

Composite fish culture enhances fish productivity in rural Tripura, Northeast India

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Fish is highly esteemed in Tripura, Northeast India, where 95% of the population consumes fish, surpassing the recommended 11 kg per capita per annum. However, local production falls short due to technological gaps. This study aimed to augment fish production by introducing the four-species composite fish culture (CFC) technology. Over three years, demonstrations were conducted in fifteen ponds across four villages in Dhalai district under low-input conditions. Annual fish production increased remarkably from 297-380 kg/ha before intervention to 935-1577 kg/ha after intervention. Gross profit per hectare surged from ₹ 58,386 to ₹ 223,192, and net profit per hectare rose from ₹ 15,719 to ₹ 112,383. The benefit-cost ratio escalated from 1.36 to 1.93, indicating improved economic returns. CFC adoption emerges as a promising means to enhance fish productivity in Tripura, presenting sustainable pathways for self-sufficiency in the region.

Keywords: Composite culture, Fish productivity enhancement, Rural aquaculture, Tripura

Aquaculture plays a pivotal role in securing livelihoods and nutritional security in Tripura. The state has made significant progress in this sector through systematic efforts and integrated approaches, with fish production soaring from 19,840 MT in 2004-05 to 82,000 MT in 2021-22. While this quantity is sufficient from a nutritional self-sufficiency standpoint, the population's high inclination to consume fish at nearly 30 kg per capita per annum, the highest in India, poses challenges. Tripura currently imports fish from other regions to meet local demand, highlighting the need for innovative strategies.

The current fish productivity in Tripura stands at 2818 kg/ha/year, slightly below the national average of 3000 kg/ha/year. In rural areas, productivity ranges from 0.5 to 1.5 MT/ha, primarily due to technological backwardness, limited access to credit facilities for quality inputs such as fish seeds and feeds, and hesitancy to adopt new technologies. To address these challenges, an initiative

was launched under the NAIP, Component-III to showcase the scientific 'Composite Fish Culture' (CFC) technology in Dhalai district.

CFC is a polyculture approach where complementary fish species are stocked together to optimize utilization of different ecological niches and natural food resources across the pond environment. The recommended species combination synergistically harnesses the unique feeding habits and spatial distribution of three major Indian major carp (IMC) species - the surface feeding Catla (*Catla catla*), column feeding Rohu (*Labeo rohita*), and bottom feeding Mrigal (*Cirrhinus mrigala*); along with three exotic carp varieties - the surface feeding Silver Carp (*Hypophthalmichthys molitrix*), column feeding Grass Carp (*Ctenopharyngodon idella*), and bottom

feeding Common Carp (*Cyprinus carpio*). By strategically integrating these cultivars with distinct feeding niches, CFC aims to comprehensively exploit the diverse natural productivity present across the vertical aquatic profile, thereby enhancing overall fish production. In this study, the hypothesis was that this ecologically-sound polyculture system could serve as a viable technology to improve fish productivity in rural Tripura, thereby encouraging farmers to adopt scientific aquaculture practices.



A haul of fish produced through composite fish culture

Methodology

Site selection and preliminary investigations

Fifteen small ponds ranging from 0.08 to 0.10 hectares in area were selected across four rural villages (Balaram, Moracherra, Kuchianella, and Shibbari) in Tripura's Dhalai district. These ponds had water depths varying from 1 to 2.5 meters and a water retention period of 8-10 months. Initial participatory rural appraisal (PRA) exercises, which involved transect walks, observations, group discussions, and semi-structured interviews, were conducted to characterize the sites and identify suitable farmers. This process provided vital insights into the existing aquaculture practices, resource conditions, and people's interests, enabling the tailoring of appropriate interventions. Subsequently, the selected farmers were provided with training and demonstrations on scientific fish farming techniques.

Pond preparation

The selected ponds underwent renovation before fish seed stocking, including desilting, embankment reinforcement using bamboo palisades wherever necessary, and clearance of aquatic vegetations, trimming of overhanging trees, etc. Eradication of unwanted species like predatory and weed fish, aquatic insects, predators, etc was carried out using a combination of kerosene application at 80 liters/ha and bleaching powder at 350 kg/ha.

Liming and fertilization

During the preliminary investigations, one of the major issues identified was that the ponds had clay-loamy soil with a pH ranging from 4.7 to 6.2, which was not conducive to fish farming. To address this issue, lime was provided to farmers. The lime was applied to ponds basally at a rate of 250 kg/ha, supplemented with quarterly doses of 100 kg/ha to correct the pH levels. Another issue identified was the low plankton production in the ponds. To address this, organic manuring was implemented, which involved basal applications of raw cattle

manure at 10,000 kg/ha (one-third of the total) followed by monthly split doses for the remaining two-thirds. In addition to organic manuring, inorganic fertilizers were applied to enhance pond fertility. This comprised urea, single super phosphate (SSP), and muriate of potash in a 4:4:1 ratio, applied basally at 75 kg/ha, quarterly at 10 kg/ha.

