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Utilization of portable FRP carp hatchery for common carp breeding during the winter season improves production and economic performance

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Abstract
The Central Institute of Freshwater Aquaculture (CIFA), Bhubaneswar, Odisha, India, has developed a fibreglass reinforced plastic (FRP) hatchery as an alternative to concrete eco-carp hatcheries. This hatchery may produce spawns for several other cultivable fish in addition to Indian Major Carp (IMC) spawn. In this view, attempts were made to breed IMC throughout monsoon and Common Carp during winter. The operation guidelines were standardized in the absence of documented procedures for Common Carp breeding using FRP carp hatcheries. The average amount of spawn produced in the IMC breeding operation during the monsoon and in the Common Carp breeding attempt during the winter was 7,46,000 and 7,26,000, respectively. The results of a thorough financial analysis showed that using an FRP carp hatchery to breed IMC with Common Carp enhanced the hatchery's net present value (NPV), internal rate of return (IRR), and benefit-cost ratio (BCR) by 140.29%, 23.36%, and 0.30, respectively. According to the current study, breeding IMC and other species all year round in an FRP carp hatchery could increase profitability and production efficiency.

Keywords: FRP carp hatchery, IMC and common breeding, economic evaluation

1. Introduction

Carp species, including Indian major carps (Catla, Rohu and Mrigala) and exotic carps (such as Common Carp, Silver carp, and Grass carp), are widely cultured in various parts of India. Carp farming is a significant contributor to the country's aquaculture production. The availability of quality carp seeds of desired species and in required size and quantity is always considered a major constraint for developing the fish culture in the nation. The high cost of establishing and operating large-scale permanent structured cement concrete eco-carp hatcheries presents a barrier for resource-poor farmers entering the fish seed production business. In such cases, it becomes crucial to explore alternative technology that are more accessible and affordable. In view of this, the Central Institute of Freshwater Aquaculture (CIFA), Bhubaneswar, Odisha, India, has invented a fibreglass reinforced plastic (FRP) hatchery as an alternative to the concrete eco-carp hatchery to produce healthy carp seed (CIFA, 2004 and 2005; ICAR, 2005; Mohapatra *et al.*, 2003; 2004; 2005, 2007, 2008a and 2011) [4-5, 13, 18-22]. The invention of the portable FRP carp hatchery aids the nation's "blue revolution" since it makes it possible to produce fish seed in a farmer's field. One breeding pool, one hatching pool, an egg collection chamber, and an overhead storage tank are the components of a portable FRP carp hatchery system. The design of this hatchery is to produce one million carp spawn per operation. This hatchery is less expensive, uses less water for fish breeding, is simple to set up and run, and offers the additional benefit of being mobile, allowing farmers to move the hatchery to a different place as needed. This technology can potentially assist marginal and small farmers in the nation and fishery cooperative societies in producing high-quality carp spawn.

This hatchery system was mainly designed and protocols standardized for the breeding of Indian Major Carp (IMC)viz., *Labeo rohita*; *Catla catla*; *Cirrhinus mrigal* and also recommended for breeding of other exotic and medium species viz. *Labeo calbasu*; *Labeo fimbriatus*; *Hypophthalmichthys molitrix*; *Ctenopharyngodon idella*; and *Cyprinus carpio* (Mohapatra *et al.*, 2016) [16]. According to Mohapatra *et al.* (2016) [16], the portable FRP carp hatchery system can be used to produce spawns of Common Carp or ornamental fish during the winter season.

Numerous portable FRP carp hatching units have been established and run nationwide (Mohapatra *et al.*, 2011) [21]. Yadav *et al.* (2016) [26] reported that draught-prone farmers in the Marathwada region of Maharashtra, India, can utilize portable FRP carp hatchery technology since it requires fewer resources such as investment, water, and space.

