Journal of Applied Life Sciences International

Volume 27, Issue 6, Page 53-60, 2024; Article no.JALSI.126724
ISSN: 2394-1103

Evaluating Growth Performance and Economic Efficiency of Indian Major Carps in Integrated Fish-duck Farming Systems

S. Paulpandi [a++*], S. Sathya [a++] and K. Velmurugan [a#]

[a] *Krishi Vigyan Kendra, Veterinary College & Research Institute Campus, TANUVAS, Namakkal-637002, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jalsi/2024/v27i6666

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/126724

Original Research Article

Received: 04/09/2024
Accepted: 06/11/2024
Published: 12/11/2024

ABSTRACT

The experiment was conducted in three villages in Namakkal district to evaluate the effects of an integrated fish-duck farming system on the physico-chemical and biological parameters of pond ecosystems, as well as on overall fish production. This eight-month trial took place from July 2016 to February 2017. Ponds were stocked with fingerlings at a density of 6,000 per hectare, using Indian major carps like Catla (*Catla catla),* Rohu *(Labeo rohita),* and Mrigala (*Cirrhinus mrigala*) in a 4:3:3 ratio to maximize energy utilization through polyculture. Indian Runner ducks (Anas platyrhynchos) were included in the system to provide meat and naturally fertilize the ponds through

[++] *Assistant Professor (Fisheries) and (Soil Science);*
[#] *Professor & Head;*
**Corresponding author: E-mail: kvkpaulpandi@gmail.com;*

Cite as: *Paulpandi, S., S. Sathya, and K. Velmurugan. 2024. "Evaluating Growth Performance and Economic Efficiency of Indian Major Carps in Integrated Fish-Duck Farming Systems". Journal of Applied Life Sciences International 27 (6):53-60. https://doi.org/10.9734/jalsi/2024/v27i6666.*

excreta while grazing freely. In this village-based cultural practice, fish were not given supplementary feed. Instead, the ducks were fed with household food scraps and agricultural by-products, such as broken cereal grains and rice bran, which are readily available in rural areas. The study revealed that water quality parameters such as pH, dissolved oxygen, and alkalinity were significantly higher in the integrated ponds compared to control ponds (without ducks). Additionally, plankton levels (both phytoplankton and zooplankton) improved markedly in the integrated ponds. The Indian major carps in the integrated ponds also achieved better body weight than those in the control ponds. This improved growth rate contributed to a yield of 8,928 kg/ha/year in the integrated system, compared to 5,145 kg/ha/year in the control ponds. These results demonstrate that integrated fish-duck farming is more profitable than non-integrated systems (control) under rural conditions in Tamil Nadu, as it yields higher fish production without additional inputs.

Keywords: Integrated duck; growth of fish; economic; abiotic parameters; proximate composition.

1. INTRODUCTION

Agricultural growth in India has been slow in recent years, despite the country's rapid economic expansion. According to the 2024 Economic Survey of India, food grain production grew at only 1.2% between 1990 and 2007, lagging behind the population growth rate of 1.9%. Projections indicate that India's population will reach 1.37 billion by 2030 and 1.6 billion by 2050. To meet the food demand, production will need to increase to 289 million tons by 2030 and 349 million tons by 2050.

“Integrated farming system of culture an traditional practice which is to improve the net income and high yield by reducing the cost of production for integrated farmers**,** relies on eco-friendly, economically viable, and socially acceptable culture systems. Recycling organic waste for fish farming serves a dual purpose: it helps manage waste disposal, thus benefiting the environment, and provides economic returns. Semi-intensive culture systems are often based on ponds fertilized with livestock manure and supplemented with low-cost feeds. Integrating fish and poultry in this way increases production efficiency and optimizes land, labor, and water use for both poultry and fish. For example, a single hectare of static-water fish ponds can process waste from up to 1,500 birds, yielding up to 10,000 kg of fish per hectare without additional feed or fertilizer inputs. This practice also minimizes environmental impacts, as it produces few effluents” [1].

“In this system, nothing is wasted and ecological balance is maintained. Recycling of organic wastes for fish culture serves the dual purpose of cleaning the environment and providing economic benefits” [2]. “The recycling of animal dung/wastes in aquaculture ponds is important for natural fish production, which supports sustainable aquaculture and also reduces expenditure on supplementary feeds and fertilizers. Fish-duck integration is a common practice in countries like China, Hungary, Germany, Poland, and Russia, though it remains limited in India” [3]. “In India, small-scale farmers—who make up the majority of the rural population—often turn to fish-duck integration to improve farm productivity” [4]. In terms of input-output efficiency, fish-duck integration represents an optimal model, combining fish, livestock, and poultry into a symbiotic system. In contrast, fish-pig integration shows lower economic efficiency, and fish-chicken integration lacks a similar symbiotic relationship. While protein inputs and outputs are comparable in fish-duck and fish-cow systems, raising ducks is generally easier than raising cows, and the economic returns from fish-duck integration are notably higher. This study aimed to evaluate the effects of duck rearing on pond productivity, along with a cost-benefit analysis of integrated fish farming

