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## Article

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## MANAGEMENT | RESEARCH ARTICLE

# Exotic fish culture in pond aquaculture system: Study of *Rupchanda* (*Piaractus brachypomus*) culture in Assam, India

Jyoti Prabhat Duarah<sup>1</sup>, Manmohan Mall<sup>1\*</sup> and Swapnali Chetia Phukan<sup>2</sup>

**Abstract:** Exotic fish species are introduced in the pond culture system with a view to improving aquaculture development. Apart from aquaculture development, the introduction of exotic species has an undesirable impact on the natural biodiversity due to prolific breeding tendencies, predation or competition with the indigenous species. However, evidence of socio-economic benefits from a specified exotic species culture to fish farmers needs to be investigated properly. There are many more exotic species which have occupied their place in the composite pond aquaculture system in India and Assam in particular. In this work, an attempt was made to study the culture of *Piaractus brachypomus* (**Local name Rupchanda**) in the pond aquaculture system of Assam. Being a native species of South America also known as *Rupchanda*, it is often confused with *Piranha* (*Pygocentrus nattereri*). From this study, it was observed that in the fish market of Assam, this fish (*Rupchanda*) fetches less price as compared to *Carps*. It was also found that this species has a good growth rate, acceptance to a wide variety of feed and the ability to be stocked in higher stocking density in ponds as well as the volume of sale is higher vis-à-vis the Indian Major Carps. It reaches marketable size within four to five months making this fish species widely accepted for culture by the farmers of Assam and also there is a good volume of trade occurring for the seeds of *P. brachypomus*. In this regard, this research work is a novel attempt in analysing the economic benefits and challenges of adopting a controlled culture of *P. brachypomus* (*Rupchanda*) in the ponds of Assam.

**Subjects:** Regional Development; Sustainable Development; Environmental Economics; Economics

**Keywords:** exotic fish; *Rupchanda* (*P. brachypomus*); Indian major carps; socio-economic development; crop intensification strategy

## 1. Introduction

Aquaculture as defined by FAO consists of “farming of aquatic organisms, including fish, molluscs, crustaceans and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc”. It supplies not only dietary supplements essential for human sustenance but also offers excellent part-time and full-time employment opportunities especially in rural areas (Jayshankar, 2018). As

per FAO (Pauly & Zeller, 2017) Report, 60 million people were directly or indirectly involved in the primary production of fish, either by fishing or in aquaculture, supporting the livelihoods of 10–12% of the world population. In addition to this, aquaculture accounts for over 50% of global fish consumption (Subasinghe et al., 2009). In India aquaculture is a rapidly growing sector with an annual growth rate of over 7% and freshwater aquaculture contributes over 95% of total annual production (Jayshankar, 2018), out of which small-scale fisheries that too in rural areas are the major producers. As the small-scale fisheries in rural areas are the major suppliers of freshwater fish in developing countries for food security and income generation (FAO 2010), Pillay (1990) stated that the problem of migration from rural areas to the urban area can be mitigated through extensive rural aquaculture. This can be achieved provided the aquaculture sector is thought of as a lucrative business option for prospective farmers and assists in the enhancement of income for existing farmers.

The farmers' income can be increased through the adoption of strategies like; an increase in productivity by horizontal and vertical expansion through species diversification to high-value crops and an increase in crop intensity. Jayasankar and Das (2015) claimed that horizontal expansion may boost fish production since only 50% of ponds and tanks out of 2.414 million hectares were presently utilized. In the same way vertical expansion deals with species diversification and includes breeding and culture technologies of a standardised diversified group of freshwater species. The study of fish farming in rural areas of Assam by Phukan and Barman revealed that fish farming was done as a business to generate income and the farmers are gradually expanding their business through acquiring more land for creating a water area. In another study by Duarah and Mall (2020) on vertical diversification through the culture of small indigenous fish species along with carps in small-scale composite culture ponds resulted in more than 100% return on investment sufficient enough to augment the farmers' income by many folds. In the same way, with a view to improving aquaculture development exotic fish species are introduced into the culture system. For example, in Chile, the exotic species "Salmon" is the largest food and agriculture export commodity and is the second largest in the global trade followed by Norway and combinedly share 80% of the global production and trade of "Salmon" (Gonzalez, 2022). According to Kumar (2000), the primary reasons for the introduction of exotic fish species might be (i) Improvement of local fishery potential and broadening of species in the aquatic system; (ii) sport fishing; (iii) aquarium purposes; (iv) control of unwanted weeds and organisms like mosquitos.