Generally, IMC and silver carp breed during the southwest monsoon (May to September) and Common Carp breeds almost throughout the year, with two peaks July to August and March to April, in Indian climatic conditions (Raizada *et al.*, 2019) [25]. Therefore, current efforts have been made to maximize portable FRP carp hatchery's production and economic performance by breeding Indian Major Carp during the monsoon and Common Carp during the winter season. The literature review revealed that comprehensive breeding protocols for IMC were accessible, but there was a dearth of information on portable FRP carp hatchery breeding methods for Common Carp. Therefore, in this report, specific breeding protocols for Common Carp utilizing a portable FRP hatchery are highlighted for usage by farmers and further study.

2. Material and Methods

FRP carp hatchery was procured from CIFA, consisting of one cylindrical shaped breeding pool of 2.15 m diameter, 0.9 m height and 3409 L capacity; one incubation chamber of 1.4 m diameter, 0.98 m height and 1200 L net egg incubation volume and one eggs/spawn collection rectangular tank of size 1.0 m × 0.5m × 0.5 m with capacity of 250 L. Filtered plankton free reservoir water, collected in outdoor concrete tank, was used for hatchery operation. For continuous water supply, 1 H.P. motor pump was used to lift the water from the concrete outdoor tank. The breeding set was installed and executed at the College of Fishery Science, Udgir. Brood fishes Indian Major Carp and Common Carp of 2-3 years age group, reared in 0.15 ha polythene lined ponds, was used for breeding operation.

2.1 Breeding of Indian Major Carp (IMC)

Three breeding operations of IMC (*Catla catla* and *Labeo rohita*) were performed in Monsoon season from June 2022 to August 2023 as per the user's manual provided by CIFA (Mohapatra *et al.*, 2008b) [18] Inducing agent WOVA-FH was used at the rate 0.3 to 0.5 ml per kg body weight of female and 0.1 to 0.3 ml per kg body weight of male for breeding operation.

2.2 Breeding of Common Carp

Three breeding operations of Common Carp, *Cyprinus carpio* were run during the winter period from January 2022 to February 2022. Following protocols were developed in the absence of standard protocols for breeding Common Carp using portable FRP carp hatchery.

2.2.1 Protocols developed for the breeding of Common Carp are as follows

2.2.1.1 Preparation of eggs collector

Eggs of Common Carp became sticky within seconds after mixing with water (Mansour *et al.*, 2009) [14]. Aquatic weeds like Hydrilla and Najas can be used for egg adhesion. However, it has been reported that egg collectors of the above plant origin face several disadvantages (Ayyapan *et al*., 2011) [3]. Therefore, synthetic fibres collected from an empty cement packing bag were used as a collector in the FRP hatchery system.

1. Clean water was used to wash the empty cement bags.
2. Fibres were separated from bags and cut into uniform lengths of 3 to 4 feet.
3. A bundle of fibres weighing approximately 50 g was prepared.
4. A stone weight was tied in the center of each bundle to sink it inside water while the fibres remained free-floating like submerged foliage.
5. In one cycle of the FRP hatchery, a total of 2 kg bundles were used to breed 10 kg females.
6. Before using fibre bundles for breeding operation, they were washed with $KMnO_4$ solution.

2.2.1.2 Breeding management protocols

1. The breeding pool was washed using $KMnO_4$ solution.
2. A PVC pipe with a height of 0.6 M was fixed vertically in the breeding pool's central outlet.
3. Two kg fiber bundles were introduced into the breeding pool.
4. Good quality brood fish, 10 kg male and 10 kg female were selected based on general maturity and health observations.
5. Brood fishes were injected with Gonopro-Fh (GnRH-based inducing hormone) @ 0.1 ml per kg male and 0.2 ml per female.
6. After injection, brood fishes were released into the breeding pool.
7. Water flow was started in the breeding pool @ 0.2 to 0.3 L per second.
8. After spawning, brood fishes were removed from the breeding pool and released in the broodstock pond after dipping in 5 ppm $KMnO_4$ solution.
9. After spawn removal, the hatching pool and the spawning pool were cleaned with $KMnO_4$ solution and then with water.
10. Fishes were found to spawn 10 to 15 hours after injection
11. (Spawning time may vary depending on water temperature. Generally, one female may lay 1 to 1.5 lakh eggs per kg body weight.)