2. MATERIALS AND METHODS

This investigation was conducted over eight months, from July 2016 to February 2017, in three villages in Namakkal district. Water samples were collected from various pond sites and tested for physico-chemical and biological parameters using a water test kit at each location. The study involved two ponds, each measuring 0.5 hectares: one designated as the integrated treatment pond (INT) and the other as the control pond (CTL). Both ponds are seasonal and tend to shrink over time. In the INT pond, ducks were allowed to graze during the day, while the CTL pond had no ducks. A laying variety of Indian Runner ducks was reared at a density of 150 ducks per 0.5 hectare. No fertilizers or feeds were added to either pond as inputs. While Indian major Carps which are candidate species for culture in integrated farming system were selected as they yield better growth and production which has been achieved in the study**.**

Therefore, advanced fingerlings of Indian major carps like Catla (*Catla catla),* Rohu *(Labeo rohita),* and Mrigala (*Cirrhinus mrigala*) in a 3:3:4 ratio) were stocked at a rate of 6,000 fingerlings per hectare. Initially, the ducklings were raised at the farmers' residences until they reached three months of age, at which point they were introduced to the ponds to graze. The Indian Runner ducks were housed at the farmers' homes and released each morning at 9:00 AM to graze in the pond, returning by 5:00 PM. They were fed with fresh kitchen waste and agricultural by-products, such as broken grains and rice bran, which were provided by each household. The families raised the ducks both to collect eggs for household consumption and to increase overall pond productivity through the integrated system.

Fig. 1. Duck cum Fish culture

2.1 Physico-chemical Analysis

"Water quality parameters in the ponds were monitored monthly to measure temperature, pH, dissolved oxygen, free CO_2, total alkalinity, conductivity, biochemical oxygen demand (BOD), ammonia, nitrate nitrogen, and plankton levels, following standard methods" [5]. "Plankton samples were collected by filtering water through a plankton net (mesh size 25, pore size 60 µm) and counted under a microscope using a Sedgewick-Rafter counting cell. The manure loading rate was determined by randomly collecting fecal samples from four ducks under the same treatment conditions in a wet laboratory. Duck manure was analyzed for phosphorus and potassium content" [6] and nitrogen content [7]. Fish growth was recorded monthly from sample catches obtained by cast netting. Statistical analysis was performed using a t-test at a 5% significance level.

3. RESULTS

Duck droppings were analyzed daily over seven consecutive days, and an average daily excretion rate was recorded. Each duck produced between 38 g and 55 g of droppings per day, resulting in an average of 4.85 kg/ha/day from 100 ducks. Fish growth was monitored monthly, and both net and gross fish production were calculated on an annual basis.

Table 1. Proximate composition of the duck manure

Proximate composition of manure	Fresh basis (%)
Moisture	55.5±1.25
Nitrogen	1.05±0.05
Phosphorus	0.74±0.02
Potassium	0.47±0.04

3.1 Physico-chemical Properties of Water

The physico-chemical properties of water play a crucial role in regulating fish metabolism, supporting their survival and growth. Duck manure significantly impacts water quality, enhancing these parameters [8]. The estimated values of the physico-chemical properties of pond water are shown in Table 2. Water temperature ranged from 20.2°C to 29.2°C, likely due to seasonal variations. The pH ranged from 6.2 to 8.07, with moderate fluctuations, and was distinctly alkaline in the duck-treated pond. Chari [9] similarly observed that duck manure promotes an alkaline environment, which is beneficial for production systems. Golterman [10] noted a relationship between pH and levels of free CO_2, HCO_3^-, and CO_3^{2-} in natural waters, with higher pH levels associated with increased carbonate concentrations. Our study found a similar trend, with higher pH correlating with lower CO_2 levels, indicating a negative correlation between pH and CO_2.