## 2. Exotic aquatic species introduction

Kottelat and Whitten (1996) stated that an introduced (exotic species) are a species which are intentionally or accidentally transported and released by a man outside its existing boundary. According to Welcomme (1988), exotic animals are species occurring outside its natural range. Similarly, the IUCN (International Union for Conservation of Nature and Natural Resources) defined "Alien Invasive Species as an alien species which becomes established in natural or semi-natural ecosystems or habitats, an agent of change and threatens native biological diversity." In a study on river system management in the John Day River, Adams et al. (1993) provided a bioeconomic model that demonstrates the expenses of watershed restoration might be justified on the basis of increased salmon and trout populations' economic advantages. Moreover, their study stated that due to the introduction of exotic species, i.e. Salmon, other aquatic and riparian creatures as well as non-salmonid fish in the stream might benefit from this improvement.

The introduction of exotic species has been practised since the middle of 19<sup>th</sup> century and more than 3000 species have been introduced in India mainly for aquaculture, sport fishing, ornamental fish keeping, mosquito control etc (Raman et al., 2013). As stated above, exotic species are introduced primarily for commercial purposes. In this context, Asche and Bjørndal (2011) in their study on "The Economics of Salmon Aquaculture" elaborates that, despite Salmon being a non-native species in Chile, the Chilean Salmon Industry has expanded since the 1980s. This is due to the good climatic condition in Chile favoring the farming of Salmon just like the conditions

favouring the natural habitat for Salmon in the northern hemisphere. Similar is the case in Norway, where the Salmon farms are spread in coastal areas which favors the environment for Salmon farming. Initially, Salmon farming was started on a small-scale basis, and as production and marketing grew, salmon farming witnessed economies of scale and economies of scope in several processes. However, the salmon industry had to encounter issues like pollution from organic wastes, the transmission of disease from farmed species, the impact on the gene pool for wild salmon etc. The negative impacts were also accounted for in the case of Shrimp farming. Shrimp farming was thought to lead to a detrimental effect on the environment through the destruction of mangroves, saltification of agricultural lands etc. But, for a well-managed farm with proper infrastructure, sustainability is not an issue. As far as Salmon producing countries are concerned, they are strictly run under certain regulations which are focused on ensuring environmental standards.

There are shreds of evidence of the successful introduction of several exotic species that are well established in Indian water bodies and creating economic benefits to the farmers; however, there are instances of failure in the introduction of some exotic species which have negatively impacted the natural biodiversity (Laxmappa, 2016). Some of the important exotic species introduced in India are provided in Table 1:

In India, the freshwater pond aquaculture system constitutes three key species of Indian major carps, Catla (*Catla catla*), Rohu (*Labeo rohita*) and Mrigal (*Cirrhinus mrigala*). These species contribute about 61% of total aquaculture production. The freshwater aquaculture system in India also accommodates three exotic species viz., silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idella*) and common carp (*Cyprinus carpio*), contributing nearly 9.5% of total inland production (Kumar et al., 2018). These three exotic Carps have been introduced to India from China. They have established themselves in the commercial freshwater aquaculture system along with the Indian major carps. Another example of alien fish species, the Panagius catfish was introduced in India in 1995 (Rao, 2010). It was introduced in India from Thailand through Bangladesh. Despite its ban on culture in India initially; during the year 2009, the government of India has permitted its culture in aquaculture. This species is cultured either along with carps or monoculture. This species owing to its feed acceptability and growth rate has attracted many farmers to farm in aquaculture ponds. In pond aquaculture, as the growth period is limited by the environmental factors; hence, the farmers should be encouraged to utilize their pond for culturing more than one crop in a year as per the seasonal feasibility. Most recently, Pacu (*P. brachypomus*) is cultured unauthorizedly brought from Bangladesh in some parts of West Bengal and Assam.

The Pacu (*Piaractus brachypomus*) also known as pirapatinga or red-bellied *pacu* is a freshwater fish of South American origin (Singh & Lakra, 2011). The red-bellied *pacu* is commonly known as “*Rupchanda*” in Assam. *Pacu* is a common name used to refer to several South American fish species. The red-bellied *pacu* is often confused with the piranha, but they are not the same and belong to different species. While the piranha is omnivorous with sharp razor teeth, the red-bellied *pacu* is herbivorous (Singh et al., 2012). The red-bellied *pacu* is harmless to humans unlike the piranha Ruiz-Carus & Davis, 2003). A study on the diet shift of *P. brachypomus* (Correa et al., 2014) concluded that the diet of introduced juvenile fishes of this species in the Sepik River of Papua New Guinea primarily composed of fish remains and aquatic plants; in contrast, the diet of the fishes in natural population which prefer allochthonous resources, mainly fruits, seeds and other plant materials. The study concluded that the low availability of fruits and seeds in the diet of introduced fishes in the Sepik River may be due to the low availability of these food items. It was stated that *pacu* is a frugivorous species and displays foraging behaviour. Due to hydrodynamics, they opt for carrion feeding rather than predation (Correa et al., 2014).