2.2.1.3 Eggs incubation management protocols

1. The incubation pool was washed using $KMnO_4$ solution.
2. In the hatching pool, FRP inner socket was fixed and then the screen on the socket was fixed.
3. P.V.C. drain pipes were fixed in the center of the tank to drain excess water; the height of the drain pipe in the pool is maintained at 0.9 m so that, up to that height, water level can be maintained.
4. Eggs collectors were removed from the breeding pool and, after dipping in 5 ppm $KMnO_4$ solution, released in the incubation chamber of the incubation pool to avoid fungal infection to eggs.
5. Mild water circulation was maintained in the egg incubation chamber through duck mouths (inlets) @ 0.1 to 0.15 L per second.
6. (Hatching was observed to start after 60 to 72 hours. After hatching, larvae were found to stick to the fibre and wall of the incubation pool. After a few periods, hatching was found to become actively swimming in the water column.)
7. After the next four days, when the yolk sac of larvae was absorbed, spawns were collected through the hapa fixed

spawn collection tank by opening the outlet valve connected to the outer wall of the hatching pool.
8. After spawn removal, the hatching pool and the spawn collection tank were cleaned with $KMnO_4$ solution and then with water.

2.3 Calculation of fertilization and hatching rate
The fertilization and hatching rate was calculated by using the given below equations (Hussan *et al*., 2020) [12]

$$\text{Fertilization rate (\%)} = \frac{\text{Number of fertilized eggs X 100}}{\text{Total no of eggs in sample}} \quad (1)$$

$$\text{Hatching rate (\%)} = \frac{\text{Number of hatchlings X 100}}{\text{Total number of fertilized eggs}} \quad (2)$$

2.4 Water quality estimation
Water temperature was measured with a mercury-filled Celsius thermometer and pH was measured with a digital pH meter. Dissolved oxygen (D.O.), total alkalinity and total hardness were measured daily morning from 07.00 to 08.00 AM during breeding operation using standard protocols given by APHA (2005) [2].

2.5 Economic analysis
Capital Cost (I), Variable Cost (VC), Gross Return (GR), Benefit-Cost Ratio (BCR), and Internal Rate of Return (IRR) were the parameters used to calculate the cost structure and economic analysis of the carp seed rearing in the farm ponds.
The Benefit-Cost Ratio (BCR) for the operation was calculated by using the following formula (Diatin *et al.* 2021) [9];

$$BCR = \frac{\sum_{t=0}^{n} \frac{(Bt)}{(1+i)^t}}{\sum_{t=0}^{n} \frac{(Ct)}{(1+i)^t}} \quad (3)$$

The NPV is defined as the present value of the net benefit stream. NPV is calculated using the formula (Diatin *et al.* 2021) [9];

$$\text{NPV} = \sum_{n}^{t} \frac{Bt-Ct}{(1+i)^t} \quad (4)$$

Where, Bt = benefit in year t, Ct = cost in year t, n = length of culture in years, and i = discount rate.
IRR is the interest rate obtained from the present value of total costs equal to the present value of total revenues. In the present study, the IRR was calculated using the following formula (Diatin *et al.* 2021) [9];

$$\text{IRR} = i + \frac{\text{NPV}}{(\text{NPV}' - \text{NPV}'')} \text{ X } (i' - i'') \quad (5)$$

Where, i′ = discount rate resulted from NPV positive, i″ = discount rate resulted from NPV negative, NPV′ = NPV in interest level i′, NPV″ = NPV in interest level i″.