Fish stocking and supplementary feeding

Once the pond waters attained a greenish hue following fertilization, indicating adequate plankton productions, the CFC model was implemented by stocking a combination of 40% Catla, 30% Rohu, 20% Mrigal, and 10% Grass Carp at a density of 5,000 fingerlings (6-10 cm) per hectare. A day after stocking fish, supplementary feed comprising a 7:3 mixture of rice polish and mustard oil cake was provided to fish at 2-5% of their biomass, every alternate day. Grass carp were additionally fed grassy and leafy fodders like banana leaves, maize leaves, chopped water hyacinth (half boiled), and vegetable wastes based on local/seasonal availability.

Monitoring and partial harvesting

In rural aquaculture, there was a notable lack of awareness regarding the importance of testing pond water and soil quality, resulting in poor pond health and reduced fish productivity. To address this issue, our intervention strongly emphasized the need for regular testing of pond water and soil quality. Water quality parameters such as temperature, transparency, pH, dissolved oxygen (DO), alkalinity, nutrients, and plankton levels were monitored bimonthly as part of our intervention. We also assessed soil quality parameters. When necessary, corrective measures were promptly implemented to address any issues and maintain the pond health.

Fish health and growth were routinely monitored through sample netting with a cast net, with 10 samples collected per pond. Additionally, starting from the third to fourth month onwards, regular partial harvesting of larger

individuals, known as 'jumpers,' was conducted.

The CFC demonstrations were annually conducted over a 8-10 month cycle from May-June to January-February, with a 1-2 month crop holiday between yearly production cycles. Key data on fish production, economics, and other parameters were recorded and analyzed over three consecutive years to evaluate performance and assess the viability of the intervention.

Impact / Results

Water and soil quality

The implementation of CFC resulted in significant improvements in water and soil quality parameters compared to pre-intervention conditions (Table 1). One of the notable improvements was observed in water transparency, which is crucial for promoting increased light penetration into the water, benefiting the production of planktonic organisms reliant on photosynthesis. Additionally, water pH levels demonstrated a steady rise from sub-optimal levels around 6.34 pre-intervention to 7.17-7.43 post-intervention, approaching the ideal range of 7.5-8.5 for productive aquaculture. This improvement in pH levels indicates a more suitable environment for aquatic life and fish growth. Moreover, DO levels increased from 4.47 ppm initially to 5.15-5.65 ppm post-intervention. Adequate DO levels are essential for fish health, and the observed increase suggests improved aeration and oxygenation in the water, which is crucial for the survival and growth of aquatic organisms. Total alkalinity, which is crucial for buffering pH fluctuations, nearly doubled from 36.0 ppm pre-intervention to 64.5-78.1 ppm post-intervention. This increase contributed to the stability of the aquatic environment, helping to maintain optimal pH levels for fish and overall pond health.

Soil fertility indicators like available nitrogen (N), phosphorus (P), and organic carbon (OC) content exhibited promising increments. Available N rose from 14.18 mg/100g to 19.85-22.15 mg/100g, while

available N increased from 1.92 mg/100g to 3.25-3.84 mg/100g. OC, a determinant of soil health, nearly tripled from 0.17% to 0.45-0.51%. Plankton abundance, reflecting the natural food supply, surged from 0.47 ml/50L pre-intervention to 2.2-3.4 ml/50L after intervention. This 7-fold increase highlights the enhanced ecological productivity attained through scientific pond management and CFC.

Fish production and economics

The CFC intervention demonstrated remarkable success in boosting aquaculture productivity and profitability in Tripura's Dhalai district. Over just three years, adoption of this low-input polyculture system enabled annual fish yields to surge from a modest 305-380 kg/ha to an impressive 934-1577 kg/ha - a staggering 206-315% increase (Fig. 1). This substantial productivity gain directly translated into higher economic returns for farmers. With the sale price of fish increasing from ₹150 per kg in Year I to ₹180 in Year II and ₹200 in Year III (the increase in fish size over the years likely contributed to the increase in sale price), gross profits per hectare escalated from ₹58,386 pre-intervention to ₹141,500 in Year I, ₹232,950 in Year II, and peaked at ₹309,083 in Year III. Net profits exhibited a similar trend, rising over ten-fold from ₹15,719 initially to ₹43,100, ₹115,350, and ₹178,700 respectively across three years. The benefit-cost ratio, a crucial marker of economic viability, improved from 1.36 to an optimum 2.37, underscoring the profitability of CFC adoption (Fig. 2).