A study on the growth performance and compatibility of *pacu* (*P. brachypomus*) along with Indian major carps has revealed that, *pacu* when incorporated into the carp polyculture system did not affect the survival of any of the three major carp. Compatibility was observed between mrigal

**Table 1. List exotic fish species introduced in India**

Fish Species	Year	Host Country
A. Game Fishes		
1. Brown Trout (Salmo trutta fario)	1863–1900	U. K
2. Loch Leven Trout (Salmo levensis)	1863	U. K
3. Rainbow Trout (Salmo garirdnen)	1907	Sri Lanka & Germany
4. Eastern Brook Trout (Salvelinus fontinalies)	1911	U. K
5. Sockeye salmon (Oncorhynchus nerka)	1968	Japan
6. Atlantic Salmon (Salmo salar)	1968	U.S.A.
B. Food Fishes		
1. Golden carp (Carassius carassius)	1870	U.K.
2. Tench (Tinca tinca)	1870	U.K.
3. Gourami (Osphronemus goramy)	1916	Java & Mauritius
4. Common Carp (Cyprinus carpio)	1939	Sri Lanka
5. Tilapia (Oreochromis mossambicus)	1952	Africa
6. Common Carp (Cyprinus carpio)	1957	Thailand
7. Grass Carp (Ctenopahryngodon Idella)	1957	Japan
8. Silver Carp (Hypophthalmichthys morlitrix)	1959	Hong Kong
9. Tawes (Puntitus javanicus)	1972	Indonesia
10. Sutchi (Pangasianodon hypophthalmus)	1997	Vietnam
11. Whiteleg shrimp (Litopenaeus vannamei)	2010	
C. Larvicidal Fishes		
1. Guppy (Poecilia reticulata)	1908	South America
2. Top Minnow (Gambusia affinis)	1928	Italy
D. Ornamental Fishes		
1. Live bearers (27 species)	From various countries	
2. Eggs layers (261 species)	From various countries	
E. Unauthorised Introduction		
1. Bighead carp (Aristichthus nobilis)		
2. African Catfish (Clarias gariepinus)		
3. Nile Tilapia (Oreochromis niloticus)		
4. Red Tilapia (Oreochromis so.)		
5. Red Piranha (Serrasalmus natteren)		
6. Rupchanda or Rup Chanda (Piaractus brachypomus)		

\*Adapted from Raman et al. (2013).

and *pacu*, while catla showed inter-specific competition with *pacu* similar to the competition in between catla and rohu. There is a possibility of overlapping of feeding niche of rohu with that of *pacu* in which the latter gets the advantage. The study gives encouraging results for introducing *pacu* in the polyculture to enhance the production and income of farmers and suggests a way forward for field validation of the results for using *pacu* as part of carp polyculture practices (Kumar et al., 2018).

### **2.1. Aquaculture management and its economic importance in Assam**

The state of Assam is located in the north-eastern part of India under the foothills of the Himalayan Mountain range. This state has a superb sub-tropical environment very much conducive to freshwater aquaculture. Apart from this, the state of Assam is blessed with more than 2.86 Lacs Ha of various water resources that includes ponds, rivers, beels, tanks etc. The market for fish in Assam is a deficit one since more than 90% of people in this state prefer to eat fish leading to higher demand. On the contrary, the supply of fish is less than the demand requiring import from other states. Fish farming significantly influences the sustenance and economy of the state. In this respect, the state is heavily investing in this sector which will help in the improvement of small-scale fish farming as well as the economy of the state. In order to increase their disposable income, the farmers of this region are already inclined towards species diversification. A case study on the incorporation of *Gudusia chapra* along with carp successfully by farmers of the Cachar district of Assam (India) has shown profitable economics (Duarah & Mall, 2020). In view of the species diversification oriented towards fish yield and thereby income, the *pacu* (*P. brachypomus*) or the *Rupchanda* qualifies to be a potential candidate for incorporation in the carp polyculture system (Kumar et al., 2018).

Despite its good growth rate, acceptance of a wide variety of feed and ability to be stocked in higher stocking density in ponds, being an exotic species *Rupchanda* (*P. brachypomus*), requires government approval for culture in this region's aquatic system. In addition to this, the species reaches marketable size within four to five months making it widely accepted for culture by the farmers of Assam. Also, there is a good volume of trade occurring for the seeds of *P. brachypomus*. In the above context, a detailed analysis of *Rupchanda* is highly essential and this study has made a novel attempt in this regard and will guide not only other fish farmers but also the government authorities may consider to legalising the culture of this exotic species. Therefore, this research work has the following objectives:

- a. To understand the socio-demographic characteristics of fish farmers in the study area.
- b. To determine the cost, profitability and viability of *Rupchanda* farming in a polyculture system.