3. Results and Discussion
Approximately 10 kg male and 10 kg female of IMC bred three times during monsoon season and results are presented in Table 1. The fishes were found to spawn 14 to 15 hrs after administration of inducing hormone. After the eggs had fully swollen, nine samples total, three from the surface, three from mid-depth, and three from the bottom, were obtained using a 500 ml beaker for egg counting. A total of 815,400 to 976,300 eggs were found to lay during the different cycles spawning period. It was found that, respectively, the fertilization and hatching rates ranged from 93.87 to 95.96% and 93.32 to 94.10%. Three days were required for the yolk sac to be absorbed. The spawn measuring cup count indicated that an average of 746,000 spawn were produced during the monsoon season.
Yadav *et al.* (2016) [26] previously reported the successful operation of a portable FRP carp hatchery in Maharashtra at the location of the current investigation. The widespread adoption of portable FRP carp hatcheries in different regions of India is encouraging. FRP hatcheries were successfully used to demonstrate IMC breeding in the districts of Keonjhar and Mayurbhanj (CIFA, 2011) [8]. The production of 82 lakhs of spawn under the project "Sustainable livelihood improvement through integrated freshwater aquaculture, horticulture and livestock development in Mayurbhanj, Keonjhar and Sambalpur districts of Orissa" increased the availability of spawn in the region (CIFA, 2012; Mohapatra *et al.*, 2013) [7, 15]. For the first time in Gujarat, the FRP Carp hatchery was successfully demonstrated to fish farmers in Middle Gujarat by the Inland Fisheries Training and Demonstration Centre at Anand Agriculture University (AAU, 2012) [1].
In the present investigation, three breeding cycles of approximately 10 kg male and 10 kg female Common Carp for each cycle were performed during the winter season. The results are presented in Table 1. The fishes were found to spawn 48 to 66hrs after administration of inducing hormone. Ten grams of egg collection fibres were randomly chosen from several bundles to determine the total number of eggs deposited. A total of 752,800 to 943,400 eggs were found to lay during the different cycles spawning period. It was found that the rates of fertilisation and hatching ranged from 93.32 to 94.10% and 95.90 to 98.12%, respectively. Four days were required for the yolk sac absorption. The spawn measuring cup count indicated that an average of 726,000 spawns were produced during winter.
There are few reports and methods available for the successful use of an FRP carp hatchery for spawn generation other than IMC. Hussan *et al.* (2020) [12] successfully developed the protocols for the induced breeding of butter catfish *Ompok bimaculatus* using a portable FRP pabda hatchery for seed production. However, this portable FRP hatchery design was different than FRP hatchery used for carp breeding. Winter breeding of Common Carp was done in the same FRP carp hatchery that was used in this experiment for breeding IMC.
The result of the water quality analysis is presented in Table 2. It revealed comparatively less temperature and more pH, alkalinity and hardness during winter than in monsoon. Comparative economic analyses were carried out between only IMC breeding and IMC with Common Carp breeding for a year and are represented in Table 3. Assuming on average, one week is required for one breeding cycle of Indian Major Carp and twelve days for Common Carp, including pre-breeding work, maintenance, actual operation and post-breeding work, total of twelve cycles of IMC and six cycles of Common Carp are possible. The Common Carp requires more time for one cycles since longer latency period, more incubation and yolk sac absorption time due to less

temperature during winter. It is well known that temperature affects fish's embryonic and larval development (Fukuhara, 1990; Fielder *et al.*, 2005; Bustos *et al.*, 2007; Pereira *et al.*, 2016) [10, 4, 11, 24]. The economic analysis shows that similar capital cost is required for breeding only IMC and IMC with Common Carp. It was reported that variable cost increased by 50.02% when FRP carp hatchery was used for breeding IMC with Common Carp rather than only IMC breeding (Table 3). However, gross income and net income were found to be increased by 63.50% and 114.08%, respectively.

