ICAR-Central Inland Fisheries Research Institute, Kolkata considering the animal care and ethical issues approved the research program and sampling methodology.

The authors consent to participate in the study.

Consent for publication

All the authors consent to publication of the study.

Availability of data and materials

The original data presented in the study are available with the corresponding author and PI of the project the study is part of.

Competing interests

The authors declare no conflict of interest.

Funding

The study was funded by Indian Council of Agricultural Research, New Delhi.

Authors' contributions

Name of the author	Type of contribution
Gunjan Karnatak	Methodology, execution of growth trial, recording onsite water and soil parameters, MS preparation
Basanta Kumar Das	Conceptualization, overall supervision and project administration
Uttam Kumar Sarkar	Data visualization and presentation
Simanku Borah	Data curation and MS preparation
Aparna Roy	Collection and analysis of fish capture data
Pranay Parida	Assistance in statistical analysis of data
Lianthuamluaia	Water quality analysis
Archan Kanti Das	Guidance on pen culture management at field
Bijay Kumar Behera	Reviewing and Editing MS
Arun Pandit	Reviewing and Editing MS
Amiya Sahoo	Reviewing and Editing MS
Birendra Kumar Bhattacharjya	Reviewing and Editing MS
Sangeeta Chakraborty,	Management of pen farm
Purna Chandra	Assistance in collection of samples

Acknowledgement

The authors acknowledge funding support from WorldFish under the ICAR-WorldFish collaborative (W-3) project “Small-scale fisheries in wetlands for livelihood and nutritional security”. The authors acknowledge NICRA project for providing climatic data of the study area. Participation and cooperation

of the Beledanga fisheries cooperative society for providing data and implementation of project activities in co-management mode is greatly acknowledged.

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Figures

Figure 1

A view of study area and Pen culture site at Beledanga wetland, India

Figure 2

Mean air temperature trend in the North 24 Parganas district in the last two decades

Figure 3

Mean annual rainfall trend in the North 24 Parganas district in the last two decades

Figure 4

Land use pattern of Beledanga wetland catchment

Figure 5

Enhancement in fish yield and generation of revenue through fish sale in Beledanga wetland

Figure 6

Jute cultivation and retting in the Beledanga wetland