### **3. Materials and method**

The fisheries sector in Assam comprises only inland sectors further classified into capture and culture sectors. Hence, a field study was undertaken in the Kalaigaon Development Block under Darrang district of Assam constituting 4700 numbers of culture fish farmers, out of which 1.2% (56 nos.) of the population are involved in the culture of exotic species along with Indian major carps. A census study technique was adopted to consider all the farmers who are involved in *Rupchanda* farming along with Carps and data were collected through a personal interview on a schedule (Anton & Curtis, 2017). In order to study the socio-economic characteristics of fish farmers descriptive analyses such as frequency and percentage were adopted. The socioeconomic characteristics of the sampled fish farmers are given in Table 2.

The results of Table-2 show that the majority of farmers (62.5%) fall within the age category of 31–40 years and the average age works out to be 32 years. Thus, it implies that farmers are in their active age and there exists a high probability for enhanced productivity in fish farming. From the data, it is found that the majority of respondents (82.5%) are graduates. Hence, the adoption of



**Table 2. Socio-economic characteristics of fish farmers in the study area**

Variable	Freq.	%	Variable	Freq.	%
<b>Age</b>			<b>Mode of Land Acquisition</b>		
21–30 Years	21	37.5	Lease/Rent	21	37.5
31–40 Years	35	62.5	Inheritance	35	62.5
<b>Gender</b>			<b>Type of Pond/Structure</b>		
Male	56	100	Earth/Concrete Pond	0	0
Female	0	0	Concrete Pond Only	0	0
<b>Marital Status</b>			Earthen Pond Only	56	100
Married	49	87.5	<b>Types of Culture</b>		
Unmarried	7	12.5	Monoculture	0	0
<b>Education Level</b>			Polyculture	47	84.5
Primary School	0	0	Integrated	9	12.5
Secondary School	7	12.5	<b>Type of Culture Species</b>		
Undergraduate	14	25.0	Only Carps	0	0
Graduate	35	62.5	Carps and <i>Rupchanda</i>	56	100
<b>Household Size</b>			<b>Fingerlings Source</b>		
1–5 Members	7	12.5	Outside the District	42	75.0
6–10 Members	49	87.5	Within the District	7	12.5
More than 10 Members	0	0	Purchased at Farm site	7	12.5
<b>Experience</b>			<b>Co-operative Membership</b>		
1–5 Years	14	25.0	Yes	7	12.5
6–10 Years	42	75.0	No	49	87.5
<b>Feed Source</b>			<b>Income Group</b>		
Local/Self Prepared	7	12.5	Less than ₹100,000	0	0
Formulated	42	75.0	₹100,000 - ₹500,000	7	12.5
Both Local & Formulated	7	12.5	₹500,000 - ₹10,00,000	42	75.0
<b>Easy access to Capital</b>			More than ₹10,00,000	7	12.5
Yes	35	62.5	<b>Capital Investment</b>		
No	21	37.5	₹100,000 - ₹500,000	56	100

Source: Field Survey.



new technology and innovative farming that would increase productivity can be expected in the study area. Similarly, as per the data, 87.5% of farmers are married and have a household size of 6 to 10 members. The implications of this finding are that with more family members usage of hired labour in the fieldwork can be reduced leading to cost reduction and improvement in profitability. As far as experience is concerned around 75% of farmers hold more than 5 years of expertise in fish farming. Thus, the considerable experience will have a positive impact on production and profitability.

As far as the mode of land acquisition is concerned 62.5% of respondents have inherited land and 37.5% own land on a lease basis. Generally, in the case of inherited land, the cost of lease rentals can be avoided, and the farmer has more freedom in land usage pattern. The table indicates that all the farmers in the study area have an earthen pond and the majority (87.5%) practise polyculture i.e., a practice to utilise all ecological niches of the pond ecosystem. Under the polyculture system, the majority of farmers adopt a species diversification strategy e.g., harvesting of carp and exotic species like- Pungus and/or *Rupchanda* and 75% of them are using the formulated feed. It is also evident from the table that the farmers in the study area have easy access to capital and 75% of them are in the income group of ₹500,000 - ₹10,00,000. Hence, the capital requirement is not a hurdle for them to pursue the fish farming activity.