Cash flow analysis was performed for the ten years assuming variable cost and gross profit increases by 2.5% per year at the 8.5% discount rate and the results are presented in the Table 4. The cash flow analysis revealed that net present value (NPV), internal rate of return (IRR) and benefit-cost ratio (BCR) were increased by 140.29%, 23.36% and 0.30 when FRP carp hatchery used for breeding of IMC with Common Carp than for only IMC breeding.

The economic analysis revealed that the efficiency of portable FRP hatcheries might be increased several folds if they are used for seed production by different fish species possessing different spawning periods.

Table 1: Details of cap breeding using FRP hatchery

Particulars	Indian Major carp			Common Carp		
	Set I	Set II	Set III	Set I	Set II	Set III
Total weight of male broodfish (kg)	9.40	9.30	9.50	10.50	9.70	9.60
Total weight of female broodfish (kg)	10.20	9.50	9.30	9.40	9.30	10.40
Spawning time after administration of inducing hormone (hrs)	14	14	15	64	66	48
Total number of eggs produced	9,76,300	8,15,400	8,36,500	8,85,600	7,52,800	9,43,400
Fertilization Rate (%)	95.96	93.87	94.68	93.88	93.32	94.10
Hatching rate (%)	98.04	96.13	97.34	98.12	96.61	95.90
Days required for yolk sac absorption by larvae after hatching	3	3	3	4	4	4
Total number of spawn produced	8,40,000	6,80,000	7,20,000	7,60,000	6,40,000	7,80,000
Average numbers of spawn produced	7, 46, 000			7, 26, 000		

Table 2: Water quality observations (Range, mean±standard deviation) during breeding operations from different seasons of a year

Sr. No.	Parameter	IMC breeding during monsoon	Common Carp breeding during winter
1.	Water temperature(^{0}C)	24 to 27 (25.25±1.06)	18 to 24 (21.08±1.83)
2.	pH	7.23 to 7.90 (7.49±0.23)	7.62 to 8.31 (7.92±0.23)
3.	Dissolved oxygen(mgL^{-1})	5.20 to 7.20 (6.33±0.76)	5.60 to 7.20 (6.50±0.42)
4.	Total alkalinity (mgL^{-1})	112.00to 152.00 (130.33±11.37)	144.00 to 172.00 (160.00±9.91)
5.	Total hardness (mgL^{-1})	208.00to 244.00(228.33±11.24)	268.00 to 300.00 (286.17±9.59)

Assumptions

- The total quantity of IMC broodstock required for 12 cycles in a year: 300 kg
- The total quantity of Common Carp broodstock required for 06 cycles during winter: 150 kg
- Area required for broodfish rearing: 500 m^2
- Average spawn production per cycle: 8,00,000 numbers

Table 3: Economic analysis of the utilization of FRP hatchery for carp breeding

Sl. No.	Items	Only IMC Breeding	IMC with Common Carp Breeding
I.	**Expenditure**	**₹**	**₹**
A.	**Fixed Capital**		
1.	FRP Carp hatchery	2,00,000/-	2,00,000/-
2.	Overhead tank construction	60,000/-	60,000/-
3.	1 H.P. mono block pump set (2 no)	8,000/-	8,000/-
4.	3 H.P. mono block pump set (1 nos)	20,000/-	20,000/-
5.	Construction of broodstock pond 500 m^2	40,000/-	40,000/-
6.	Construction of Hatchery shed platform (6.0 x 4.0 m)	50,000/-	50,000/-
7.	Nets and accessories	10,000/-	10,000/-
8.	Miscellaneous items	5,000/-	5,000/-
	Sub-total	3,93,000/-	3,93,000/-
B.	**Variable Cost per year**		
1.	Brood fish (@ ₹. 200/kg)	60,000/-	90,000/-
2.	Feed for brood fish @ 40 per kg	12,000/-	18,000/-
3.	Electricity and fuel	10,000/-	15,000/-
4.	Inducing agent (@ ₹ 330/10 ml vial)	3940/-	5940/-
5.	Wages (@ ₹. 200/day for 8 man-days per operation *i.e.*, 4 days) i.e. ₹ 1600 per cycle	19,200/-	28,800/-
6.	Miscellaneous	12,000/-	18,000/-