Dissolved oxygen levels were relatively high in the duck-treated pond, creating favorable conditions for fish growth, possibly due to the

Table 2. Physico chemical parameters of INT and Control pond

Parameters	July		Aug		Sept		Oct		Nov		Dec		Jan		Feb	
	CTL	INT	CTL	INT	CTL	INT	CTL	INT	CTL	INT	CTL	INT	CTL	INT	CTL	INT
Water temp (^{0}C)	27.0	26.7	29.5	29.5	23.0	23.5	22.6	23.7	29.3	28.7	29	29.2	30.4	30.2	32.3	32.1
pH	7.1	7.3	6.7	7.0	6.9	7.6	6.0	7.6	6.0	7.2	6.9	7.7	6.9	7.6	7.0	7.4
DO (mg/l)	5.5	6.7	5.9	6.6	6.1	7.2	6.0	7.3	5.9	7.2	5.9	7.0	5.7	6.5	5.4	6.4
Ammonia (mg/l)	0.003	0.009	0.008	0.018	0.007	0.008	0.003	0.006	0.009	0.001	0.008	0.001	0.004	0.006	0.005	0.007
Nitrate Nitrogen(mg/l)	0.37	0.22	0.38	0.20	0.16	0.17	0.18	0.20	0.19	0.21	0.20	0.24	0.19	0.22	0.20	0.26
Total alkalinity (mg/l)	122	217	139	200	157	187	163	185	135	208	131	182	158	210	162	198
BOD (mg/l)	9.25	7.3	8.65	7.2	8.35	6.4	8.4	6.1	8.5	6.4	8.7	6.7	9.3	7.6	10.2	8.0
Plankton (ml/50 l)	0.15	0.25	0.15	0.30	0.25	0.30	0.20	0.20	0.25	0.40	0.35	0.50	0.40	0.60	0.30	0.65

** Integrated fish cum duck farming (INT) ** Control pond (CTL)* ducks' movement aerating the water. Dissolved oxygen also showed a positive correlation with zooplankton in the treated pond. Free CO_2 levels did not differ significantly between the treatments, and a negative correlation was observed between free CO_2 and phytoplankton, consistent with Chari [11], who noted that free CO_2 may not limit phytoplankton production. Alkalinity was higher in the duck-treated pond (108-194 ppm) compared to the control pond (93-172 ppm), showing a positive correlation with both pH and dissolved oxygen. The biochemical oxygen demand (BOD) in the treated pond ranged from 6-8 mg/L. Maitra [12], who recorded 5.0-6.0 mg/L BOD in fish-duck integration systems, which is lower than BOD levels in fish-pig or fish-poultry integrations. Our findings also revealed that duck droppings did not cause oxygen depletion stress, a common issue with organic matter deposition. Plankton production differed significantly between treatments. Both phytoplankton and zooplankton biomass were higher in the duck-treated pond, likely due to increased manuring rates, which supported enhanced plankton growth.

Pond sediments are an integral part of the pond ecosystem [13]. The Physico-chemical analysis of the soil was neutral to alkaline in reaction (6.92-7.82) and electrical conductivity increased from0.11to 0.485 milli mhos/cm. Organic carbon, available nitrogen, phosphorus and total nitrogen showed increasing trend (Table 1), indicating the important role that the pond sediments play in cycling of nutrients in fertilized pond [14,15].

3.2 Growth Performance of Fish

Table 3 presents the growth parameters of fish species under different treatments. The average initial length and weight of the fingerlings (Catla, Rohu, and Mrigala) at stocking were 8.5 cm, 9.2 cm, and 10.0 cm, and 8.9 g, 7.8 g, and 7.2 g, respectively, for both treatments. At the time of harvest, the average final lengths of Catla, Rohu, and Mrigala in the treated pond were 27.8 cm, 28.1 cm, and 29.6 cm, respectively, compared to 23.5 cm, 21.7 cm, and 24.8 cm in the control pond. The final mean weights of the fish at harvest were also higher in the treated pond: 615 g and 432 g for Catla, 535 g and 412 g for Rohu, and 504 g and 365 g for Mrigala, in the treated and control ponds, respectively (Table 3).

3.3 Growth Performance of Ducks

The ducks were primarily reared in a scavenging system with minimal supplemental feeding. Their main diet came from pond benthos, including insects, leeches, snails, and various detrital plant and animal materials. Farmers provided small amounts of broken rice grains, rice bran, and fresh kitchen scraps at a rate of 60-75 g per duck per day. Growth performance was monitored biweekly by measuring weight gains over the nine-month rearing period in the integrated system (INT). The ducks' average initial weight was 820 g, reaching a maximum mean weight of 1,304 g. By the end of the experiment, their final mean weight was 970 g. Between March and May, weight gain slowed due to higher temperatures. Duck survival was 81%, influenced by the availability of food organisms in the pond and prevailing environmental conditions. Mortality was partly due to predation from dogs and cats, as well as high temperatures during the rearing period.

3.4 Economics of the Study

Integrated fish-duck farming significantly boosted the economic returns of fish ponds by generating additional income from increased fish production, duck eggs, and duck meat. The cost of fish production per kilogram was Rs. 7.29 in the control pond (CTL) and Rs. 4.82 in the integrated pond (INT). The benefit-cost ratio for the integrated system was 2.27:1, offering farmers considerably higher profitability compared to fish culture without ducks, which had a benefit-cost ratio of 1.3:1 in the village conditions of Namakkal (Table 4).