#### 4. Economic modelling

The economic implication of *Rupchanda* farming along with Carp was analysed by adopting Gross Margin Analysis (GMA). In the contemporary farming and economic environment GMA is a vital tool in measuring the level of farm profitability. A Gross margin (GM) is the difference between the Gross income (Total Revenue) earned by the fish farm and the total variable costs required to produce the output (Firth, 2002). The total revenue is the total output multiplied by the price per unit of fish. The variable costs are those costs that vary in direct proportion to the level of production. The total variable cost includes costs on inputs such as fertilisers, transportation, labour input, feeding cost and cost of other inputs like fingerlings etc. The above discussion can be represented in the following equation as follows:

$$\text{Gross Margin} = \text{Total Revenue} - \text{Total Variable Cost}$$

Let us suppose, *GM* = Gross Margin; *TR* = Total Revenue; *TVC* = Total Variable Cost; *TFC* = Total Fixed Cost; *S* = Selling Price per unit; *Q* = Quantity Produced & Sold; *V* = Variable cost/unit

$$GM = TR - TVC = (Q * S) - (Q * V)$$

The rate of return on total investment can also be calculated to know the profitability of the proposed scheme as follows:

$$ROI = \frac{\text{Net Margin}}{\text{Total Cost}} * 100, \text{ where}$$

$$[\text{Net Margin} = \text{Gross Margin} - \text{Nonoperating Expenses}]$$

In the above formula Net margin is determined after paying non operating expenses like interest on loan etc. In this study, it is assumed that the farmer undertook working capital loan to meet the variable cost.

#### 5. Practice of *Rupchanda* (*pacu*) farming

The *pacu* (*Piaractus brachipomus*) locally known as *Rupchanda* was introduced unofficially possibly during 2004 via Bangladesh (Chatterjee & Mazumdar, 2009; Singh & Lakra, 2011). Due to unauthorised introduction in the Indian aquatic system, it lacks required scientific information; hence, there exists no such standard culture practice. Farmers are practising culture of this species as per their own system and convenience. In India, this species is mostly cultivated in inland coastal areas of West Godavari and Krishna districts apart from West Bengal, Odisha, Kerala and

Assam. In particular to Assam, the practice of *Rupchanda* farming specifically within the study area involves three activities viz.,

- (1) **Activity-1 (Fry procurement):** The farmers of the study area purchase the *Rupchanda* seeds from outside the district/state. The procurement of seed depends upon the capital availability and sometimes pre-order from local farmers. The *Rupchanda* seeds of 1 cm to 1.5 cm are purchased at a price of INR 0.70 to INR 1.60 per seed.
- (2) **Activity-2 (Nursery rearing):** The seeds are stocked in the nursery pond of the farmer. The sale of seed begins right after the first day of stocking. Depending on the number of days in the nursery, the price of seed also increases. The seeds are fed with formulated floating feed of more than 28 percent protein. The *Rupchanda* fry grows to a size of 4 inch to 5 inch within 1 to 2 months. This size is considered to be ideal for grow-out culture. In the study area, it was found that, the working capital requirement of growing about 35,000 numbers of seeds (fry of 1-1.5 cm) in 0.13-hectare pond for 2 months culture to attain size of 4-5 inch is approximately INR 80,000.00. The cost of production of *Rupchanda* seed of 4-5 inch is INR 2.30. The sale price of seed (fingerling of 4-5 inch) is INR 7.00 to INR 10.00.
- (3) **Activity-3 (Grow-out culture):** In the grow out pond, the *Rupchanda* fingerlings are stocked maintaining a stocking density of 2000 numbers per 0.13-hectare pond. The feeding is done using supplementary floating feed of more than 28 percent protein. *Rupchanda* normally feeds on anything that is being applied. In the same pond the farmers are also culturing Indian major carps. The stocking density of carps in the pond is maintained at average of 1000 numbers of fingerling in 0.13-hectare pond. The working capital for *Rupchanda* in the study area was found to be approximately INR 100,000.00 for 4-5 months culture. The *Rupchanda* attains a size of 1 KG during this period and are sold at an average price of INR 130.00 per Kg. In the same pond the carps are also raised, and the working capital incurred for carps are approximately INR 60,000.00. The production of *Rupchanda* is achieved around 1800 Kg. The cost of production per kilogram of *Rupchanda* is around INR 56.00. The production of carps from the same pond is approximately 400 KG, and the cost of production per kg carp fish is approximately INR 150.00.

## 6. Economic analysis of *Rupchanda* farming along with carps in Assam

The economic analysis generally consists of a cost-revenue framework. In this study, the estimated cost of inputs borne by the respondents in the farming practice of carps along with *Rupchanda* is provided in Table 3. The cost estimated is for 0.13-hectare (1 Bigha) pond area, where data had been collected. The estimated cost includes Variable Cost only.