Significantly, these accomplishments were realized through relatively simple management practices that deviated from standard CFC protocols. The stocking density of 5,000 fingerlings/ha was only half the recommended 10,000 fingerlings/ha. Supplementary feeding was carried out on alternate days instead of daily regimens. Moreover, there were no periodic water exchanges of 25-50% as typically prescribed in scientific farming. This suggests there is

immense potential for further yield increments by optimizing inputs and intensifying CFC practices.

With strategic use of quality seeds, formulated feeds, fertilizers and adherence to good management practices (GAPs) like regular water exchanges, disease management, etc., it is projected that fish productivity could be pushed to the range of 3-4 metric tonnes/hectare/year under high-input CFC management regimes. Achieving such yields would place Tripura's rural aquaculture firmly enroute to the state's target of 3,000 kg/ha/year, bridging supply gaps to attain self-sufficiency.

A key success factor in this intervention was the promotion of an integrated approach that encouraged efficient utilization and recycling of locally available resources within farm households. Cost-effective alternatives like a mixture of rice polish and mustard oilcake substituted expensive commercial fish feeds. Farm residues like grasses, banana leaves and vegetable wastes served as nutritious supplementary fodders for fish like Grass carp. Cattle manure, traditionally used as organic fertilizer for crops, was channelized to enhance pond productivity through sustainable recycling. This integration aligned well with the small-holder production systems where financial resources were limited but organic residue availability was abundant. It catalyzed enthusiastic participation from entire farm families, with near 100% involvement of women

in activities like fish feeding, pond fertilization, watch and ward, etc. This community engagement approach fostered a sense of ownership and self-reliance among rural beneficiaries under study.

Interestingly, around 65% of the fish harvests were marketed post-intervention compared to only 60% previously. This indicated that CFC enabled households to divert a greater proportion of their farm produce towards income generation after meeting subsistence needs. The resultant increase in cash flows could drive reinvestment in inputs, assets and diversification for livelihood enhancement.

Previous bottlenecks like the lack of quality fish seed and feed supplies were strategically addressed through forging input supply chain linkages facilitated by the project. However, the intervention employed fingerlings of only 6-10 cm size. Stocking advanced fingerlings of 12-15 cm following a nursery rearing phase *in situ* could potentially accelerate growth and decrease cultivation periods, enabling higher productivity through multiple cycles annually. To ensure reliable seed supply chains accessible to rural farmers, investments in decentralized seed rearing facilities and entrepreneurship models are recommended. Eliminating dependence on distant hatcheries through locally empowered seed production could enhance fingerling quality and optimize transportation costs.