	Sub-total	1,17,140/-	1,75,740/-
C.	**Total Costs**		
1.	Total Variable Cost	1,17,140/-	1,75,740/-
2.	Depreciation cost on fixed capital @ 10% yearly	39,300/-	39,300/-
	Grand Total	1,56,440/-	2,15,040/-
II.	**Gross Income (per year)**		
1.	Sale of spent brood (@ ₹. 150/kg)	45,000/-	67,500/-
	Spawn production @ 0.8 million per cycle	9.6 million	16.0 million
2.	Sale of spawn (ave. @ ₹ 2000/lakh)	1,92,000/-	3,20,000/-
	Sub-total	2,37,000/-	3,87,500/-
III.	Net Income (Gross income – Total costs)	80,560/-	1,72,460/-

Assumptions

A. Variable cost and gross profit increases by 2.5% per year

B. Discount rate, 8.5%

C. IMC breeding cycles: 12; Common Carp breeding cycles:6

Table 4: Cash flow analysis (₹) for FRP hatchery for seed production of Indian Major Carp and Common Carp for the period of ten years

Breeding	Economic parameter	Year 0	1	2	3	4	5	6	7	8	9	10	NPV @ 8.5%	IRR	BCR @ 8.5%
Only IMC	Capital cost	393000	0	0		0	0	0	0	0		0	4,73,662	20.01%	1.38
	Variable cost	0	117140	120069	123070	126147	129301	132533	135846	139243	142724	146292			
	Total cost	393000	117140	120069	123070	126147	129301	132533	135846	139243	142724	146292			
	Gross profit	0	237000	242925	248998	255223	261604	268144	274847	281719	288761	295981			
	Net returns	-393000	119860	122857	125928	129076	132303	135611	139001	142476	146038	149689			
	PV	-393000	110470	104361	98590	93138	87988	83122	78525	74183	70081	66205			
IMC and Common Carp	Capital cost	393000	0	0		0	0	0	0	0		0	11,38,156	43.37%	1.68
	Variable cost	0	175740	180134	184637	189253	193984	198834	203805	208900	214122	219475			
	Total cost	393000	175740	180134	184637	189253	193984	198834	203805	208900	214122	219475			
	Gross profit	0	387500	397188	407117	417295	427727	438421	449381	460616	472131	483934			
	Net returns	-393000	211760	217054	222480	228042	233743	239587	245577	251716	258009	264459			
	PV	-393000	195171	184378	174182	164550	155450	146854	138733	131061	123813	116966			
Extra economic benefits of utilization of FRP hatchery for common breeding during the winter season													6,64,494	23.36%	0.30

IMC, Indian Major Carp, NPV, Net Present Value; IIR, Internal Rate of Return and BCR, Benefit-cost ratio.

Conclusion

The portable, less expensive FRP carp hatchery technology designed by CIFA, Bhubaneswar is a tried-and-true technology ideal for farmers with limited resources. The hatchery can increase its profitability by implementing Common Carp seed production technology in the winter and adhering to the standardized procedures outlined in the present analysis. Additionally, research augmentation is necessary to extend the FRP hatchery's year-round utility by undertaking breeding trials of other cultivable fish that have different spawning seasons.

Authors contribution

S.R.Y. conceptualized and conducted research; S.N.K. carried out data analysis; M.M.G. assisted for laboratory analysis; S.S.G. assisted in experimental set-up and J.S.S. extended help with sample collection.

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The research content of the manuscript is original and has not been published elsewhere.

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Consent to publish

All authors agree to publish the paper in The Pharma Innovations Journal.

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