Table 3. Growth parameters of fish species in different treatments

Parameters	Integrated pond			Control pond		
	Catla	Rohu	Mrigala	Catla	Rohu	Mrigala
Growth rate / day (gm)	2.32	2.05	1.93	1.75	1.57	1.53
Average weight at harvest (gm)	615	535	504	432	412	365
Survival rate (%)	67.0	62.5	57.5	56.0	50.5	46.5
Yield of (kg)	1605	1325	1534	1110	900	1077
Total production / (kg/ha)	4464			3087		
Productivity(kg/ha)	8928			5145		

Table 4. Economics of fish cum duck farming system

S. No	Particulars	Integrated pond	Control pond
A	Fixed cost (Rs)	93000.00	93000.00
B	Variable cost (Rs)	63560.00	37520.00
C	Total cost (A+B) (Rs)	156560.00	130520.00
D	Total cost per ha (Rs)	313120.00	200866.00
E	Returns Sale of fish (Rs.100/kg)	446400	308700.00
	Sale of egg, (Rs.10/egg)	48600.00	00.00
	Duck meat (235/kg) @75)	17625.00	00.00
F	Gross return (Rs)	512625.00	308700.00
G	Net return (F-C) (Rs)	356065.00	178180.00
H	Net return per ha (Rs)	712130.00	313634.00
I	Benefit: cost ratio	2.27	1.3
J	Cost of production/kg	4.82	7.29

4. DISCUSSION

Chand et al. [16] observed that the stocking of fishes of Indian major carps in the treatments D1 (No ducks), D2 (200 ducks), D3 (300 ducks) and D4 (400 ducks) for 10 months culture period were 602,763,827 and 708 g (Catla), 516, 688,715 and 721 g (rohu), 475, 516, 623 and 636 g (mrigal), respectively for treatment and control pond. Average daily gain (ADG) was found to be higher in treated pond i.e. 2.47 g, 2.07 g and 1.92 g/day as compared to control pond, where it was 1.70g, 1.49 g and 1.47 g/day for Catla, Rohu and Mrigal, respectively. Chand et al. [16] also reported average daily gain (ADG) in D4 (400 ducks) at 2.67, 2.35g, 2.08g/day, in D3 (300 ducks) at 2.70g, 2.33g and 2.04g/day, in D2 (200 ducks) at 2.49g, 2.24g and 1.68g/day and in D0 (control) 1.95 g, 1.67 g, 1.54 g/ day for catla, rohu and mrigal, respectively.

“The total yield was 4464kg/ha with rearing of 300 ducks/ha. This production is similar to the yield of 4174.5kg/ha/yr [17,18] reported to similar to the yield of 4290kg/ha/yr obtained in poly culture experiments with supplementary feeding and fertilization. In Vitenam raising 1000-2000ducks/ha on pond increased the average fish yield to as much as 5000kg/ha/yr, Compared to 1000kg/ha/yr without ducks” [19].

In present study Net return was Rupees 356065/- integrated pond (INT)and Rupees 178180/- control pond (CTL), Abhishek Majhi [20] reported that indicate that in case of Traditional Pisciculture the average Investment, Income and Profit were Rupees 34210/-, Rupees 54325/- and Rupees 20015/- respectively. On the other hand in case of Integrated Duck cum Fish Farming the average Investment, Income and Profit were Rupees 53560/-, Rupees 82950/- and Rupees 29290/- respectively.

The integrated fish cum duck farming improved the economic returns from the fish ponds as additional income from duck meat and eggs with increased fish production. The cost benefit ratio in case of integrated fish cum duck farming was found to be 2.27 which was much more profitable to farmers than in case of fish culture without ducks, found to be at 1.3 [21] report that The cost benefit ratio in case of integrated fish cum duck farming was found to be 3.11 which was much more profitable to farmers than in case of fish culture without ducks, found to be at 1.4 under village conditions of Chhattisgarh.

5. CONCLUSIONS

This study demonstrated that duck excreta significantly enhance fish pond productivity by boosting plankton production in treated ponds. The physico-chemical properties of water in these ponds were within a productive range, supporting high survival rates for both fish and ducks. Integrated farming offers a sustainable, effective approach to improving rural economies through its cost-efficiency, low investment requirements, and high profitability. Achieving optimal production with minimal costs relies on recycling waste and residues between farming systems with careful attention to environmental impact. Sustainable integrated farming practices provide a viable option for increasing overall farm productivity and economic returns for rural, pond-based farming communities. Hence promoting the same in the rural area is an significant approach to enhance fish production.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

ACKNOWLEDGEMENT

Authors would like to thank TANUVAS, Chennai for technical guidance and ICAR, ATARI, Hyderabad for funding to carry out the FLD successfully at Namakkal district, Tamil Nadu.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/126724