Though impressive, the demonstrated mean CFC yields of

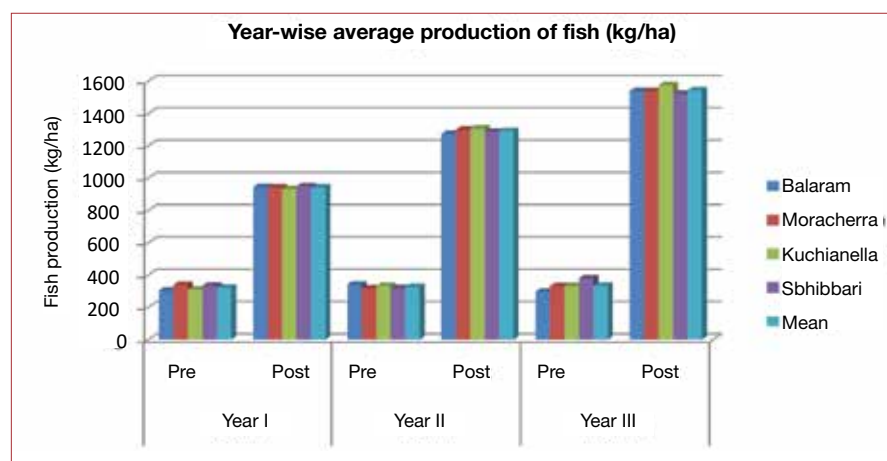


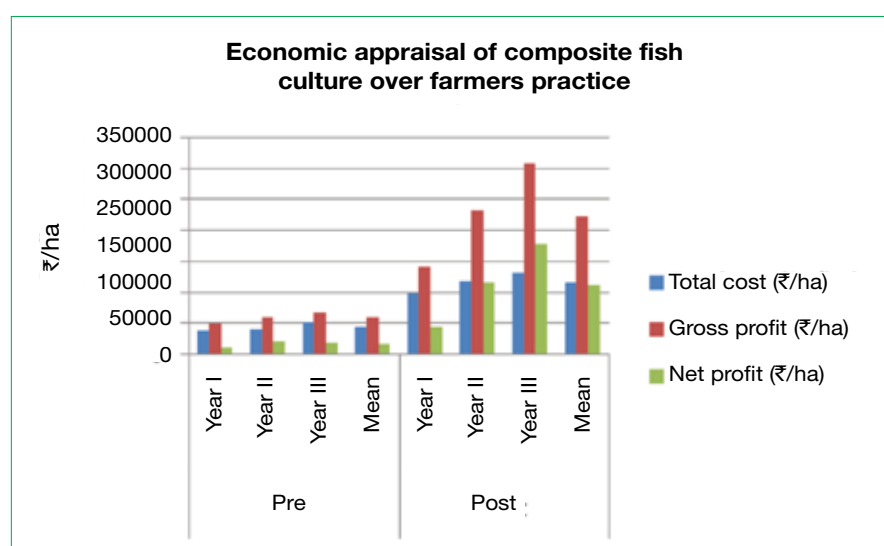
Fig. 1. Year-wise average fish production in different sites

Table 1. Water and soil quality parameters of the ponds

Parameter	Pre-intervention (Farmers' practice)	Post-intervention		
		Year I	Year II	Year III
Temperature (°C)	28.72±0.35	28.8±0.20	28.66±0.16	28.74±0.25
Transparency (cm)	45±8.04	17.71±2.62	18.52±3.15	19.14±3.14
pH	6.34±0.35	7.17±0.12	7.26±0.32	7.43±0.54
Dissolved oxygen (ppm)	4.47±0.07	5.15±0.62	5.65±0.54	5.22±0.43
Total alkalinity (ppm)	36.0±4.93	64.5±12.12	78.1±8.32	75.5±6.33
Nitrate-nitrogen (ppm)	2.65±0.95	1.82±0.05	2.23±0.12	2.15±0.16
Nitrite-nitrogen (ppm)	0.10±0.12	0.04±0.007	0.05±0.003	0.08±0.011
Phosphate-phosphorus (ppm)	0.72±1.05	1.37±2.07	2.32±1.15	2.54±1.43
Silicate (ppm)	1.89±1.25	5.15±0.60	5.22±0.11	5.27±0.15
Soil pH	6.34±0.16	6.5±0.17	6.57±0.14	6.65±0.22
Soil available nitrogen (mg/100g)	14.18±1.53	19.85±2.70	21.12±2.43	22.15±1.54
Soil available phosphorus (mg/100g)	1.92±0.40	3.25±0.55	3.84±0.14	3.45±0.15
Organic carbon (%)	0.17±0.07	0.45±0.13	0.48±0.15	0.51±0.21
Plankton (ml/50L)	0.47±0.19	2.2±0.74	3.1±0.12	3.4±0.13

935-1577 kg/ha/year represent only 51.9% of Tripura's overarching target of 3,000 kg/ha/year set for 2022 to achieve self-sufficiency in fish production. This highlights opportunities to intensify efforts and drive accelerated CFC promotion across Tripura's rural aquaculture clusters through conducive policies, committed investments in technology transfer, and strategic capacity development of fish farmers.

In this study, factors like the education levels of beneficiary farmers, their prior aquaculture experience, and individual farm sizes played an important role. The relatively faster uptake among educated fish farmers already engaged in aquaculture operations underscores the need for tailored capacity building approaches. Comprehensive training through theoretical and hands-on modules covering all aspects of aquaculture as an enterprise is crucial, especially for small-holders transitioning from subsistence to commercial scales. Supplementing this with regular extension outreach, exposure visits to progressive farms and cluster-level farmer field schools could accelerate peer-based learning and mass awareness. Developing decentralized supply chain networks for quality inputs like seed, feed and other accessories adapted

**Fig. 2.** Economic appraisal of composite fish culture

to location-specific conditions is recommended. Community-led entrepreneurship models and public-private partnerships could be explored to strengthen these supply chains while generating rural employment opportunities.

CONCLUSION

The composite fish culture system demonstrated its potential as an economically rewarding and environmentally sustainable approach for intensifying aquaculture productivity among rural farming communities in Tripura. By capitalizing on synergies between complementary fish species and promoting circular resource-

use, CFC optimized biosystem services for enhancing yields while generating attractive economic returns. With strategic policy support, investments in research and extension, and emphasis on community participation, CFC could be replicated rapidly across Tripura's rural clusters. Simple innovative techniques promoting resource-use efficiency and ecological integration provide pathways for realizing the enormous untapped potential in this sector towards achieving regional food and nutritional security alongside inclusive income growth.

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