In the study area, farmers generally adopt the key species mix under Carps (Rohu, Catla, Mirgal, Silver Carp and Grass Carp). Along with the above Carps mix farmers also diversify into various compatible exotic species like-Pangus and more recently *Rupchanda*. The major cost involved in the above polyculture system includes purchase of fingerlings (29% of total variable cost) and formulated feed (66% of total variable cost). Thus, 95% of the total cost is absorbed in these two components. Regarding sourcing of fingerlings, the farmers are dependent on traders/commission agents and private hatcheries located outside the district. The stocking of *Rupchanda* seeds is made in higher numbers than Carps. After identification of costs involved in the *Rupchanda* fish farming along with Carps, the profitability analysis is provided by comparing the variable cost for polyculture of carps and *Rupchanda* (Table-3) with the variable cost of only carp polyculture system (Table 4).

The production of carps in 0.13-hectare pond at the rate of 550 Kg is estimated based on the productivity achieved by the respondents when only poly culture of carps are done. The input quantity in the polyculture system of carps followed by the respondents is as per the package of practice prescribed by the World bank aided Assam Agri-business and Rural Transformation Project for polyculture. The respondents are successful in achieving an annual harvest of 550 Kg of carps from the carp polyculture system. As per the respondents, the farm-gate<sup>2</sup> price of carps is fetched

**Table 3. Cost analysis of *Rupchanda* and carps fish farming**

Sl. No	Items of inputs*	Quantity applied by farmers**	Rate*** (₹)	Amount (₹)
1	Lime	190 kg.	20.00	3,800.00
2	Urea	100 kg.	12.00	1,200.00
3	SSP	100 kg.	20.00	2,000.00
4	Raw Cow Dung	1000 kg.	3.00	3,000.00
5	Fingerlings <i>Rupchanda</i>	2000 nos.	7.00	14,000.00
	Fingerlings Carps	1000 nos.	12.00	12,000.00
6	Formulated feed (25% protein)	2800 kg.	44.00	1,21,000.00
7	Labour	Approximate Cost		5,000.00
8	Prophylactic measures	Approximate Cost		1,000.00
Total Variable Cost				1,63,000.00

\*Estimated for Water Area 0.13 Ha.

\*\*Field Survey.

\*\*\*Price of inputs is based on the prevailing local market price.

**Table 4. Cost analysis of only Carps<sup>1</sup> polyculture**

Sl. No	Items of inputs*	Required Qty*	Rate** (₹)	Amount (₹)
1	Lime	65 kg.	20.00	1300
2	Urea	26 kg.	12.00	312
3	SSP	39 kg.	20.00	780
4	Raw Cow Dung	1300 kg.	3.00	3900
5	Fingerlings <i>Rupchanda</i>	NA	NA	NA
	Fingerlings Carps	1000 nos.	12.00	12480
6	Formulated feed (25% protein)	780 kg.	44.00	34320
7	Prophylactic measures	Approximate Cost		520.00
Total Variable Cost				53,612.00

Source: Field Survey.

at an average of ₹ 180.00 per Kg. Similarly, when *Rupchanda* is introduced in the polyculture system of carps, the production of carps slightly reduces and the annual harvest in 0.13-hectare pond for carps is achieved up to 400 kg. But from the same pond, the loss in carps production is compensated by the annual harvest of *Rupchanda* up to 1800 kgs. So, the farmers achieve a production of 400 kg carps and 1800 kgs *Rupchanda* from 0.13-hectare pond. The farm-gate price of *Rupchanda* is fetched at an average of ₹ 130.00 per Kg.

It can be observed from Table 3 that the respondent farmers are using very high quantities of Lime, Urea and SSP when integrating *Rupchanda* with carps. This may be because of the voracious feeding habit of *Rupchanda* which consumes almost all the supplementary feed applied. The carps may be dependent on only the natural food produced after the application of fertilisers. Increased dose of lime may be due to the higher stocking density of fish and thereby avoid any outbreak of diseases.

**Table 5. Profitability analysis of fish Production**

Particulars	Carps only	Carps & <i>Rupchanda</i>
Average Quantity produced (.13 Hectare)	550 kgs	2200 kgs(Carps-400 Kg, <i>Rupchanda</i> -1800 kg) (Carps-400 Kg, <i>Rupchanda</i> -1800 kg)
<sup>3</sup> Average Price per kg	₹18.00	Carps @₹180; <i>Rupchanda</i> @₹130 per kg
Total Revenue (TR)	99,00	3,06,00
1. Average total Variable Cost (₹)	53,612.00	1,63,00
2. Variable Cost per unit (₹)	97.48	74.10
Gross Margin = TR - TC	45,388.00	1,43,00
<sup>4</sup> Interest Expenses @12% p.a.#	5,147.00	15,648.00
Net Margin	40,241.00	1,27,352.00
ROI	75.06%	78.13%
Improvement in ROI		3.07%

# Interest Expenses for Working Capital Loan (Assumed that 80% of variable cost met from short term loan). All figures are annualised data.

\*Source: Field Survey.

In the profitability analysis as reported in Table 5 fixed cost component was not computed owing to unavailability/inadequacy of appropriate data. The total revenue was determined by multiplying the price per kilogram with the yield. The yield per 0.13-hectare of pond in case of carps only was 550 kgs, and this species fetch higher value in the market @₹180 per kg. In Carps, only polyculture the variable cost per unit of production comes out ₹97.48 and return on investment was 75.06%. On the other hand, under Carps and *Rupchanda* polyculture system the variable cost per unit of production was ₹74.10. The fall in variable cost per unit has enhanced the return on investment to 78.13%. In this study, to calculate net margin interest expenses @12% p.a. was introduced as an implicit cost, if the farmer finance 80% of his working capital i.e., the variable cost. Thus, it can be concluded from the above analysis that addition of *Rupchanda* in Carps polyculture system will enhance the net margin by 3.07%.

## 7. Findings and discussion

The rapid surge in human population and their growing dependence on fish as a diet has necessitates for supply side expansion. This can be achieved through introduction of new species along with major Indian carps' species without altering the bio-diversity. In the above context, the present study was conducted on fish farmers engaged in Carps polyculture along with *Pacu* in Assam, has revealed a unique business model that assists in enhancing the income of small farmers. It was observed that in the fish market of Assam, *Rupchanda* (*Pacu*) fetches less price as compared to Carps. However, owing to good growth rate of this species, acceptance to a wide variety of feed and the ability to be stocked in higher stocking density in ponds as well as higher volume of sale vis-à-vis the Indian Major Carps, culture of this species has a positive impact on the fish farmers income.

It was found that the farmers purchase *Rupchanda* (*Pacu*) fry on a large number because of low price and start selling after 1 to 2 months of rearing when it attains the size of 4-5 inch as fingerling. In a 0.13-hectare pond, a farmer generally keeps about 35,000 numbers of fry, and after two months, the fry reaches fingerling stage. The farmers keep only 2000 numbers (approximately) of fingerlings to grow in their grow-out pond as table fish and rest of the fingerlings they sold in the open market as seeds that will fetch an average price ₹8.50 per fingerling. This is a continuous process that mimics the operating cycle in working capital management found in most of the manufacturing organisations. Moreover, from this study it was observed that the

variable cost per unit under *carps* & *pacu* polyculture system has dropped by 24% vis-à-vis *carps* only culture. The reason for such drop in variable cost per unit could be attributed to the enhanced production quantity irrespective of 200% increase in total variable cost. The gross margin from the *carps* & *pacu* culture had shown a 215% rise, since the total revenue was increased by 209%. Thus, the rise in total revenue and fall in variable cost per unit was reflected in the increase in gross margin as well as ROI.

It was observed that the farmers in the study area were generating additional earning from fingerling sales (which is not a part of the total revenue in this research work). Hence, while performing cost and return analysis of *Pacu* farming along with *carps* on 0.13 hectare of pond area, excluding this additional earning focus was made only on the revenue earned from the sale of table fish. In the cost analysis, it was observed that 95% of the total variable cost relates to feed and fingerling, while purchase of *Pacu* fry, rearing and selling as fingerlings could be sufficient to cover the cost of production of *Carps* and *Pacu* together resulting in optimal usage of loaned capital. In this respect, the major findings of this study establish enhancement of return on investment if a farmer undertakes *carps* polyculture along with *Pacu*.

**Observations on *Rupchanda* farming in carp polyculture system:** In the study area, the observations on the culture practice of *Rupchanda* along with *carps* are as follows.

- No visible competition of carp and *Rupchanda* for feed.
- Sufficient supplementary floating feed of high protein is given, to avoid any possible predation upon *carps* by *Rupchanda*.
- *Rupchanda* are also fed with boiled chicken viscera. This indicates they are meat eaters, but they are not active predators, which indicates their foraging behaviour, scavenging in search of food.
- When application of supplementary feed is less, especially during the winter season; it is observed that some carp species like rohu (*L. rohita*) and Grass carp (*C. idella*) have bite marks in the caudal fin. The *Rupchanda* might have tried to prey upon these fishes due to limited availability of supplementary feed.
- In ponds with monoculture of *Rupchanda*, sometimes due to high feed application, there is algal bloom. In such case, silver carp fingerlings are stocked in the pond to control the bloom. At the end of culture period, the farmers are also able to harvest Silver carp without significant mortality of silver carp or predation by *Rupchanda* upon Silver carp.
- *Rupchanda* after attaining table size in 4-5 months are harvested depending on the market demand and prevailing price in the market. *Carps* on the other hand are grown for about 10 months and the significant sale is done during the month of January only.
- The sale of *Rupchanda* fry begins right after the day of import.
- The *Rupchanda* are vigorous feeder and have good Food Conversion Ratio (FCR). The weight of *Rupchanda* increases as the feeding is done in sufficient volume. In contrary, if the feeds are not given the weight of the *Rupchanda* fish starts losing at faster rate.
- Inorganic fertilisers are applied in high dosages in case of integration of *carps* and *Rupchanda*.
- The farmers are having sufficient capital to invest in the supplementary feed are involved in *Rupchanda* farming.

## 8. Conclusion and recommendations

The state of Assam is the gateway to north east India that plays a key role in trade and commerce not only within the state but also in other adjoining states. The economic development of Assam will no doubt impact positively the economies of other states. In Assam, freshwater aquaculture contributes significantly to the economic development by creating employment opportunities for the people in general and the youth in particular because of its sub-tropical climate and presence of large aquatic bodies. This potential can be garnered with government support and adoption of scientific procedure by fish farmers. The fish farmers in general harvest Indian major *Carps* (Catla, Rohu, Mirgal etc.) owing to their consumer demand. However, the return on investment is low and these species require 8–9 months to catch for sale. As we know, in pond aquaculture, the growth

period is limited by the environmental factors. Hence, farmers should be encouraged to utilise their pond for culturing more than one crop in a year as per the seasonal feasibility. In this respect, many farmers adopt species diversification strategy, so that they can harvest throughout the year for continuous flow of income. One such species diversification strategy includes practice of exotic fish species. This study primarily focuses on cost and return analysis of *Rupchanda* farming along with Carps, which is a native species of South America and introduced in India from Bangladesh.

The findings from culture of *Rupchanda* in pond aquaculture system along with carps in the study area asserted that farmers income can be boosted owing to its high rate of growth. The farmers were able to stock their ponds thrice in a year after every harvest of *Rupchanda* on an average interval of three to four months. The culture of *Rupchanda* in ponds could be a crop intensification strategy for enhancing in the income of fish farmers. The *Rupchanda* is simple to grow. Its popularity is growing day by day as an aquaculture species. Based on the above findings, the authors recommend the following:

- (1) *Pacu* being an exotic fish is still not an authorised species for culture in aquaculture pond. But it is found that it is compatible for polyculture in carp tanks, hence, alike pangasius species, which is now permitted for aquaculture, the *Pacu* may also be authorised for culture in aquaculture ponds.
- (2) The culture practice of *Pacu* need to be studied in a more technical manner such as impact on ecology and natural habitat by the research agencies and design a package of best practice for its culture.
- (3) The seeds of *Pacu* are imported from distant places, resulting in high cost of seeds. The artificial breeding of *Pacu* may also be permitted in the local hatcheries.
- (4) A proper guideline for *Pacu* farming needs to be designed keeping in concern the biosecurity aspect.
- (5) Since high protein diet is required and supplementary feeding is done, the feeds should be available in the proximity of the farmers at low cost.

This study was conducted with the primary aim to understand the role of exotic fish culture adoption in polyculture system by small holder farmers. However, the major limitations of small holder farmers were not achieving economics of scale, which debilitate the ROI. Hence, if this study was replicated for large scale fish farmers, then the improvement in return on investment (ROI) could be expected. This study did not consider the earnings from *pacu* (*Roopchand*) fingerling sale and fixed cost component. In the event of due consideration of these factors the economic model proposed, here would provide better insight for large scale adoption of *carps and pacu* polyculture in the state of Assam.

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#### Notes

1. Inputs required as per package of practice followed under world bank aided APART polyculture project for a 0.13-hectare pond.
2. The farm-gate price is the price of the fish per Kg. received by the producer farmer. This is the latest price obtained from the farmers during field survey in the month of June-July 2022.



3. Average price per kg was the price charged by farmers at the farm gate. However, the wholesale price trend in the local wholesale market has been provided in Appendix.
4. The interest expense was the amount of interest paid by the farmer on short-term loans and advances for a 1-year duration. The interest rate as quoted by banks for loans above ₹50,000 up to ₹2,00,000 was MCLR + 0.65%. The 1-year MCLR was 8.65%. However, the farmers get these loans depending on their credit score ranging from 10% to 14%. Hence, an average interest rate of 12% was assumed to determine interest expenses.

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